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Woods Hole Oceanographic Institution

TECHNICAL PROGRESS REPORT

ADVANCED MARINE TECHNOLOGY

1 February 1973 - 31 July 1973

December 1, 1973

Sponsored by
Advanced Research Projects Agency

ARPA ORDER NO. 293-008

Dr. A. E. Maxwell, Principal Investigator

*Prepared for the Office of Naval Research
under Contract N00014-71-C-0284; NR 293-008.*

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WOODS HOLE, MASSACHUSETTS 02543

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1 February 1973 - 31 July 1973

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Report Summary

This report covers a period which finds several of the projects nearing completion. It is expected that the next semi-annual report should contain final technical reports on Submerged Navigation, Hydraulic Impact Hammer, Deep Sea Rock Drill and the Self Contained Ancillary Modular Package (SCAMP). It is possible that extensive testing and use of SCAMP will not take place until next year. The responsibility for these worthwhile equipments then shifts to the users, who in most cases has been intimately involved in the development.

The Submerged Navigation system continues to attract much attention both within and without the Institution. Delays in the fitting and testing of ALVIN in the new Titanium hull configuration has slowed the field work with ARPA developed equipment but the next six months should contain considerable work.

Brief summaries of the reports are given below.

(a) Submerged Navigation

The development of two more copies of the ARPA/WHOI deep navigation systems by the Geology/Geophysics and the Physical Oceanography Departments at Woods Hole has materially aided in the refinement of the system, particularly in the analysis aspect. An error analysis of the various possible modes of operation has been made and enables one to choose the best mode for each situation (relative position of ship target, transponders, etc.). Cooperative efforts in programming have improved the programs for the ray bending calculations (SETUP), relative geometry of a two transponder net (SURVEY II), the real time navigation program (ACNAV) and are developing a program for the three transponder net (SURVEY III).

A current description of the Timing Controller is given. Although parts of this have appeared in the previous progress report (1 August 72 - 31 January 73) it was felt its inclusion was justified here for completeness.

(b) Hydraulic Impact Hammer

The hydraulic impact hammer has gone through considerable design changes. Using Belleville washers instead of a spring, counteracting the momentum impulse with a damping plate instead of the use of weight, and the construction of a mechanical arm for placement has resulted in a tool that should be effective in obtaining rock samples from submersibles.

(c) A Self Contained Deep Sea Rock Drill

The rock drill mechanical reliability has been improved by changing the piston sealing in the drill barrel and the electrical reliability by re-configuring the electrical circuits. Drilling efficiency was improved by selecting the proper bit configuration by experiment. Shallow tests in salt water have shown the instrument to behave properly and sea expeditions are planned.

(d) Self Contained Ancillary Modular Platform (SCAMP)

The design and construction of SCAMP is nearing completion. This pictorial report gives a good overview of the working parts of SCAMP including the frame, battery assembly, suction pods, clamping mechanism, pumping system and other pertinent details. Some of the testing program is described.

(4) A Deep Submersible Modular Acoustic System

Design, construction and testing of the sub units of the modular acoustic system are proceeding on schedule. These units are Control, Display, Tape Monitor and Log, Transmitters, Trainable mount, Transducers, and Computer system.

This is a status report with some description of the function of the sub units.

Submerged Navigation

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Submerged Navigation

Introduction

During the reporting period two copies of the ARPA Submerged Navigation system were under construction with schedules to go to sea during the summer of 1973. An informal W.H.O.I. interdepartmental committee of investigators concerned with applications of submerged navigation was formed. This group has representatives from three of the five scientific departments at the Institution. Agreements were worked out to pool information and efforts to develop, as nearly as practical, common systems and computer programs. Three Timing Controllers were constructed, one each for the three W.H.O.I. systems as follows:

- a) ALNAV - the ARPA ALVIN Navigation System
- b) ANGUS - Geology and Geophysics System
- c) ANBUS - Physical Oceanography System

A major joint users HP 2100 series computer programming effort is underway. Four primary programs are being written. These are:

- a) SETUP - Given a sound velocity profile this program calculates the ray bending correction coefficients.
- b) SURVEY II - Given surface ship baseline crossing data this program calculates the depths and distance between two near bottom transponders.
- c) SURVEY III - Given surface ship track data this program calculates the depths and distances between three near bottom transponders.
- d) ACNAV - This is the real time program that processes the information from the acoustic system, calculates the position of the ship and submerged device, and displays the calculated positions.

An error analysis of the navigation equations was made by J. A. Metzler of the Physical Oceanography Department.

A cassette tape recorder was ordered to perform the data logging for the ALNAV System.

The HP 9100 calculator programs were rewritten to be compatible with the new Timing Controller and to include several corrections not included in the original program.

The final at-sea evaluation trials of the ARPA ALNAV system will be conducted in the next reporting period.

The main body of this report is organized in three sections:

- I. Navigation Equations and Error Analysis
- II. Preview of Joint-Users Computer Programs
 - a) SETUP
 - b) SURVEY II
 - c) SURVEY III
- III. W.H.O.I. Timing Controller
 - a) General Information
 - b) Detailed Functional Description

I. Navigation Equations and Error Analysis

Previous reports discussed the equations used to calculate the position of a ship and a submersible when two reference transponders are available. The geometry was defined using the location of one of the transponders as the origin of an x,y,z coordinate system. During this reporting period it was found that the use of a surface origin coordinate system simplified the equations somewhat. The origin now being used is shown in Figure 1 and is at the surface directly above the Reference No. 1 transponder. Using the terms defined in Figure 1 the equations for the positions of the ship and submersible become:

$$X_s = \frac{(R_1)^2 - (R_2)^2 + (X_2)^2 + (D_2 - D_s)^2 - (D_1 - D_s)^2}{2X_2}$$

$$Y_s = \pm \sqrt{(R_1)^2 - (X_s)^2 - (D_1 - D_s)^2}$$

$$D_s = D_s \text{ known}$$

$$X_f = (F)(D_f) + I \text{ where } F = \frac{D_1 - D_2}{X_2} \text{ and,}$$

$$I = \frac{(R_3)^2 - (R_4)^2 + (X_2)^2 + (D_2)^2 - (D_1)^2}{2X_2}$$

$$Y_f = (G)(D_f) + H \text{ where } G = \frac{D_1 - D_s - (X_s)(F)}{Y_s} \text{ and,}$$

$$H = \frac{(R_3)^2 - (R_5)^2 + (X_s)^2 + (Y_s)^2 + (D_s)^2 - (D_1)^2 - 2(X_s)(I)}{2Y_s}$$

$$D_f(1,2) = -S \pm \sqrt{S^2 - 4PT} \text{ where } P = (F)^2 + (G)^2 + 1 \text{ and,}$$

$$2P$$

$$S = 2[F I + G H - D_1] \text{ and, } T = I^2 + H^2 + (D_1)^2 - (R_3)^2$$

Figure 1. Geometry for Ship and Submersible (or Fish) Navigation Problem

To calculate the fish (or submersible) position, D_f is evaluated first.

An error analysis of these equations was made by James A. Metzler. As a result of his findings two changes in the navigation programs were made. He found that the optimum ship position to minimize the errors in Y_s was at $X_s = 0$ and with Y_s a large number, i.e., far from the baseline. The analysis of equation (2) showed that as X_s increased (R_1 must also increase) the controlling variable terms, $|2(R_1)(\delta R_1)| + |2(X_s)(\delta X_s)|$

in the error equation also increased. This effect can be reduced. There are two possible equations for Y_s :

$$(2.0) \quad Y_s = \pm \sqrt{(R_1)^2 - (X_s)^2 - (D_1 - D_s)^2} \text{ or}$$

$$(2.1) \quad Y_s = \pm \sqrt{(R_2)^2 - (X_2 - X_s)^2 - (D_2 - D_s)^2}$$

As explained above, when equation (2.0) is used, the minimum error in Y_s is along the line of $X_s = 0$. If equation 2.1 is used, the minimum error in Y_s is on the line of $X_s = X_2$. Thus for minimum overall error, if the ship is to the left of midpoint of the baseline shown in Figure 1, equation (2.0) should be used and if the ship is to the right of the midpoint of the baseline then equation (2.1) should be used. If the depths of the transponders are assumed to be equal then equation (2.0) is preferred if R_2 is greater than R_1 . Likewise, equation (2.1) is preferable if R_1 is greater than R_2 . The navigation computer programs have been rewritten to examine R_1 and R_2 to select the best equation for Y_s .

It was also found that equation (5) was very sensitive to errors in the position of the ship. Three equations for Y_f were then studied:

$$(5.0) \quad Y_f = G D_f + H \text{ and}$$

$$(5.1) \quad Y_f = \pm \sqrt{(R_3)^2 - (X_f)^2 - (D_1 - D_f)^2} \text{ and}$$

$$(5.2) \quad Y_f = \pm \sqrt{(R_4)^2 - (X_2 - X_f)^2 - (D_2 - D_f)^2}$$

Equation (5.0) has the advantage of not producing a redundancy in Y_f but is very sensitive to error multiplication. In a fashion similar to that described for Y_s it was found that if R_4 was greater than R_3 then equation (5.1) is preferable and if R_3 is greater than R_4 then equation (5.2) is preferable. The computer programs have been rewritten to examine R_3 and R_4 to select equation (5.1) or (5.2). Equation (5.0) is also evaluated to obtain the sign of Y_f , which is then assigned to the answer of equation (5.1) or (5.2) to solve the $\pm Y_f$ redundancy.

Mr. Metzler's study also indicated:

- a) The X_s and X_f errors, for positions between $X=0$ and $X=X_2$, were strongly dominated by the error in X_2 . The need for an accurate survey of X_2 is obviously indicated.

- b) The Y_s and Y_f errors are very bad at or near the baseline and they are greatly reduced as one moves away from the baseline.
- c) To minimize the errors in D_f , the ship should be directly above the fish (or submersible).

The following section discusses the equations used to calculate the position of the fish (or submersible) when a surface bounce path is present. Figure 2 illustrates the geometry of signal traveling from the fish, bouncing off the surface and traveling to a reference transponder to interrogate it.

Assume the following definitions:

- t_{3a} = acoustic travel time from the fish to the surface
- t_{3b} = acoustic travel time from the surface to the transponder
- $t_3 = t_{3a} + t_{3b}$
- $\overline{c_f}$ = arithmetic average sound velocity between D_f and the surface
- $\overline{c_T}$ = arithmetic average sound velocity between D_T and the surface

Under these conditions:

$$t_{3a} \approx t_3 \frac{\overline{c_T} D_f}{\overline{c_T} D_f + \overline{c_f} D_T} \quad \overline{R_{3a}} = \overline{c_f} t_{3a}$$

$$t_{3b} \approx t_3 - t_{3a} \quad \overline{R_{3b}} = \overline{c_T} t_{3b}$$

Use of the ray bending correction discussed in the last progress report permits:

$$R_{3a} = \overline{R_{3a}} [A_{ks} + B_{ks} \overline{R_{3a}} + C_{ks} (\overline{R_{3a}})^2]$$

$$R_{3b} = \overline{R_{3b}} [A_{ks} + B_{ks} \overline{R_{3b}} + C_{ks} (\overline{R_{3b}})^2]$$

then, $R_3 = R_{3a} + R_{3b}$

The above illustrates a method for calculating the length of a surface bounce signal paths. The equations used to calculate the position of the submersible when one or more signal paths is in the surface bounce mode will now be examined.

Figure 2. Surface Bounce Geometry

Refer to Figure 1 for the direct path geometry. The direct path solution of the position of the submersible started with the following three equations:

$$(6) (R3)^2 = (X_f)^2 + (Y_f)^2 + (D_f - D_1)^2$$

$$(7) (R4)^2 = (X_f - X_2)^2 + (Y_f)^2 + (D_f - D_2)^2$$

$$(8) (R5)^2 = (X_f - X_s)^2 + (Y_f - Y_s)^2 + (D_f - D_s)^2$$

From Figure 2 a replacement for equation (6) when R3 is in the surface bounce mode may be written:

$$(9) (R3)^2 = (X_f)^2 + (Y_f)^2 + (D_f + D_1)^2$$

similarly, a replacement for equation (7), when R4 is in the surface bounce mode becomes:

$$(10) (R4)^2 = (X_f - X_2)^2 + (Y_f)^2 + (D_f + D_2)^2$$

Comparing equations (6) and (9) plus (7) and (10) it can be seen that the equations for the direct path solution of the position of the submersible can be used if the sign of the depth of the transponder(s) being interrogated in the surface bounce mode is changed from (+) to (-). The surface origin coordinate system thus provides a simple solution to the change from direct path to surface bounce path position equations.

II. Preview of Joint-Users Computer Programs

A. Program SETUP has been written for use on either the W.H.O.I. Sigma 7 computer or on the HP 2100 series sea going computers. It is used to prepare input information before a navigation exercise. The inputs are:

- a) A sound velocity table with depth in meters and associated sound velocity in meters per second.
- b) A typical deep operating depth in meters. Normally this would be an average depth of the bottom moored reference transponders.
- c) A typical shallow water depth in meters. This is usually the depth of the ship's transducer.

The program calculates the coefficients for the ray bending corrections used in the real time navigation program discussed in the last progress report. The program uses ray tracing techniques to determine the travel times for various rays starting at the typical deep depth. For the deep to deep case the "K" correction factors are calculated for rays returning to the starting depth at 2000 meter horizontal range intervals

to a maximum horizontal range of 20,000 meters. This table is printed for inspection of the operator. The program performs a least squares fit of the tabulated data to determine the coefficients of the deep to deep correction equation:

$$K_d = A_{kd} + B_{kd} \bar{R} + C_{kd} (\bar{R})^2$$

where $\bar{R} = \bar{c}t$ and

$\bar{c}$ = arithmetic average sound velocity between the starting depth and the end point depth

t = actual travel time

For the deep to shallow case the program starts with a ray traveling directly up to the shallow depth, i.e. the initial elevation angle of the ray is 90 degrees. The elevation angles are successively reduced by 5% until the ray bends away from the shallow depth. The output listing gives the following information for each calculated ray:

X = horizontal distance traveled, meters

R = straight line slant range, meters

T = travel time along the ray path, seconds

C = arithmetic average sound velocity between the starting depth and the end point depth

K = ray bending correction factor = $\frac{R}{CT}$

An inspection of this table tells the operator the errors expected at various horizontal ranges if he did not correct for ray bending. The table also provides an estimate of the maximum horizontal range that can be traveled before the rays bend away from the shallow depth, i.e. the approximate range at which the shadow zone is reached. The program performs a least square fit of the K's in the table to determine the coefficients of the deep to shallow correction equation:

$$K_s = A_{ks} + B_{ks} \bar{R} + C_{ks} (\bar{R})^2$$

- B. SURVEY II is a computer program used to determine the relative geometry of a two transponder net. It requires data sets obtained from at least three ship crossings of the transponder baseline and/or the baseline extensions as shown in Figure 3. It is desirable that these crossings be made perpendicular to the baseline while traveling in a straight line. The program automatically corrects for reasonable variations of these desirable conditions. The data set for each ship track must include data points on both sides of the baseline. The data is in the form of measured travel times between the ship and the two transponders. To initialize the program the operator

must input the estimated depths of the two transponders and the horizontal distance between them plus the depth of the ship's transducer. Using the estimated depth of each transponder, the program calculates the horizontal range between the ship and the two transponders for each data point. Consider ship track 2 in Figure 3. When the ship is directly over the baseline the sum of the horizontal range from transponders A and B will be a minimum and approximately equal to the estimated distance between the two transponders. For tracks 1 and 3 the sum of the horizontal ranges will be considerably greater than the estimated distance between the two transponders. On tracks 1 and 3, when the ship is over the baseline extension the absolute value of the difference of the horizontal ranges to the two transponders will reach a maximum. The program evaluates the data from each track to determine if the crossing was between or outside the two transponders and selects the data set which gives the appropriate maximum or minimum combinations of the horizontal ranges.

Having thus selected a data set from each crossing the program iteratively adjusts the depths of the two transponders and the distance between them to cause the calculated depth of the ship at each crossing to be as nearly equal to the known depth of the ship's transducer as possible. With the minimum of three crossings the error figure will go to zero because there is a unique solution. With four or more crossings the error figure will probably not reach zero. Having thus revised the estimated depth of the two transponders and the distance between them the program starts over by reevaluating all of the data points along the three or more tracks to see if better data points are available. Three iterations is usually sufficient to select the best data points and provide the best estimate of the relative positions of the two transponders. Working with simulated data it has been found that if only three crossings are to be made that those illustrated in Figure 2 give the best and fastest convergence.

- C. SURVEY III is a computer program designed to calculate the six unknowns needed to describe the relative positions of three transponders. This program is not yet complete but will use an iterative method of adjusting the six unknowns to cause the calculated depth of the ship's transducer for all of the available data points to lie in a horizontal plane at a depth equal to the known depth of the ship's transducer. It is planned that the program will accept 7 to 300 data sets. A key problem to be solved is how to select the best data sets from the several thousand that might be gathered during an extended survey.

Figure 3. Ship Tracks for SURVEY II

III. W.H.O.I. Timing Controller

A. General Information

- a) Definition of Terms. The following terms are used throughout the descriptions that follow:

SHIP - The surface vessel upon which the navigation system is located and from which it is operated.

FISH - Any device, tethered or nontethered, other than the "SHIP" which is tracked by the navigation system. This can include submarine, towed instrument, free-float instrument, sonobuoy, etc.

T₀ - Time zero. The time of initialization of some sequence of time related events.

T_A - The time of initialization of time interval A.

T_B - The time of initialization of time interval B.

- b) General Description. The timing control unit was designed and built at the Woods Hole Oceanographic Institution for use as the system control in the ALNAV, ANGUS, and ANBUS acoustic navigation and tracking systems. Used in conjunction with the rest of the system components it provides all of the necessary timing, relay, and control signals needed for automatic operation of the systems. It additionally provides signals to the data processor concerning system status and operator selected sense switches. These sense switches allow the operator to select options within the computer program without interruption of the system. Figure 4 is a photograph of the W.H.O.I. Timing Controller.

- c) Unit Components. The timing control is designed as a compact integral unit containing transistorized and integrated circuits. A self contained gelled electrolyte battery is provided to supply power for an excess of one hour in case of line power failure or during transport. All indicators and controls necessary for operation are located on the front panel.

(1) Front Panel

The front panel contains push button switches, digital thumbwheels, power toggle switch, mode selector switch, mixer potentiometers, and illuminated indicators for system operation. These will be discussed in detail in a following section.

(2) Rear Panel

The rear panel contains all connectors for inter-connection of the timing control to the other system elements. BNC connectors are provided for the acoustic mixer which is contained within the unit. A locking toggle switch located on this panel allows selection of a spare relay driver line discussed later.

(3) Card File

The internal card file contains slot locations for the following printed circuit cards:

- a) Timing control card
- b) Relay one-shot and driver
- c) Acoustic mixer

The card file is arranged so that circuit boards may be placed in a card extender for adjustment and troubleshooting. Three empty card slots are provided to allow for future additions or modifications.

(4) Power Supply

The 12 volt power supply is an assembly located on the main chassis. It is of open modular design and may be replaced as a unit or maintained on a component level. The modular unit consists of transformer, rectifier-regulator P.C. card, overvoltage P.C. card and series regulator power transistor.

(5) Battery

The battery pack consists of one 4 volt and one 6 volt at 1 amp hour gell-cell batteries series connected to form a 10 volt pack. This pack is floated across the 12 volt DC power bus and trickle charged when AC power is on. When power is lost, the battery provides 10 VDC to the bus via a series diode to provide power to the timing electronics and lamps. It does not provide power to the acoustic mixer.

- d) Specifications. Specifications of the W.H.O.I. Timing Controller are listed in Table 1.

Figure 4. WHOI Timing Controller

Table 1

Specifications, W.H.O.I. Timing Controller

<u>Function</u>	<u>Characteristics</u>
Input voltage	105-125 VAC
Input Power	.75 watt nominal 1. watt maximum
DC Power Requirement	10-12 V DC @ 200 MA nom. with sense switches <u>off</u> 1.3 A. with sense switches <u>on</u>
Controls:	
Run	Illuminated pushbutton (green)
Power On-Off	Locking toggle switch
Mixer 1-6	Mixer level potentiometers
Cycle normal/special	Locking toggle switch
Mode selector	8 position rotary switch
Interval A	2 position thumbwheel
Interval B	2 position thumbwheel
Estimated depth	2 position thumbwheel
Initial sync	Guarded pushbutton
Resync	Illuminated pushbutton (red)
Sense switches	13 illuminated pushbuttons
Indicators:	
Run	Flashes once per second in <u>run</u> , off in stand by.
T _A	Flashes when T _A transmission is made.
T _B	Flashes when T _B transmission is made
2 Min Sync	Flashes at time of 2 min sync pulse.
Cycle A	<u>On</u> during entire A cycle
Cycle B	<u>On</u> during entire B cycle
Sense switches 1-13	Illuminate when <u>on</u>
Time Intervals	1 to 99 seconds determined by thumbwheel settings
Estimated Depth	0 to 9900 meters in steps of 100 m., by thumbwheel
Modes:	
1 ship only	See detailed operating instructions
2 ship fish	See detailed operating instructions
3 ship sub	See detailed operating instructions
4 ship sonobuoy	See detailed operating instructions
5 fish only	See detailed operating instructions
6 sub only	See detailed operating instructions
7 spare	See detailed operating instructions
8 spare	See detailed operating instructions

Connectors:

Function:

Mixer BNC 1-6	BNC connectors to mixer inputs 1-6 respectively
Mixer Out BNC	BNC mixer output
Sync Out BNC (Front Panel)	Output to synchronize other systems such as submarine clock or precision timed beacons.
Clock BNC	Input from external 1 second clock
J1	Interface to BCD card in 2570 coupler
J2	Jumper plug or interface to special devices (ANVUS TW, ALNAV BOUNCE, etc.)
J3	Interface to AMF 205 receiver
J4	Interface to AMF 200 coder (Modified for auto control)

B. Detailed Functional Description

- a) General Description. The timing controller was designed to provide integrated and flexible control of the navigation system. This unit provides ten coded BCD characters to the computer system coupler to permit the operator to set-up a variety of subprograms in the computer system.

The timing controller receives 1 sec time tics from the surface clock. Two (2) digit time interval thumbwheels, 0 to 99 seconds, are provided to permit the operator to set up the signal timing intervals. Typically, interval "A" (determine ship position) is set at 15 seconds and interval "B" (determine the position of the submerged device) is also, but not necessarily, set at 15 seconds.

When operating at maximum range from the reference transponders these settings are increased to accomodate the longer acoustic travel times.

The timing controller contains indicator lights that tell the operator whether the current cycle is "A" or "B" plus indicating the 1 second time tics.

The position of the mode selector is coded into a BCD character and is sent to the computer coupler for program control. The computer coupler also receives a coded signal which indicates whether the data being received is from interval A or B.

The shipboard acoustic components are remotely controlled by the timing controller. This includes commands to transmit one of two interrogation frequencies, commands to start the time interval counters and a signal to inhibit the altitude mode of the 205 receiver when in the interval "A" (SHIP) cycle.

To simplify the system cabling the timing controller is used as a junction box to route miscellaneous signals from the 205 receiver to the computer coupler. These signals include the bad data signal lines and the position of the Altitude Delayed selector.

The timing controller contains an audio mixer to mix the analog signals from the 205 receiver for display on an optional graphic recorder.

A two digit thumbwheel switch permits the operator to input to the computer coupler the estimated depth of the submerged device being tracked. The computer program uses this input to solve the "Z" redundancy of the calculated depth of the submerged device.

A battery within the timing controller keeps the timing circuits operating in case of a momentary power interruption.

The A & B interval counters can be reset with a reset pulse. The timing controller contains a guarded "Initial Sync" push button to permit starting the interval counters at 00 seconds on the clock. While the push button is held in, the external 1 second tic's will keep resetting the interval counters. If the push button is released between 00 and 01 seconds the 00 second sync will be initiated. The push button can also be used to set up two separate systems in a time sync.

The timing circuits include an automatic recycling two minute counter. This counter is reset by the Initial Sync push button. The two minute counter buffered output pulse is connected to a front panel light and BNC connector labeled SYNC OUTPUT. The sync output is used to sync external devices such as the ALVIN clock, future FISH clocks and/or future clock controlled beacons.

When the thumbwheels of the interval counters "A" and/or "B" are changed, the new intervals are no longer uniquely related to the initial sync of the timing circuits. A RESYNC switch is provided which when momentarily pressed will cause the next internal 2 minute sync signal to reset the interval counters.

The RUN switch allows the operator to suspend or initiate system operation without interrupting power to the system. A light within the switch flashes once per second when the system is in "RUN" mode and is extinguished when the system is in "STANDBY".

The output status word is a 10 digit BCD number which is input to the HP 2570 at location 6. Table 2 illustrates the format of the status word.

Table 2

Timing Control Status Word

Listing is from left to right (MSD to LSD)

1. Estimated depth MSD
2. Estimated depth LSD
3. Mode selector position 0 to 7
4. Cycle: 4 = SHIP 0 = FISH
Bad Data: 1 = A channel 2 = B channel
NOTE: Ship cycle plus A and B Bad Data = $4 + 2 + 1 = 7$
5. Bad Data: C channel = 1 D = channel = 2
Sense switch 13 = 4
6. AMF 205 Altitude Mode Switch Settings
0 = OFF 1 = A 2 = B 4 = C
7. Sense Switch #10 = 1 #11 = 2 #12 = 4
8. Sense Switch #7 = 1 #8 = 2 #9 = 4
9. Sense Switch #4 = 1 #5 = 2 #6 = 4
10. Sense Switch #1 = 1 #2 = 2 #3 = 4

Thirteen sense switches are mounted on the timing controller. The position of these switches is coded and sent to the computer coupler. This feature provides great flexibility in computer subroutine control without having to interrupt the computer program. The projected functional assignments of these switches for the LULU/ALVIN problem is shown in Table 3.

- b). Controls and Indicators. This section lists the operator controls and indicators and contains a complete description of the function of each.

(1) Power Switch

The power switch is a locking bat-lever toggle switch. The bat handle must be pulled out (away from the panel) in order to change its position. This prevents accidental power interruption. When the power switch is OFF both the AC line and the DC battery bus are disconnected.

(2) RUN Switch

The run/standby push button is used to interrupt system operation without loss of system synchronization. It is a push-on push-off switch. The lamp contained within the switch cover will flash once per second in (RUN) and be extinguished in standby.

(3) T_A and T_B Indicators

The T_A and T_B indicator lamps illuminate for 100 MS at the beginning of time intervals A and B respectively. They are driven by the relay driver lines and indicate that the system is commanding the relays in the matching coil panel to switch in the proper matching transformer for transmission of the acoustic interrogation. They also serve as an indicator of time-of-transmission when the system is in one of the single modes such as Ship Only.

(4) Re-Sync Push Button

The Re-Sync push button is used to re-initialize the time interval counters after a change in the thumb-wheel settings. It is also used for re-initializing after the system has been switched from STANDBY to RUN. When the system is used with a companion synchronous system such as the LULU/ALVIN system the resync is absolutely necessary in either of the previous two cases. It is also a convenience in non-synchronous systems to trigger the transmissions at

Table 3

ALNAV Sense Switch Assignments

- #1 The ship is clockwise or counterclockwise from a two transponder baseline.
- #2 Enables the program velocity filter to eliminate the plotting of spurious positions.
- #3 Average the ship positions before and after a submersible fix and use this improved ship position in the calculation of the submersible position.
- #4,5,6 Use 205 Channels A, B, C to calculate the ship and submerged device positions. For a two transponder baseline problem only two of the sense switches would be enabled. With a three transponder net the operator would select one of four combinations for position calculations - AB, AC, BC or ABC.
- #7,8,9 Use the surface bounce routines to calculate the ranges for the A, B or C transponders when the appropriate sense switch is depressed.
- #10 When depressed, log the raw data gathered during each cycle.
- #11 When depressed, print the raw data gathered during each cycle.
- #12 Spare
- #13 When depressed, use the third transponder not selected by sense switches #4-6 to automatically solve the "Y" redundancy of the two transponder ship position and to calculate the depth of the ship as an indication of the errors in the calculated positions. The error indicator will be particularly useful in alerting the operator of conditions of poor system geometry.

known clock intervals such as once per minute on the minute or once each 15 seconds at 0, 15, 30, 45 seconds past the minute. The lamp within the RE-SYNC push button illuminates when the button is activated. It will remain illuminated until the re-sync occurs. The re-sync counter has a two minute period, therefore the maximum time until re-sync must be less than two minutes. The system will continue to operate normally until re-sync occurs. The lamp indicates only that re-sync has been requested/completed.

(5) 2 MIN SYNC Lamp

This lamp flashes at the end of the two minute resync counter period. It indicates that the counter is working and can be related to second-of-the-minute to check system lock-on after initial synchronization.

(6) Cycle A/Cycle B Indicators

These lamps remain illuminated during the entire time interval A or B to indicate which cycle the system is in. In the single cycle modes such as SHIP ONLY the appropriate lamp will remain illuminated continuously.

(7) CYCLE Switch

This switch is a locking bat lever type identical to the power switch. In the NORMAL position intervals A and B occur alternately if a two cycle mode such as SHIP/SUB has been selected.

The SPECIAL mode is used for the situation wherein it is desired to produce more FISH cycles than SHIP cycles. This might occur when a fish device contained its own transponder receiver or when two ships are operating within the same net.

1. INTERVAL A and interval B are simultaneous NOT alternate in the special mode.
2. Interval B sets total cycle time interval A sets ship and fish relief cycle length.
3. Interval B must be evenly divisible by interval
A. EXAMPLE: A = 15 and B = 60 is ok;
A = 13 and B = 60 is wrong

To set up the system for a ship cycle (interrogation) once per minute and fish interrogations every 15 seconds (SFFF SFFF...) proceed as follows:

1. Set CYCLE to special.

Table 4

Mode Selector Position Function

<u>Position</u>	<u>Interval A</u>	<u>Interval B</u>
1 Ship Only	Ship	None, interval A keeps repeating
2 Ship Fish	Ship	Relay transponder (FISH)
3 Ship Sub	Ship	Remote timed pinger (ALVIN)
4 Ship Sono	Ship	Sonobuoy, adds radio receiver
5 Fish Only	None, interval B repeats	Relay transponder repeats
6 Sub Only	None, interval A repeats	Remote timed cycle repeats
7	Spare	Spare
8	Spare	Spare

2. Set INTERVAL B to 60 (for a one minute total cycle time).
3. Set INTERVAL A to 15 (for a fish cycle every 15 seconds except for the initial 15 second ship cycle).
4. Press RE-SYNC to cause the fish cycle and total cycle to be initiated simultaneously.

(8) MIXER Potentiometers

Each control attenuates the level of signals into mixer inputs 1 through 6 on the rear panel. The mixer is used to mix signals such as the AMF 205 post filter outputs, for display on a PGR or oscilloscope.

(9) MODE Selector

The mode selector switch has six active and two spare positions to set up various system operations. Table 4 lists the switch positions and their functions.

(10) TIME INTERVAL Thumbwheels

The time interval thumbwheels are used to set up the time, in seconds, that interval A (ship cycle) and interval B (fish cycle) will last. As an example, a setting of interval A = 10, interval B = 15, MODE = SHIP/FISH, cycle = normal, will cause the following to occur:

At the beginning of INTERVAL A the ship will send an interrogation to the transponders. The replies will be received during the 10 seconds INTERVAL A. After the 10 second interval A FISH interrogation is made at the beginning of INTERVAL B. The fish in turn interrogates the transponders. These signals are received during the 15 second INTERVAL B. At the end of this interval the "A" cycle is again initiated.

(11) ESTIMATE DEPTH Thumbwheels

These switches are used to input the two most significant digits of the estimated depth of the fish or submersible for use by the computer program. The range of input is 0000 meters to 9900 meters.

(12) SENSE SWITCHES

The sense switches are push-on push-off type illuminated push button switches. They are used to allow the operator to request certain options of the computer software.

Hydraulic Impact Hammer

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Hydraulic Impact Hammer

Problem

The primary goal during this period of time was to complete a series of modifications to the impact hammer which would:

- 1) Reduce the recoil of the hammer on impact with the addition of a reaction plate mounted on the top of the hammer.
- 2) Replace the prototype piston positioning system with a mechanical arm design.
- 3) Modify the hydraulic pump and manifold system to operate the mechanical arm system.
- 4) Increase the overall impact energy of the hammer by replacing the spring unit with a stronger stacked washer assembly, increasing the mass of the hammer, and eliminating the chisel assembly.
- 5) Modify the submersible tray unit to handle the heavier weights associated with the modification listed above.
- 6) Replacing the original lock assembly with a more reliable unit.

Method of Approach

- 1) During the 1972 summer evaluation dives on ALVIN a counterweight system of lead was used to reduce the recoil of the hammer. It was determined at that time that to effectively reduce recoil the weights should be increased from 25 lbs. to over 100 lbs. Such an increase would be impossible since it would put undue stress upon the hydraulic system. As a result an alternate recoil system using a reaction plate was designed, constructed, tested, and found to greatly eliminate the recoil energy loss and at the same time result in a savings of overall weight.
- 2) The original positioning system using a series of hydraulic pistons required a great deal of maintenance and limited the degrees of positioning freedom. A major amount of effort, therefore, went into the design and construction of a new positioning system. Now completed, this unit is in essence a mechanical arm which holds the impact device. Of major importance is that this system is seven times stronger than ALVIN's present arm (capable of lifting 350 lbs. at full extension) and was built for less than \$10,000. It is hoped that this work will be followed to completion and that the positioning unit will be made into a mechanical arm with the addition of a hand assembly similar to ALVIN's present arm.

- 3) The hydraulic pump which operated the original hammer and piston system was modified to run the new mechanical arm system.
- 4) Tests conducted in air and in water indicated that the impact energy delivered by the original device was greatly below the theoretical capabilities of the system. As a result a series of modifications were made to the system followed each time by additional air and water tests.
 - (a) The impact point was changed from a pointed to a blunt end which better distributed the shock wave in the sample to be broken.
 - (b) It was determined that the chisel assembly resulted in a major loss due to inefficient energy transfer. It was therefore eliminated by having the hammer hit the sample directly.
 - (c) The mass of the hammer was more than doubled to increase impact effect.
 - (d) The cocking spring was replaced by a substantially stronger cocking system which consists of a series of Belleville washers stacked in such a way as to create a powerful spring.
- 5) The additions mentioned above resulted in an increase in the overall weight of the system. As a result the tray assembly on which the system is mounted and by which it is attached to ALVIN had to be further strengthened.
- 6) The original latching mechanism had a low operational reliability. To remedy this problem, a new mechanism was designed, constructed, tested, and found to operate properly.

Summary

With these modifications completed the new impact hammer is scheduled to undergo a series of tests at sea in a variety of geological settings. The test program will be of a dual nature; to first test the operational reliability of the system and its ability to break-off outcrop samples and second to compare its functional efficiency to alternate methods of sampling.

A Self Contained Deep Sea Rock Drill

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A Self Contained Deep Sea Rock Drill

Introduction and Background

The previous semi-annual report (1 August 1972 - 31 January 1973) described drill developmental progress in Woods Hole Harbor during an ALVIN dive and on an attempted surface ship lowering. Although we had a working drill at that point, the lack of high operational reliability indicated a need for more engineering and testing. In addition, it was felt that the drilling function could be optimized to recover longer cores through additional study of the drilling parameters and bit configuration.

Further testing utilizing a DSRV was deemed both impractical and unnecessary, especially since the ALVIN attachment system and the capability of ALVIN to transport the drill, had already been demonstrated. Therefore, the remaining development work was completed at the W.H.O.I. dock and included preparation for deep-sea trials from a surface ship.

Testing

Past drill performance suggested that many of the reliability problems were a result of poor piston sealing in the drill barrel and from spurious electronic noise interference in the control instrument (Figure 1). A new piston was designed around a Parker "T-seal", which provided the required bi-directional sealing and low frictional breakout forces (Figure 2). Also, the aluminum drill barrel was Teflon coated by a commercial anodizing process for improved sealing, less friction, and greater corrosion control.

The control instrument was relocated with respect to the battery box and main motor, a common ground was established, and numerous electronic refinements were incorporated to improve the dependability of the automatic control function.

After these modifications towards improving reliability of the drill were made, it was employed as a test stand, primarily to gather engineering data towards determining a better drill bit configuration, and secondarily, as a continuous check of drill reliability. A new rock test rig was constructed to accommodate an 18-inch cube of granite, which was suspended beneath the drill for all underwater and topside dock testing (Figures 3 and 4).

During June and July, the drill was lowered eighteen times into 50 feet of water for fully automatic systems operation. Nine dry runs on the dock were also made, and together produced 257 inches of core in 211 minutes of coring without a drill malfunction (Figures 5 and 6). Five different XRT-size bit configurations were tried, with one clearly outperforming the others in achieving drilling rates of over $2\frac{1}{2}$ inches per minute. A detailed evaluation of this testing will be presented in the final technical report.

ROCK DRILL WORKING SCHEMATIC

Figure 1. Rock Drill Working Schematic

Figure 2. "T"-seal and Piston Assembly. Shown with a "T"-seal installed, the assembled piston, flush fluid flex line, torque rods, and core barrel.

Figure 3. Rock Drill with granite test rig suspended below. Prior to lowering from WHOI dock for automatic operation.

Figure 4. Dry running of drill to allow closer observation of bit testing. On the WHOI dock.

Figure 5. Five-inch thick oceanic basalt specimen shown with two 3/4-inch diameter corings removed during bit configuration investigation.

Figure 6. Granite test specimen showing 16 bore holes. Note XRT size coring bit in center of specimen. Holes are 1.15 inches in diameter.

From the wealth of engineering data collected, we have also been able to optimize those other parameters controlling drilling rates, as well as to debug the systems that previously contributed to erratic behavior.

Present Status and Future Plans

The drill would now seem to be a workable, reliable tool that could be utilized from either DSRV or a surface vessel to recover rock samples from the oceanic crust. We hope to prove its feasibility by coring on the New England Seamounts and in the Gulf of Maine in August and September of this year. This last phase of testing would utilize surface vessel deployment, and if successful, would lay the groundwork for future hard-rock coring on the mid-Atlantic ridge in 1974.

Self Contained Ancillary Modular Platform

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Self Contained Ancillary Modular Platform

Abstract

The principle objective of this contract is to design, fabricate and test a self contained platform that can be attached to the ALVIN deep submersible, effectively increasing the payload capability of the vehicle.

A detailed description of the platform concept has been reviewed in previous semiannual progress reports, and will not be covered at this time.

Construction Milestones:

1. Frame

Figure 1 depicts the completed SCAMP frame, and illustrates the general location of the syntactic foam used as flotation material. As shown in the photograph, the foam has been shaped to fit into the cavity formed by the two flanges of the aluminum I beam, and, while they are not considered as load bearing blocks, they do provide a substantial increase in the load carrying ability of the aluminum structure. The syntactic foam is attached through the use of threaded stainless steel tie rods that pass through the frame. When the bolts are tightened, the syntactic foam blocks sandwich the I beam into an integral structure.

Additional flotation foam has been added to the open rectangular areas shown in Figure 1, and in order to minimize the gross weight of the platform they have been secured through the use of threaded nylon bolts.

The use of threaded nylon provided a substantial weight saving over the stainless steel rods used to attach the blocks in the load bearing areas.

A water weight and balance test was performed using the platform configuration illustrated in Figure 1. Prior to immersion, the platform was loaded with lead blocks to simulate the water weight of the batteries, relays, pumps, motors, battery racks, and their associated electrical wiring. A total of 400 lbs. was distributed throughout the battery tubes and relay/pump nose cones. The two battery tubes, as well as the four nose cones were allowed to free flood with sea water, and as such, the effect of having oil filled battery and relay compartments was neglected.

The in-water test indicated a negative buoyancy of 200 lbs., with a very slight stern down condition. The platform was suspended by a four point attachment cable, with a common lift ring at the top of the bridle. The athwartship attitude was excellent and the slight stern down condition did not exceed three degrees. As a point of interest, the stern down condition could be corrected

by a light one hand lift by a diver. The platform appeared to be stable, although until the full complement of batteries, oil pumps, etc. have been installed, a firm comment on its actual stability cannot be made.

2. Battery Assembly

Figure 2 illustrates a typical battery rack assembly that fits into oil-filled tubular battery box. Main buss fuses, contactors, as well as the battery cables are packaged securely along the sides of the sliding rack assembly. They are bolted to the split mounting rings and do not move with the sliding battery tray.

The existing main buss tubular fuses, two of which are shown on the terminal board rack, will be replaced by the spring loaded configuration illustrated in Figure 3. The spring loaded fuse assembly was developed specifically for deep submergence use through a joint effort of the Naval Ship R & D Center, Annapolis, Maryland, and the Bussmann Manufacturing Company. By virtue of its spring loaded configuration, the active fuse element spacing is widely separated after it has blown due to overload. The wide mechanical spacing generated, prevents the formation of carbon clinkers which could continue to pass current to the defective circuit.

The two main buss battery cables used to connect the sliding battery pack to the fixed contactor boards, are of sufficient length to accommodate the total travel of the battery tray without placing undue strain on the connectors or battery posts. The two cables are secured to a sliding collar that is free to move the length of the fixed ring spacer rod. The arrangement provides free movement of the cables, and prevents kinks or mechanical interference with any moving parts.

Figure 4 is a close-up of the sliding battery tray drive mechanism. In its basic form, the device consists of a small 12 volt DC permanent magnet pancake motor direct coupled to an 8:1 gear box. The output shaft of the reduction gear is connected to the ball screw mechanism through the use of a 1:1 sprocket and roller link chain assembly. The sliding battery tray is driven by the linear travel of the ball screw. Micro switches are located at both extremes of tray travel, automatically cutting off power to the drive motor if the switch is inadvertently left on.

A pancake motor of the type used to drive the battery tray is shown in Figure 5. It is a DC permanent magnet motor using a printed circuit as the armature. Two motors were originally procured to test the feasibility of using this type device in an oil filled environment.

The first motor tested was a 28 VDC device, approximately 8½ inches in diameter, and rated at 1/8 hp at 2500 rpm. When immersed in oil, the windage loss was considerable. The current drain increased from an in air value of six (6) amperes to approximately 13 amperes in oil. While even this figure may have been tolerable, the brush gassing and windage loss was too high to be acceptable. In an attempt to reduce the gassing and windage, the motor was operated at ½ voltage, or 12 VDC. Gassing was considerably diminished, and in fact would have been acceptable. The output torque, however, was insufficient to operate the end load in a satisfactory manner. The second pancake motor was a 12 VDC configuration, six (6) inches in diameter, with a rating of 1/30 hp at 2100 rpm. Its in air current rating is five (5) amperes. Immersed in oil, the current drain increased to seven (7) amperes with no noticeable gassing of the brushes. The windage loss was approximately 50%, which is a fairly high value. However, in all fairness to the motor design, it must be pointed out that both these motors have extremely good potential for oil filled deep submergence use. They are well within the \$50.00 price range, did not require modification, and could be considered as throw away, or one time use devices. While we do not intend to research small motor design in this project, I do recommend that further investigation be initiated to obtain additional data on printed circuit permanent magnet motors of this type.

3. Suction Pod Assemblies

No additional work has been performed on these devices. The following is an abstract of a previous report, and is considered applicable for this report period. With the exception of actual bottom shallow water tests, the three assemblies are considered as complete. After initial bottom test of the platform, it is expected that additional work will be performed in an attempt to improve their characteristics through the use of rubber skirts and/or porous stone filters similar to those designed at the University of Rhode Island. The initial design did not include the filter assembly although the device was constructed in a way that will permit the inclusion of the filter with a minimum effort.

4. ALVIN SCAMP Interface

A firm decision has been made concerning the couple/decouple method to be used in clamping the SCAMP to the ALVIN deep submersible. Several laboratory tests have been performed utilizing the principle of fire hose expansion to provide a soft but rigid clamp that would conform to the skin and skid irregularities of the ALVIN vehicle.

Figures 6, 7, and 8 illustrate the full scale mock-up of the originally proposed system being tested in the Baldwin tensile machine. As illustrated in Figure 6, the basic device consists of two lengths of four (4) inch fire hose secured to a matching set of skid back-up rails. The fire hose clamps are shown in the deflated condition. Figure 7 illustrates the ALVIN skid cross-section positioned between the deflated tubes. Figure 8 depicts

the expansion ratio that can be obtained when the device is inflated. The data obtained from the first series of tests, indicated that a 175 pound pull could be exerted by the clamp, when both tubes were equally inflated with 15 lbs. of air. The "active" clamping length of a single hose is 18 inches. The overall length of the hose, including the end manifold is 24 inches. As the test progressed, it became clear that as the vertical load or tension was increased, the hose had a tendency to roll in the upward direction. The clamping action did not break away, but the skid did lose contact with the bottom mounting plate.

To alleviate the rolling condition, the final clamp design incorporated a flat mounting plate secured on the inside of the tube. Studs welded to the mounting plate protrude through the side wall of the tube, and are bolted to the skid side rails. Some minor rolling or tube deformation still occurs, and must be expected in a "soft" clamp. The clamp action however, has been substantially improved over the original version.

Figure 9 illustrates a full scale test of the SCAMP and the ALVIN frame. Using sea water as the fluid medium, the tubes were pressurized to 18 psi. The overhead crane applied a pullout force of 1400 pounds prior to any noticable movement of the ALVIN frame skids and the clamp rails on the platform. The dynamometer in the right center of the photograph was used to measure the load applied to the system. The 1400 lb. tension load applied to the system. The 1400 lb. tension load applied to the clamp rails is the true load corrected for the weight of the ALVIN frame.

Figure 10 is an aft view looking forward and down on the SCAMP frame. The fire hose clamp and skid back up rails are clearly illustrated. They run the length of each main I beam assembly, and are shown in the deflated condition. While one continuous length of hose would provide far more clamping action than the twelve individual 18 inch lengths, the complexity of preventing "tube roll" over the six foot distance became prohibitive.

5. ALVIN/SCAMP Skid Clamp System

Figure 11 illustrates the basic hydraulic (sea water) system used to control the skid clamps. In the pump or clamp mode, sea water is drawn through a strainer that filters out coarse particles that may be in suspension. The fluid is pumped through a delrin manifold block containing check valves, directional control valves, pressure switches, and the emergency dump valve.

As the fluid is pumped, it is directed to six sets of skid clamps as illustrated at the top of the system schematic. The sea water inflates the hose assemblies providing a clamping action at the base of the submersible skids. The system continues to pump automatically until a pressure of 18 psi above ambient is reached.

At this level a preset pressure switch shuts down the motor/pump assembly.

Assuming leakage of the system, or external ambient pressure increases due to submersible descent, a low level pressure switch set at 14.5 lbs. will reactivate the pump to return the system pressure to the 18 psi limit. During the pump mode, all flow is through the check valve, with dump valve V_1 closed. A relief valve R_1 bleeds internal water pressure back to ambient as the external pressure decreases during ascent of the submersible and platform.

One interesting point noted during the pump mode test with the ALVIN frame, was the fact that the clamps are a self centering device. Regardless of the athwartship position of the frame, it was always centered by the clamp mechanism as the pressure increased within the tubes. It is doubtful however, that the clamps would have sufficient force to reposition the 30,000 lb. dead weight of the ALVIN in air. The in-water weight at initial contact between the submersible and the platform is sufficiently low that self centering would take place.

The pump time from initial start up to pressure switch cut-off is three to four minutes with an air laden system. It is hoped that after the residue air in the system has been removed, that a faster pump up will be obtained. The present pump time is directly coupled to the pump capacity, rpm, and the torque that can be obtained from the existing drive motor. The pump and motor combination was constructed from off the shelf components and could be improved if designed specifically for the system.

In the pump down or release mode, dump valve V_1 opens and the pump direction is reversed. Sea water from the skid clamp hose assemblies passes through the passages in the manifold block, through valve V_1 and back to ambient via the strainer, pumping continues until the majority of fluid has been removed from the system. A vacuum switch set at eight inches of mercury cuts off the motor/pump set. At this time the skid clamp hose assemblies are flat against the skid rail brackets, reducing the interference and possible damage to the clamps as the skids of the vehicle move into or out of the slot.

In the event of failure of either the motor/pump assembly, and/or the main dump valve, the skid rail clamp sea water pressure can be released through the actuation of the emergency dump valve. While it is understood that releasing the internal sea water pressure in the clamp tubes will not cause the tubes to go flat against their respective rail brackets as normally found in the pump evacuation mode, the clamps will release and allow the SCAMP to drop away from the submersible. By design, the SCAMP will always be in an approximate 200 lb. negative buoyant condition. This primary objective was to assure no buoyancy unbalance existed between

the normal surface or submerged condition of the submersible. It also assured the SCAMP would drop free of the submersible should an emergency exist.

It is anticipated that the ALVIN frame and SCAMP, as illustrated in Figure 9, will be immersed in shallow water and both the normal dump cycle as well as the emergency dump mode tested to assure proper operation of both systems prior to the actual mating of the two vehicles.

The pump used to move the sea water is a conventional Oberdorfer Herringbone gear device which is quite tolerant to small foreign material, as well as being capable of generating both positive and negative pressures depending on its direction of rotation. Figure 12 illustrates the pump and motor assembly mounted in the forward starboard nose cone. The cone is filled with a pressure compensating fluid, and has a rubber diaphragm separating the sea water from the Marcol compensation oil. The motor armature windings as well as the gear pump seals are compatible with the compensating fluid. Figure 13 depicts a typical nose cone assembly illustrating the pump lines of stainless steel tubing, as well as the plastic conduit used to house the electrical control cables. Both hard tubing and electrical cables use a Danco feed-through assembly as a standardized penetrator. All electrical cables used to operate the various components as well as interconnect the two tubular battery boxes, are filled with the pressure compensation fluid common to all systems. Each of the individual nose cone assemblies are attached to the tubular battery compartments with quick $\frac{1}{4}$ turn latches, and are easily removed for maintenance purposes.

Figure 14 illustrates the sea water strainer assembly for the skid clamp system. It is located on the forward port nose cone. As shown by the photograph, the strainer is at the top of the assembly with the lower two thirds of the cylinder acting as a sea water reservoir. By retaining the fluid above the pump suction, the system may be operated on deck, providing a method of mating the submersible and SCAMP without drawing air into the system.

6. Skid Clamp Pump System Components

A. Pump Drive Motors

Two permanent magnet DC motors were procured to evaluate their operational characteristics in an oil-filled environment, and to test their ability to drive the sea water clamp system pump.

The motor illustrated in Figure 15 is a permanent magnet $\frac{1}{4}$ hp 1800 rpm 48 volt DC motor having a flat commutator in lieu of the standard cylindrical configuration. The field is provided by four permanent magnets secured with epoxy to the inside of the cylindrical shell.

In an effort to reduce windage, the end windings of the armature were potted with a paste consisting of resin and microsphere balloons. After curing, the excess resin was cut away and the surfaces machined smooth. A cylindrical sleeve of heat shrink tubing was slipped over the armature, extending past the edge of the flat commutator. The assembly was rotated slowly in a lathe while the tubing was evenly shrunk around the armature. No attempt was made to make the armature an oil tight component. In fact, sufficient passages were left in the end of the assembly to allow the free passage of oil, effectively making the unit an oil filled pressure compensated device with smooth external surfaces for minimum windage loss. After completion of the modification, a spiral groove was machined into the copper segments of the armature to provide a wiping screw action to reduce oil buildup under the brushes.

In oil operation at the 48 VDC rating generated an excess of gas at the brushes. The 1800 in air rpm dropped to 1000 in oil, however, sufficient torque was generated to more than adequately drive the sea water pump system. The voltage was reduced to 30 volts DC and the test repeated. Brush gassing was still excessive, and further investigation was discontinued. Additional work on this motor involving methods of reducing the current density of the brushes, could result in a low cost high torque motor that is compact and easily adapted to oil filled environments.

A second motor, illustrated in Figure 16, was modified in a similar method. The commutator, however, was of the conventional cylindrical configuration. The machined armature grooves in this case were 32 threads per linear inch. The motor had a 3/4 hp rating at 1800 rpm, drawing 4.7 amperes at 90 volts DC. The in oil characteristics were 900 rpm, drawing 2.5 amperes at 30 volts DC. Brush gassing was non-existent even under the normal pump load conditions.

While the pump/motor combination assembled from this unit was considerably slower at pumping the sea water into the skid clamps, it was felt the lack of brush gassing under loaded conditions would be a major advantage to the system and it's reliability.

B. Sea Water Dump Valve (Item VI - Fig. 11)

Figure 17 is an overall view of the prototype sea water dump valve, and its vibrating type drive motor. The device illustrated was designed, fabricated and assembled from various vendor components, after a thorough search of valve manufacturers failed to turn up an acceptable device with the following characteristics.

1. Capable of controlling silt laden sea water without degradation to the sealing surfaces.
2. Operating range of 28°F to 100°F.
3. Operating pressure of 20 psig to a negative pressure of 10 inches of mercury.
4. Operating voltage of 24 to 32 VDC.
5. Corrosion resistant materials and/or compatible elastomers in areas in direct contact with sea water.
6. Capable of complete immersion in oil for the purpose of pressure compensation.
7. Capable of operating at ambient pressures as great as 10,000 psig.
8. No holding current required after on/off actuation.

In its basic form, the valve illustrated in Figure 17 consists of a vibrating type motor driving a hydraulic piston through a worm gear mechanism. A cylindrical elastomer sleeve is compressed around a teflon bullet through the action of hydraulic fluid, effectively closing the valve. In the open cycle, the hydraulic fluid pressure is released, and the elastomer relaxes to its original open position.

Figure 18 is a cross sectional sketch of the valve mechanism. Item 1 is the worm drive gear from the vibrating motor. A detailed description of the motor is covered in part C of this section. On actuation, the worm and pinion gear drive a connecting rod, Item 2, converting rotational motion to a linear action. Piston 3 begins to move into the cylinder bore compressing the hydraulic fluid. As the stroke continues, the cylindrical elastomer tube, Item 6, begins to compress. On full stroke the elastomer tube is compressed around the teflon bullet, Item 7, stopping all sea water flow through the valve. Micro switches at both the top and bottom extremes of stroke, automatically stop the valve action. The worm and pinion ratio, in addition to an internal clutch mechanism in the drive motor, prevents the valve from snapping open when drive power is disconnected.

On the open command, the piston travels upward releasing the hydraulic pressure in the cylinder and the area between the elastomer tube and main valve body, Item 5. On full stroke, the elastomer tube returns to its relaxed position allowing a free flow of sea water through the valve. Pressure compensation of the hydraulic fluid, as well as any slight compressibility effect is compensated by the flexibility of the elastomer tube. The hydraulic fluid volume is minimal, being

approximately 12 milliliters. Laboratory tests as well as in system surface operations appear to be satisfactory. However, one modification has become apparent, and should eventually be incorporated in the valve mechanism. The initial oil quantity used to fill the cylinder and valve body cavity is quite critical. Over filling excessively loads the vibrating drive motor, while underfilling could conceivably result in incomplete valve closure.

The suggested modification would be to incorporate a small combination check relief valve in the hydraulic piston. In the release or upward stroke of the piston, the check valve opens drawing in the compensation fluid surrounding the valve, thereby assuring a full cylinder charge. On closing, or down stroke, the check valve closes and operates in the opposite direction as a preset relief valve. As the piston continues its downward or compression travel, sufficient pressure would be generated to assure positive valve closure against the normal 18 psig system pressure. Excess pressure generated by additional piston travel would be released, unloading the drive motor and preventing motor stall.

C. Dump Valve Drive Motor

At initial concept of the SCAMP program, the intent was to try new areas of approach in the design of the various systems and hardware. In carrying out this concept, the sea water dump valve motor became a prime candidate. Past drive mechanisms have frequently been of the conventional rotating armature type, with their inherent problems of brush gassing and windage loss. The drive motor selected for the sea water dump valve is a unique device having no brushes, minimal windage loss, and by virtue of its design, it delivers a low speed rotary motion without the use of gears.

Figure 19 is a simplified sketch of the device. In its basic form, the motor consists of a ferrite permanent magnet which has been magnetized in a way that forms two magnets. There are two sets of laminated pole pieces located on each side of the permanent magnet. Only the front set is shown in the sketch. The magnet is arranged to present a north magnetic face to one laminated pole, and a south magnetic face to its opposite mating laminated pole. The other portion of the permanent magnet, which is the second magnet, has its north and south magnetic forces arranged in the opposite direction to the first magnet shown in the sketch. Consequently the second set of laminated poles has a reversed magnetic force from those illustrated.

When an alternating current is applied to the coil, an alternating magnetic flux is generated in the laminated poles. At time one, the flux is additive to the flux from one pole of the permanent magnet, and subtractive from the opposite pole,

forcing the oscillator yoke to one side. At time two, the AC current is reversed and flux direction is reversed, forcing the oscillator yoke in the opposite direction. The oscillator yoke pulses back and forth 100 times per second with a 100 cycle AC input current.

The oscillator yoke is part of a cylindrical stator assembly which is driven back and forth in a rotary oscillating motion. Spring loaded rollers provide a unidirectional clutch by wedging and releasing between the oscillator yoke and the rotor as it pulses back and forth. The clutch mechanism illustrated, drives the rotor in a clockwise direction.

The motor assembly used in the sea water dump valve system requires a 30 volt DC input, has a stall torque of 4.2 inch lbs., drawing 215 milliamps when operating at 26 rpm.

The original driver circuit provided by the manufacturer, consisted of a single transistor connected to a collector to base feedback oscillator with the collector circuit tuned with a 400 microfarad non-polarized capacitor. As expected, the capacitor was unable to withstand the 10,000 psi test pressure, and promptly collapsed. The circuit and motor however, continued to operate satisfactorily while under pressure.

A new circuit was designed, with two major goals as the prime requisites. (1) The circuit must have redundancy to assure valve operation in the event of transistor or other circuit component failure. (2) The circuit must be capable of complete immersion in oil, and able to withstand an ambient test pressure of 10,000 psig.

Based on the above requirements, several basic rules were formulated to evaluate the components selected for the new circuit. (1) Use only plastic cased transistors and integrated circuits, (2) Use only capacitors such as ceramic, mica, or rolled film dielectric types, avoiding those which might have voids or entrapped gas bubbles, such as electrolytic capacitors. The modified circuit illustrated in Figure 20, uses a .001 microfarad capacitor as the frequency determining element, as well as integrated circuits in lieu of the 400 microfarad capacitor. The oscillator which consists of two sections of a CD4001AE, an astable multivibrator chip, operates at 100 Hertz. The output is divided down by ten with a CD4017AE chip. The 100 Hz output is used as the motor drive frequency. Laboratory tests on the motor, using a pulse generator, determined that an optimum drive cycle was between 30 and 40%. The drive circuit illustrated was designed to pulse the motor at a 30% duty cycle.

Circuit redundancy was provided by coupling a small capacitor between the two oscillators, forcing them to oscillate in phase.

Either oscillator will continue to operate if the other unit fails. The divide by ten circuits are synchronized by cross reset lines. A separate drive transistor circuit, MJE340 is duplicated in the output of each divide by ten chip.

The drive transistors usually fail in two different modes. The most common failure is an emitter collector short. After a short delay, this failure mode will cause the fuse to open in the defective section. The second oscillator and countdown circuit will still continue to operate, driving the motor. The second failure mode is an open base lead, or an emitter collector open. Neither of which will effect the opposite circuit.

The motor and electronic package illustrated in Figure 21, has been pressure cycled in an oil-filled vessel to 10,000 psig. No degradation of motor operation was noted, and no problems were discovered with the electronic drive circuit. The components used in the electronic circuitry are standard off the shelf hardware. The only modification performed to these components was to drill a small vent hole in the end caps of the two fuses, assuring the entry and pressure equalization of the compensation oil within the fuse.

It is anticipated that the present fuse will be replaced with a Buss grasshopper fuse, which is more in line with the type developed by the Naval Ship Research and Development Center, Annapolis, Maryland. The grasshopper fuse has a spring loaded fuse bar, that snaps apart on melting, assuring a positive open circuit condition.

7. SCAMP Support Equipment

The shallow water evaluation will require operational tests of the following circuits:

A. Rail Lock Pump System

1. Pump up pressure switch control between 14.5 and 18 psig.
2. Pump down pressure switch cut off at eight inches Hg.
3. Automatic cycling to compensate for simulated rail lock leakage.
4. Sea water dump valve operation, pump up and pump down cycle.
5. Emergency dump valve operation.
6. Couple and decouple of SCAMP and simulated submersible.

B. Suction Pod Operation

1. Ability to control one, two, or all three pods in the suction

mode.

2. Ability to individually control pods in the release mode.

C. Battery Traverse Mechanism

1. Selective battery tray travel to maximum extreme of tray movement both fore and aft.
2. Positive operation of travel limit switches.
3. Tray position holding ability at preselected positions.

D. Main Battery Circuit Operation

1. Ability to activate vehicle and emergency system from either port or starboard battery pack, assuming one pack as dead.
2. Ability to operate all devices and emergency system components from either port or starboard battery pack.
3. Operation of enable and overload switches, using port, starboard, and both battery packs.
4. Ability to operate all systems, normal and emergency, with both battery packs in parallel.

Surface Control Console

In view of the lengthy system check out required for initial surface tests, and the mandatory requirement to perform the same series of tests in shallow water, the two control boxes illustrated in Figure 22 were constructed.

Both boxes have been provided with cannon type multipin connectors for ease in attachment to the SCAMP. For shallow water tests, at diver depth, two 50 foot multiple bundles have been prepared, and will be used to connect the SCAMP to the surface support vessel.

Dry surface tests with the control boxes indicate satisfactory system operation. Some minor relay problems were uncovered, with the difficulty traced to surface contamination on the open pole relays used in the control system on SCAMP. The relays were operating dry at the time, and did not have the benefit of being "washed" by the compensation fluid in which they will normally be immersed. No further difficulty is anticipated with these relays after contact cleaning.

The speed of the battery traverse mechanism, powered by the pancake motor drive noted in Figure 4, was excessive when first cycled. The tray and its 260 pounds of batteries moved at a speed that was ex-

cessively high, over-running the limit switches at the travel extremes. Minor circuit tracing revealed that a 10 ohm resistor had not been included in the power circuit. Consequently, the 12 volt DC motor was being operated at the full 30 volt level of the battery pack. A modification of the circuit corrected the problem. It was, however, interesting to note that the over voltage did not adversely effect the motor or its printed circuit armature. The motor may be more versatile than originally thought.

Surface Buoyancy Package

In view of the 200 lb. negative buoyancy characteristic of the SCAMP, the pneumatic surface buoyancy package illustrated in Figure 23 was constructed. The flotation package was initially designed to provide a means of moving the platform onto the submersible support cradle without the use of a crane. As the platform progressed, it became apparent that some means would be required not only to float the SCAMP to the shallow water test area, but to also allow it to be slowly submerged to the divers test site. The system was modified to provide diver control of both ascent and descent through the use of a pneumatic variable ballast system.

In its basic form, there are four elastomer inflatable bags, Item 1, that are attached to the four corners of the platform frame, Item 2. The four flotation bags are capable of providing pressure hose to a control manifold. Four toggle valves, Item 8, provide selective fill and vent control for each individual bag assembly. A SCUBA bottle and regulator assembly, Item 9, provides the pneumatic supply source.

To inflate the bag, the operator actuates the fill valve. Air at 50 psig flows through the inlet tube, Item 6, forcing piston, Item 10, against the vent seat in the valve body, Item 3. When the system dead ends, the spring loaded check valve opens, allowing air to inflate the bag, Item 4. Any excess air is allowed to free vent out the open base of the stand pipe tube, Item 5. In the vent mode, the operator moves the toggle valve in the opposite direction. Air is released from the backside of the piston, Item 10, allowing the internal bag pressure to act on its front face, moving the piston off the vent seat in valve body, Item 3. The entrapped air in the flotation bag escapes, the bag deflates, and the platform submerges. To return to the surface, the operator reverses the procedure, filling the bags until the ascent starts. As the assembly lifts off the bottom, the diver controls the rate by either quick vent pulses, or if it stops its ascent, a quick fill pulse.

Unfortunately, the diver has to have exceptionally quick reflexes to operate the device in its present form. Shallow water tests using a dummy frame, indicates that reasonable control can be obtained, but it is far too critical to be considered as satisfactory and safe. Slight delay on the divers part in either the

fill or vent mode results in a large scale yo-yo!

Additional tests on the ascent-descent method for lowering the platform in shallow water will be deferred for the time being. The flotation bags however, are satisfactory and will continue to be used as surface buoyancy. The four flotation bags are piped to the control manifold and pneumatic source using quick disconnects. Each bag attaches to a frame "U" bolt with conventional snap type safety hooks. Figure 24 illustrates a typical flotation bag assembly attached to one corner of the SCAMP. The system is rapidly removed or attached without the use of tools. The flotation bags are not required when the SCAMP is attached to a submersible.

8. Pulsed Light Control System

All components have been procured to fabricate a prototype transmitter and receiver section. Due to personnel schedules over the past several months, no action has been taken on this task. The initiation of the circuit development will be started within the month.

Figure 1. Completed SCAMP frame, illustrating syntactic foam floatation blocks.

Figure 2. Relay contractors, fuses and power cabling of a typical battery rack assembly.

Figure 3. Spring Loaded "Grasshopper" fuse assembly.

Figure 4. Sliding battery tray, motor drive assembly.

Figure 5. Printed circuit armature pancake motor assembly.

Figure 6. Skid clamp hose assembly illustrated in deflated condition.

Figure 7. Skid clamp test assembly with simulated cross section of ALVIN skid.

Figure 8. Fully inflated skid clamp assembly.

Figure 9. Full scale test of break-out forces required to separate skid clamp assemblies and ALVIN frame.

Figure 10. Close-up view of SCAMP skid clamp assemblies.

Figure 11. Schematic diagram of sea water hydraulic system for skid clamp activation.

Figure 12. Skid clamp motor and sea water pump assembly.

Figure 13. Typical battery tube nose cone illustrating electrical and mechanical feed through fittings.

Figure 14. Sea water strainer and reservoir assembly.

Figure 15. D.C. permanent magnet motor assembly with flat commutator.

Figure 16. Conventional D.C. permanent magnet motor potted for deep ocean use.

Figure 17. Skid clamp sea water control valve and motor drive assembly.

Figure 18. Cross sectional sketch of sea water control valve.

Figure 19. Simplified schematic of sea water valve oscillating motor assembly.

Figure 21. Circuit board and oscillating motor used with the sea water valve assembly.

Figure 22. SCAMP electrical system surface control boxes.

Figure 23. Schematic diagram of SCAMP surface control floatation system.

Figure 24. Typical inflatable bag assembly used in the SCAMP floatation system.

Modular Acoustic System

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Modular Acoustic System

Control

Design and breadboard test of all manual-mode control circuitry has been accomplished. Controls for operator control of pulse rate, pulse length and receiver range gating have been implemented and tested. Circuitry for keyboard entry and lighted digital displays for conversation with the on-board computer have been designed and tested independent of the computer. Provision is made for manual parameter entry and storage of 6-digit numbers with the ability to hold five such numbers in a lighted front panel display as a reminder for the operator. The control panel and circuit assemblies are shown in Figures 1 and 2.

Display

For display purposes it is necessary to take the relatively slow acoustic data, store it and present it in readily understood form to the operator.

A block diagram of the display is shown in Figure 3. It is built around the Hughes scan converter, model MSC-1, which will accept line-by-line data, store the data, and then read it out in television format. The display scope is a Ball Brothers Research Corporation five inch television monitor scope. Both scan converter and scope have been acquired. (Figure 4).

Because the scan converter can only accept data during the television interframe time, the slow acoustic data has to be stored for one line (one sweep) in a shift register and then read-out quickly during the interframe time, as described below.

The acoustic data is first fed into an integrator whose time constant is matched to the particular sweep rate in use. This value is then stored in a "sample and hold" circuit while the A/D conversion takes place. The digitized data consists of 16 levels, more than adequate for a grey scale readout.

The data next enters the shift register which is 512 words long and provides sufficient resolution. The information in the register is next converted back to an analogue signal and fed (through a switching matrix) to the scan converter. This portion (integrator, sample and hold, A/D, shift register, D/A fast clock, and slow clock) has been constructed and checked out using simulated signals.

Still to be done are the various sweep generators which will generate the various displays. The fast and slow sweep circuits will generate linear ramp signals. The PPI ... sweep generator will take the sine and cosine functions generated from the azimuth or elevation signals and multiply them by the fast and slow sweeps to give the PPI sweep voltages.

The panel will contain the azimuth and elevation controls and read out. It will incorporate a super 8-mm camera which will operate in a single frame mode and record pictures of the scope display automatically.

Tape Monitor and Log

The tape monitor and log section is designed as follows:

The digital data logger scanner can scan up to 128 channels of 6 bit-BCD information. After conversion of ASCII code, it is stored on one track of a tape recorder as a teletype-compatible, serial, frequency shift-keyed signal. The data logger completes a scan upon command from a crystal-controlled clock source. The clock has three outputs: a 7-segment LED display for visual use, a standard I.R.I.G. "B" modulated output which goes on a separate tape recorder track and is used for tape search, and a static BCD output which is recorded on the teletype-compatible tape track through the BCD scanner.

The whole system has been breadboarded and tested. In addition, printed circuit cards have been built and tested for the complete clock and BCD-to-ASCII-to-teletype code converter(Figure 5).

The Borg-Warner tape recorder has been acquired (Figure 6).

Transmitters

The transmitter power amplifiers (Figure 7) have been designed and fabricated. Each of the two amplifiers consist of six RCA-hybrid 100 watt power amplifier modules. The modules are driven in parallel and the outputs are combined in a broadband toroidal transformer. Actual measured CW power output across resistive loads in excess of 600 watts is available from each amplifier unit.

The amplifiers are built on the aluminum end-caps of their respective pressure cases. This provides good heat-sinking to the surrounding water. The pressure cases also contain a silver-cadmium battery stack to power the amplifiers. Sufficient power is available from the battery stack for approximately 40 minutes of actual full-power CW transmission. Float charging of these batteries from the submersible's main power bus can be implemented if necessary.

Pressure cases are fabricated from titanium to minimize corrosion and weight.

Trainable Mount

The trainable mount is presently under construction. The elevation portion is assembled and operating. An eighteen inch diameter flat disc is provided for transducer mounting. The normal axis of this plate (transducer main-lobe axis) is trainable from -25° to $+105^{\circ}$ from the horizontal. Note that the entire assembly may be inverted for bottom search.

Construction (Figure 8) is almost entirely of nonmetallic materials except for shafts and fasteners. All structural members are G-10 Epoxy fibreglass, screw, and epoxy cement assembly. Gearing in both elevation and azimuth consists of stainless steel driving gears and Delrin driven members.

Drive motor and shaft-angle pickoff housings are PVC with neoprene equalization windows. Both housings are oil-filled.

Drive motors for both azimuth and elevation are step-by-step motors allowing precise positioning of the platform as each motor turns 1.8° per step. Drive circuitry for the motors has been designed and operated which allows complete digital control of transducer position either by means of manual joy-stick control, selectable sector-scan, or direct computer control.

Transducers

Two of the axial beam transducers have been specified and ordered. They cover the frequency ranges of 5-15 kHz and 15-40 kHz.

Computer System

The computer system has been specified, purchased, and tested. Our choice contained the following components (Figures 9, 10 and 11).

1. NOVA 1210 computer with 8K memory for use in the submersible.
2. NOVA 1220 computer with 8K memory for use ashore in generating programs and use afloat as back-up for the 1210. (The 1220 duplicates many of the components of the 1210). The 1220 can also be used for some analysis work while afloat.
3. Graphics terminal with associated print-out for interaction with the 1220 computer system while generating programs.
4. High speed paper tape reader for entry of new programs and system programs into the system disc.
5. 1.247 million word disc. This, coupled with the graphics terminal, greatly increases the efficiency of program generation. The disc requires a minimum of 12K of memory to function properly. Thus the 8K of memory in the 1210 computer must be used at this time in the 1220 to permit program generation (it is then switched back when programs are run in the 1210).
6. Two Ross Cassette units - one is attached to the surface system, receives completed programs intended for the submersible. We also intend to use it as a scratch area during program generation. The second, part of the submersible package, is the means for inputting the desired program to the 1210 computer. It can also be used as a digital data storage device.

7. Parameter input and echo display devices on the submersible front panel to permit the investigator to vary frequency, repetition rate, pulse length, etc. The number of possible parameters is constrained only by the program and not by these devices.

Despite delays in computer system delivery, programming has proceeded. Drivers for the cassette operation have been written as has our first frequency generation program.

The interfaces to the cassette, parameter input and echo display devices, and to the frequency synthesizer, have been designed and partially constructed. Additional interfaces for the training mechanism, scan converter unit and analog-to-digital conversion have not been started.

Figure 1. Main Sonar Control Panel. Receiver Sub-Assembly at Left.

Figure 2. Digital Control Assemblies for Memory Display, Keyboard Interface and Computer I/O.

Figure 4. CRT Display. Hughes Scan Converter on Right. Sweep and Control Electronics at Left.

Figure 5. Time Code Generator and BCD-to-ASCII Converter Electronic Assemblies.

Figure 6. Tape Recorder and Synthesizer.

Figure 7. One of Two Outboard Power Amplifier/Battery Packs.

Figure 8. Transducer Training Mechanism. Elevation Drive Assembled. Step Motors in Oil-Filled Boxes.

Figure 9. Surface Computer System. Repco High Speed Printer at Left Rack, Top to Bottom: Disc Storage Unit, Remex High Speed Tape Reader NOVA 1220 CPU, Scope Graphics Terminal, Keyboard, Disc Controller (under table). ASR-33 Teletype at Right.

Figure 10. Block Diagram of Surface Computer System.

* Not part of Computer system

Figure 11. Block Diagram of Submersible Computer System.

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