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(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY (Corporate author)

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts 02543

2a. REPORT SECURITY CLASSIFICATION

UNCLASSIFIED

2b. GROUP

3. REPORT TITLE

TECHNICAL PROGRESS REPORT
ADVANCED MARINE TECHNOLOGY

4. DESCRIPTIVE NOTES (Type of report and inclusive dates)

1 February 1971 - 31 July 1971

5. AUTHOR(S) (Last name, first name, initial)

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6. REPORT DATE

29 February 1972

7a. TOTAL NO. OF PAGES

48

7b. NO. OF REFS

8a. CONTRACT OR GRANT NO.

N00014-71-C-0284

8b. ORIGINATOR'S REPORT NUMBER(S)

WHOI-72-33

a. PROJECT NO.

8b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report)

10. AVAILABILITY/LIMITATION NOTICES

11. SUPPLEMENTARY NOTES

The report describes progress

12. SPONSORING MILITARY ACTIVITY

Office of Naval Research
Code 480
Arlington, Virginia 22217

13. ABSTRACT

This is a progress report for the period 1 February 1971 - 31 July 1971 on the following projects in Advanced Marine Technology: (a) Submerged Navigation and Submersible Instrumentation (development of precise navigation for a small submersible), (b) Handling and Transfer at Sea (use of energy absorbers in small boat and buoy handling alongside in rough weather), (c) Bottom Reconnaissance and Detailed Site surveys (use of submersible in geological mapping), (d) Near Bottom Magnetic Studies from a deep submersible, (e) Near Bottom Gravity Studies from a deep submersible, (f) Deep Sea Rock Drill and Heat Flow Instrument for use from submersible, (g) Deep ocean biological research (observation and collection under pressure of benthic biology), (h) Offshore Monitoring of Industrial Waste (use of gas chromatographic techniques to determine pollutants in sea water), and (i) Air Sea Systems (use of air-dropped arrays of sonobuoys and explosives for seismic reflection, refraction and side-scan echo ranging).

Details of illustrations in
this document may be better
studied on microfiche

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14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
1. Advanced Marine Technology 2. ALVIN 3. Navigation of Submersible 4. Transponders 5. Boat Handling Buoys 6. Small Craft 7. Geological Mapping 8. Gulf of Maine 9. Geological Sampling 10. Magnetometer (deep) 11. Gravimeter (deep) 12. Rock Drill 13. Heat flow 14. Benthic Biology 15. Biological (deep) Station 16. Pollutant Detection 17. Refraction 18. Reflection 19. Echo Ranging						

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WHOI-72-33

TECHNICAL PROGRESS REPORT
ADVANCED MARINE TECHNOLOGY

1 February 1971 - 31 July 1971

by

Wilfred B. Bryan	William M. Marquet
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Robert D. Ballard	Peter H. Wiebe
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WOODS HOLE OCEANOGRAPHIC INSTITUTION
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February 29, 1972

Dr. A. E. Maxwell, Principal Investigator

Sponsored by

Advanced Research Projects Agency

ARPA Order No. 293-008

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

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III
Earl E. Hays
Earl E. Hays, Chairman
Department of Ocean Engineering



TABLE OF CONTENTS

	Page
Report Summary	1
a. Submerged Navigation and Submersible Instrumentation	5
b. Handling and Transfer at Sea	10
c. Bottom Reconnaissance and Detailed Site Surveys	14
d. Near Bottom Magnetism Studies Using a Deep Submersible	24
e. Near Bottom Gravity Studies from a Deep Submersible	28
f. A Self Contained Deep Sea Rock Drill	30
g. Development of Equipment for Use in Deep-Ocean Biological Research	35
h. Offshore Monitoring of Industrial Waste	41
i. Air Sea Systems	47

IV

Report Summary

This program is directed mainly towards improving and implementing the work performance of deep submersibles. Only two of the subjects discussed below diverge from this theme, namely (h) Offshore Monitoring of Industrial Waste, and (i) Air Sea Systems. Subject (b) Handling and Transfer at Sea, does not specifically deal with submersibles in this report, but the launching and recovery of the vehicle is perhaps the most outstanding problem in the use of small submersibles, and results obtained here may be useful in solving the problem.

One of the most important functions of the submersible is to allow scientists and engineers to observe the deep sea environment, but this is not sufficient; samples must be obtained, and measurements made if the observations can be put to practical use. As is well known to SCUBA divers, things that are easy to do on land become difficult to do underwater; there is another equal increase in difficulty when the observer is inside a vessel trying to do something outside. The effective use of the deep water areas of the ocean will require the capability to do many things there, and this capability is being sought in this program.

(a) Submerged Navigation and Submersible Instrumentation

The purpose of the Submerged Navigation and Submersible Instrumentation project is to develop a three dimensional, local navigation system for submersibles and their support ships. This system will initially provide improved navigation in the normal operational situation and will be used to evaluate techniques that are required to satisfy future needs for deep ocean, near bottom exploration. The system will be developed based on components that are proven in the at-sea environment.

The effort during the first six months of the program has been directed toward specifying, purchasing, building and integrating a basic components in preparation for at-sea testing. The three subsystem areas include components as follows:

1. Navigation Center

- a) Transducer
- b) Power Amplifier
- c) Receiver
- d) Display
- e) Digital Coupler
- f) Buffer
- g) Calculator
- h) Extended Memory
- i) Printer
- j) System Clock
- k) Shipboard Coder

2. Submersible Equipment

- a) Electronics
- b) System Clock

3. Bottom Beacon

- a) Transponder/Release
- b) Flotation
- c) Anchors

The system components have been integrated in the laboratory and the next phase is at-sea testing. This testing will be directed at evaluation of the operation of the coded acoustic transmissions, launch and recovery of the bottom beacons and measurement of acoustic power and sensitivity.

(b) Handling and Transfer at Sea

Any object in a sea way has a motion determined by its physical characteristics and the spectrum of the sea. Except for trivially light objects the energy and momentum can be significant. Two identical objects situated next to each other will have different motions and may damage each other. A field study is being made on the effectiveness of various means of absorbing the energy and impact of a small boat next to a large boat. Aircraft landing gear has been mounted athwartships fore and aft on a three ton 24' Coast Guard boat and tests are being carried out in a variety of sea states. Anyone who has made many transfers at sea will recognize that this cushioning is highly desirable and necessary in submersible handling.

(c) Bottom Reconnaissance and Detailed Site Survey Using a Deep Submersible

It is often of interest and sometimes necessary to know much of the detail of an area of the ocean bottom. ALVIN has been used during this period to evaluate some methods of detail gathering. A calibrated photography and viewing system has been constructed; a subbottom profiler, and a prototype nuclear densiometer/penetrometer have been tested, and a support ship survey system was assembled and used in site surveys (continuous seismic profiler, 12 kHz echo sounder, sonobuoy receiver and an Omega navigation set). This suite combined with the other instruments being developed will improve the site survey capabilities of submersibles.

(d) Near Bottom Magnetic Studies Using a Deep Submersible

Magnetic fields are caused by dipole-like structures, with a resulting rapid decrease ($\frac{1}{d^3}$) with distance away from the source. By towing a magnetometer near the bottom, more evidence of individual sources will be obtained, whether geologic or otherwise. The presence of the submersible allows quick identification of the field source if visible. An airborne proton precision magnetometer has been modified to work at pressure

(the sensor) and in ALVIN (DC electronics) and necessary tow cables and flotation obtained. Simple calculations show that the magnetometer should be at least 15 meters away from the steel hull to reduce effect of the hull to less than 10 gammas.

(e) Near Bottom Continuous Gravity Profiles from a Deep Submersible

Near bottom continuous gravity profiles from a deep submersible place the sensor near the bottom so that more detail about gravity anomalies can be obtained. The use of gravimeters on surface ships has become routine and it is felt that the use of small submersibles should offer no major problems. Design and assembly of a prototype system for use with ALVIN has proceeded and it is expected to be tested in dives this fall.

(f) A Self Contained Deep Sea Rock Drill

The submersible allows the scientist/engineer to examine the bottom and to find exposed outcrops of rock. The sampling of sediments is fairly easy; rocks require a drill. A study of existing rock drilling methods has been made and a design on a self contained rock drill for use by ALVIN has been completed and construction started. The self contained construction allows the submersible to search unimpeded for a desirable drill spot; then to place the drill and to start it drilling. The submersible can then perform other functions during the drilling period, return and retrieve the unit. A capability of making heat flow measurements in the hole is being added to the unit to obtain one more piece of geophysical information.

(g) Development of Equipment for Use in Deep-Ocean Biological Research

- (1) The small submersible offers an excellent platform from which observations, collections and experiments can be made. Many of the sightings of biological fauna seen in the bottom from submersibles have given new information to biologists, even though samples of the same type had been retrieved previously by dredges and nets from surface ships. During this period some equipment has been designed and constructed and some has been used in dives from ALVIN.

The equipments are

- (1) A Longhurst-Handy Plankton Recorder System - this system collects a plankton on a gauze which is wound up, and correlated with recordings of temperature and pressure so the environment of the particular plankton be determined.
- (2) A sediment trap has been designed. This instrument placed on the bottom for a lengthy period will give samples of the present day fallout of biological detritus and other sediments. It is

very difficult to obtain this by any bottom sampling technique.

- (3) One of the unknowns in the chemical balance of the oceans is the uptake of oxygen by the bottom and its inhabitants. A respirometer to monitor this process has been constructed. Unfortunately the deep tests of this equipment were unsuccessful due to electronic failures. The basic design however seems sound.
- (4) A Birge-Ekman box core has been modified to act as a bottom dweller sampler and has received preliminary tests.
- (5) Time lapse photography can be used to determine biotic and sedimentary processes over periods of weeks or months, and a camera-light system has been assembled for this purpose.

This phase of the Advanced Marine Technology Program has been the catalyst for the growth of a strong interest and participation by biologists in the use of ALVIN and the development of a long term bottom stations.

(h) Offshore Monitoring of Industrial Waste

The chemical monitoring of industrial wastes has been investigated by analyzing the extractable organic content of samples taken along a transect extending from mid-Buzzards Bay into New Bedford Harbor. A programmed-temperature gas-chromatographic technique utilizing flame ionization detector was utilized for the analysis and the sample extraction and analysis has been investigated for reliability, sensitivity, and resolution.

The analysis of 160 samples indicate that the sensitivity is adequate to give large signals from all natural samples treated. The resolution is in all cases inadequate to resolve a substantial fraction of the sample, and the reliability of the method is unknown but apparently strongly affected by biological activity occurring in the water before analysis is begun.

(i) Air-Sea Systems

The combination of explosives and sonobuoys can form an effective echo ranging system. If the sonobuoys are planted in an array, directionality can be obtained and large areas of the sea and sea floor can be examined for structure like ridges, sea mounts, etc. During this period preliminary plans were made for such an experiment. The experimental area will be examined by another technique (towed array and explosives) during August 1971 so that a comparison can be made of the results of the two methods. The actual air drop experiment time is related to availability of government furnished aircraft and may be delayed until 1972 as winter weather degrades the results.

**Submerged Navigation
and
Submersible Instrumentation**

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Submerged Navigation and Submersible Instrumentation

I. Purpose and Background

The purpose of this program is to develop a three dimensional, local navigation system for use by submersibles and their associated support ships. The goal for the first year is to build and test a working system that provides navigation for ALVIN and her support ship while permitting evaluation of fundamental acoustic and electronic techniques that will lead to an optimized future system. The basis system will be developed using components that have been proven in at sea applications and provide the capability for expansion into a system that satisfies the broad requirements of deep ocean, near bottom exploration and research.

The navigation system being developed is specifically configured for the small submersible and recognizes that the on board space and weight allowances are limited. The system takes advantage of the fact that the small submersible always operates with a surface support ship. The three basic components of the navigation system include (1) submersible electronics and transponder package, (2) the surface ship electronics, transponder, computer and control package, and (3) the bottom transponder, recovery flotation and anchor package.

The choice of major equipment manufacturers was made early based on considerations consistent with obtaining a working system within a realistic time frame. Past favorable experience within the Institution with the specific manufacturers products gives confidence in reliable field operation. Standard products exist that were close to the final units required and minimized component development time and costs. The manufacturers have provided good technical support to assure good system interface. The standard product lines have existing options to permit convenient system expansion for future use.

As the operational geometry and environment varies from dive site to dive site, several modes of operation are suggested. The system being developed is intended to provide a working system in a standard situation and at the same time allow the investigation of the parameters that control other modes of operation. This evaluation capability is a key to the long range development of a flexible useful navigation system that is required for the deep ocean.

The work effort during this first six month period has been directed toward specifying the components of the basic system, purchasing, building and integrating these components in preparation for the at-sea testing phase that is scheduled for the second six month period.

II. System Description and Diagrams

A description of the basic system operation for the navigation system will be useful in establishing the framework within which the initial investigation will be carried out. By envisioning as flexible a system as possible in the early planning stages growth potential will be provided for. The operational sequence for the navigation system is useful in reviewing the system block diagrams.

When the support ship, with the submersible aboard, arrives at a local operating area, a minimum of two bottom moored acoustic transponders will be placed on the bottom and surveyed from the surface. This establishes the local navigational base. The support ship will continue to interrogate the bottom moored transponders to maintain a plot of her position relative to the bottom units. Upon command of an on-board precision clock the submersible will transmit an interrogation signal to the bottom moored transponders. These units then reply with individual coded signals that are received by the surface ship. Submersible depth is to be measured acoustically and transmitted to the surface ship either via telemetry or underwater telephone. The surface ship then has travel times and therefore distances to define the geometry of both the submersible and the surface ship relative to the bottom units. The use of precision clocks on the surface ship and submersible allow a significant noise reduction and should it be desirable to use other submersibles or even unmanned submersible platforms, the same surface ship and bottom transponders could be time shared to provide an integrated navigation capability. In areas of rough terrain where direct paths from the submersible to the bottom transponder units do not exist precision timing will be useful to permit the use of surface bounce path. At the conclusion of operations in a given area, the bottom transponders will release the anchor assembly and be recovered at the surface.

III. Hardware Development Program

1. Shipboard Navigation Center

The majority of the equipments are located in the surface support ship. The individual units have been received and integrated into a working system in the electronics laboratory. All of the cabinetry, wiring harnesses and physical preparation has been accomplished in readiness for installation aboard R/V LULU prior to the initial sea trials. The following paragraphs define and discuss the individual units.

- a) Transducer - the device used to input acoustic interrogations to the water and to listen for the transponder replies and the DSV "ping". This is an AMF Model 200 unit with 250 feet of cable. It was ordered May 4, 1971, received on July 15, 1971.
- b) Power Amplifier - The equipment which amplifies the output signals from the Coder and drives the Transducer. This was manufactured by AM^T and is a Model SS200.
- c) Receiver - The unit amplifies the return acoustic signals and differentiates the various frequencies from the individual transponders and the DSV. This was manufactured by AMF and is Model No. 205. The unit was modified to W.H.O.I. specifications. It was ordered on May 4, 1971 and received on July 15, 1971.

- d) Display - This portion of the AMF Model 205 receiver determines the times from system trigger to reception of the return acoustic signals.
- e) Digital Coupler - Converts the digitized time information to a form acceptable by the calculator. This is a Hewlett Packard Model 2019A unit. It was ordered on April 26, 1971 and was received on June 26, 1971.
- f) Buffer - Interfaces all of the calculator peripheral. This is a H/P Model Number 9102A and was ordered on May 3, 1971 and was received on May 28, 1971.
- g) Calculator - Actually a mini-computer, this unit uses the time data plus additional information that has been input to memory to determine the ships position in an (X,Y) coordinate system and the position of the DSV in three dimensions. A H/P Model 9100A calculator is being used.
- h) Extended Memory - Increases the capacity of the calculator for program storage to accomodate the large programs needed to solve the system geometry. This is a H/P Model 9101A. It was ordered on May 3, 1971 and received on July 10, 1971.
- i) Printer - Prints hard copy of the "raw" data and the positions. A H/P Model 9120A printer is being used.
- j) System Clock - Provides all timing signals for the control of the system and provides synchronization with the DSV electronics which also has a very stable system clock. This breadboard unit was built at W.H.O.I. and was borrowed from the laboratory equipment.
- k) Shipboard Coder - This unit is keyed by the system clock and generates a signal to drive the power amplifier for transmission to the bottom transponders and the submersible. This is a Model 200 coder manufactured by AMF.

2. Submersible Equipment

- a) Electronics - The electronic system aboard the DSV transmits an acoustic signal at a time precisely in synchronization with the transponder interrogation by the surface ship. This signal will be detected by the surface receiver. Again, synchronous to the surface clock, the DSV equipment will emit a pulse, coded to interrogate the transponders. (See geometry diagram) This equipment was designed and built in the laboratory at W.H.O.I. The circuit cards, hardware and electronic parts were ordered May 4, 1971 and received on June 1, 1971.
- b) System Clock - This is the same as the surface clock.

3. Bottom Beacon Hardware

- a) Transponder - These units reply with unique frequency coded pulses when they are interrogated by a common frequency either from the surface ship or the DSV. They are additionally capable of releasing their anchors upon acoustic command from the surface vessel. These are manufactured by AMF and are Model No. 324 - "Sea-Link" transponder-release units. They were ordered on April 12, 1971 and received on July 9, 1971.
- b) Flotation Assembly - A metal frame holds two Corning 16" glass sphere/plastic case units, a radio beacon, and a neon flasher to provide buoyancy and high visibility for surface recovery.
- c) Anchor Assembly - This is a length of $\frac{1}{2}$ " common chain with a tow cable leader that causes the transponder to float about 100 feet above the bottom.

IV. Conclusions

The effort during the first six months of the program has been directed toward specifying, purchasing building and integrating the basic components of the system. The second six month period will be directed at integration with the submersible and support ship systems and at-sea testing. The testing is scheduled in three phases. The first phase is to check out the acoustic link operation and establish system feasibility. The second phase of the testing is to make modifications as required and integrate these into the system in preparation for phase 3. The third phase is to operate the system to provide navigation during the integrated sea trials to include magnetics, gravity and related studies.

Specific areas of investigation will include: the operation of the coded acoustic transmissions between transponders in the deep ocean environment, launch and recovery of bottom beacons, comparison of accuracies, between this navigation system and the existing tracking system, possibility of using the submersible in a transponder mode, and measurement of all acoustic power and sensitivities.

Handling and Transfer at Sea

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Handling and Transfer at Sea

1. Technical Problem

The present limited ability to handle, launch or transfer heavy equipment, work boats, and submersibles at sea seriously interferes with the efficiency of many oceanographic and military operations. Even more serious, it has discouraged consideration of concepts and methods for greater tactical use of deep submersibles, specialized work boats and large instruments.

Specific examples are the rarity of pre-scheduled transfers at sea, the occasional difficulty of even getting liberty parties ashore, and the serious sea state limitations when using small submersibles.

2. General Methodology

Several aspects of what has and has not been done in handling leads this investigator to be optimistic that major improvements may be possible along several lines.

The success and wide-spread adoption of resilient energy absorbing approach techniques used by aircraft landing on Navy carriers has shown that one exceedingly difficult sea going approach problem has been solved by using an appropriate combination of wheels, springs, and energy absorbers with each of the key components and techniques based on rather elementary design concepts. The same concepts and practices have been even more widely applied and hence more generally understood on the wheels and springs of land vehicles.

The first essential part of this investigation is a series of elementary and rather crude experiments in local waters to see if the difficulty and danger usually inherent in contact between a work boat and a ship in a seaway can be significantly reduced. The second part of the investigation is to compute and estimate more refined design criteria for the approach and contact problem in the light of previous experience. The third part of the investigation is to try and apply these principles to a few actual cases where meaningful field results can be obtained.

3. Technical Results

Technical results to date can be summed up as follows:

- (a) Without going into how the resiliency can best be obtained, the basic relationships between relative velocity, stopping distance and acceleration as shown in Figure 1 have served as quantitative guide lines in bounding the operational and mechanical aspects of the problem.
- (b) A three ton 24' Coast Guard work boat (Figure 2) has been equipped fore and aft with a pair of horizontally mounted free swiveling aircraft landing wheel assemblies to facilitate approaching the side of a ship or the side of a dock.

Movies have been taken and several dozen interested people have participated in demonstrations. In repeated trials in local waters this energy absorbing approach gear has shown its ability to make underway approaches to docks and ship sides at six knots and approach angles of 30° ; and second, that the resultant decelerations of about 0.25 g are fairly trivial to occupants that are aware of the approach.

- (c) The advantages of using rolling contact with wheels rather than rubbing contact with semi-fixed fenders in the usual dynamic situation has been demonstrated in at least a qualitative way in operations with the 24' work boat. Apparently the wheel only needs to be large enough in diameter to accomodate the roughness of the side of the ship or dock. Figure 3 shows the general relative motion of the boat alongside a ship in a sea way. Although this work was done in local waters it was done in a very severe chop and most of it was on the windward side of the ship. While a free swivelling or castered wheel has some obvious advantages it may be that having only fixed horizontal axles will be nearly as effective and permit smaller and simpler energy absorption approach gear.

The principle thing learned from these experiments was that the danger of a small open boat being smashed alongside a ship can be made trivial compared to its danger of being swamped. Clearly the next step is to get a small boat that cannot be swamped and then continue work in larger seas.

- (d) Work under this contract has somewhat supplemented a smaller earlier contract with the coast Guard that emphasized round buoy-like objects.

It quickly became apparent that a round resilient floating object had uses and implications beyond being a buoy. As a result two large tire casings were purchased under this contract to utilize in several other experimental ways. One such way is shown in Figure 4 as a "mannable" float-fender to ease approach and transfer between small boats and ships.

The large tires are relatively compliant 10-ply with a diameter of 10 feet and a width of four feet.

4. DOD Implications

These investigations may be useful to DOD in several ways:

- (a) To help identify and separate the most important technical aspects of physical contact between seaborne objects.
- (b) To suggest how our high competence in techniques for handling aircraft may be useful in improving our low competence in handling work boats.

(c) More specifically to the problems of handling:

- (1) . liberty parties
- (2) amphibious and other small boat logistics
- (3) heavy salvage gear
- (4) submersibles
- (5) large sonar arrays for echo sounding or echo ranging
- (6) tugs or other small craft coming alongside ships or submarines.

- (d) Expand consideration of surveillance and survey techniques that use groups of manned or drone satellite small boats operating in the vicinity of a parent ship and controlled from the parent ship. The Oceanographic Office is already doing some of this in coastal waters.

5. Implications for Further Research

The present effort has been to obtain a better understanding of some of the factors, principles and desirable mechanisms involved in making resilient contact. Clearly equipment needs to be made and tried to see which of the principles are the correct and key ones and to see if a sea-going system functions worse than, or better than, a designer would predict. Specific recommended next steps are:

- (a) Develop an over-the-side gangway ladder for dockside and/or ship side use. Suggested first tests at Woods Hole dock, then at the Newport, Rhode Island dock at Destroyer Development Group II pier, then at sea.
- (b) Obtain at least the temporary use of a small boat that cannot be swamped, fit with appropriate aircraft type landing gear energy absorbers and conduct more along side tests in much rougher weather than has been done to date.
- (c) Build a mock-up of a good sized towed echo sounder fish to see if handling procedures of such sonars can be significantly improved.
- (d) Establish criteria and design for a small boat that would be sufficiently sea worthy and useful that research or special mission Navy ships would want to carry it.

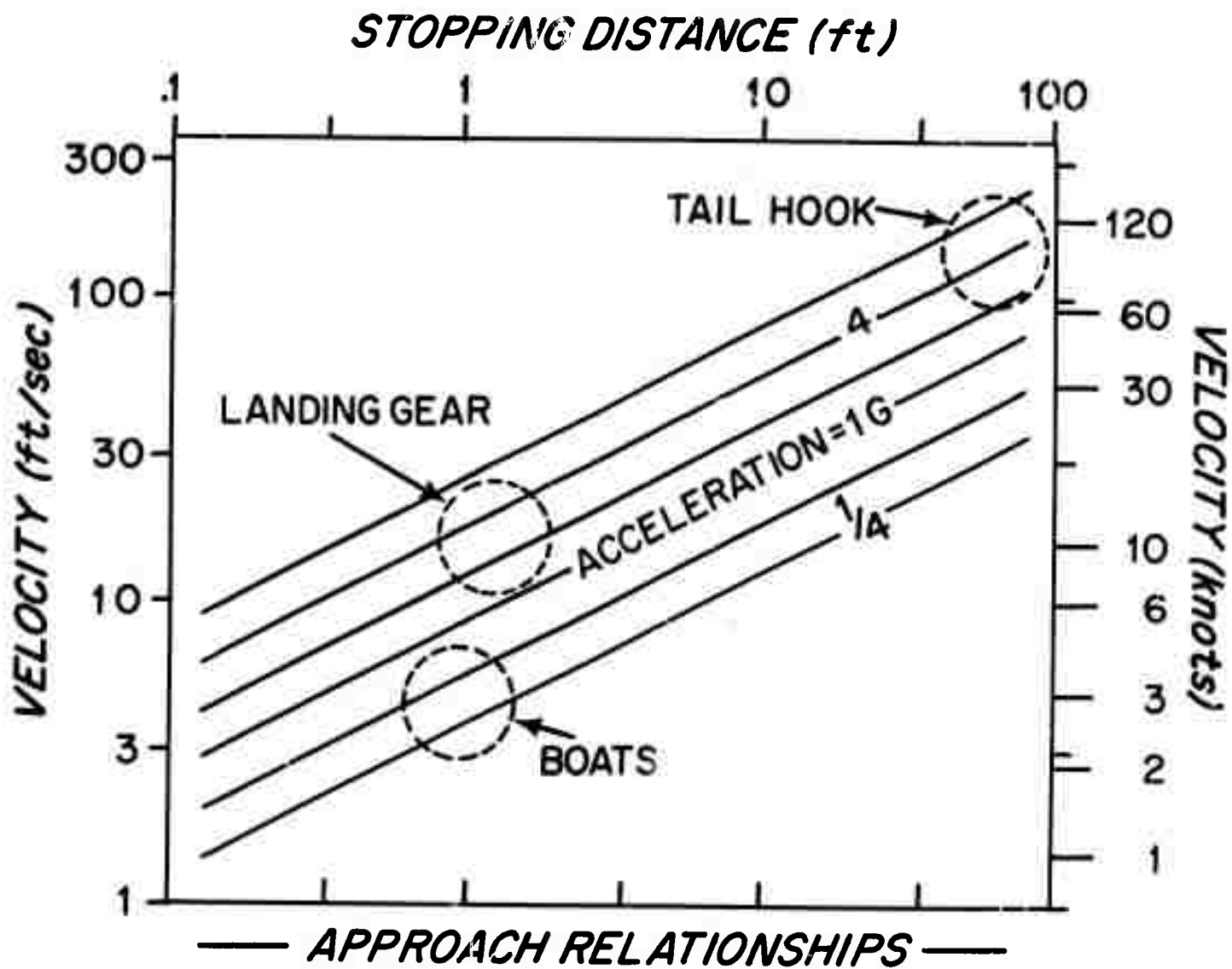


Figure 1.

13a



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Figure 2.

ALONGSIDE MOTION
RELATIVE SHIP MOTIONS CAUSE
THE CASTERED WHEELS TO RIDE
ANYWHERE OVER THE SHADED AREA.

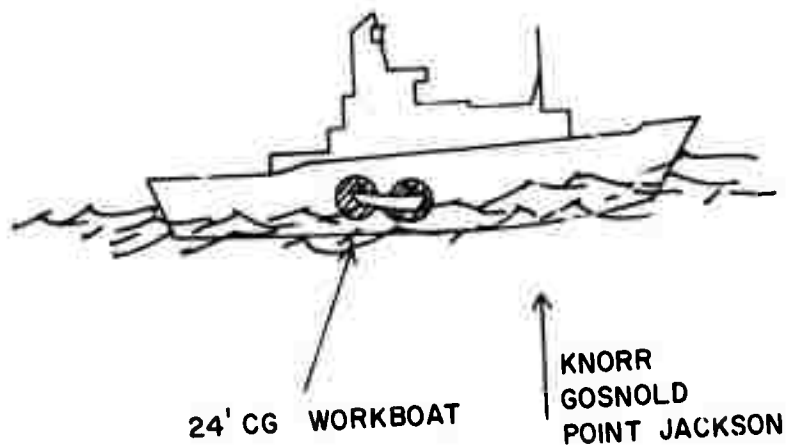


Figure 3 .

13c

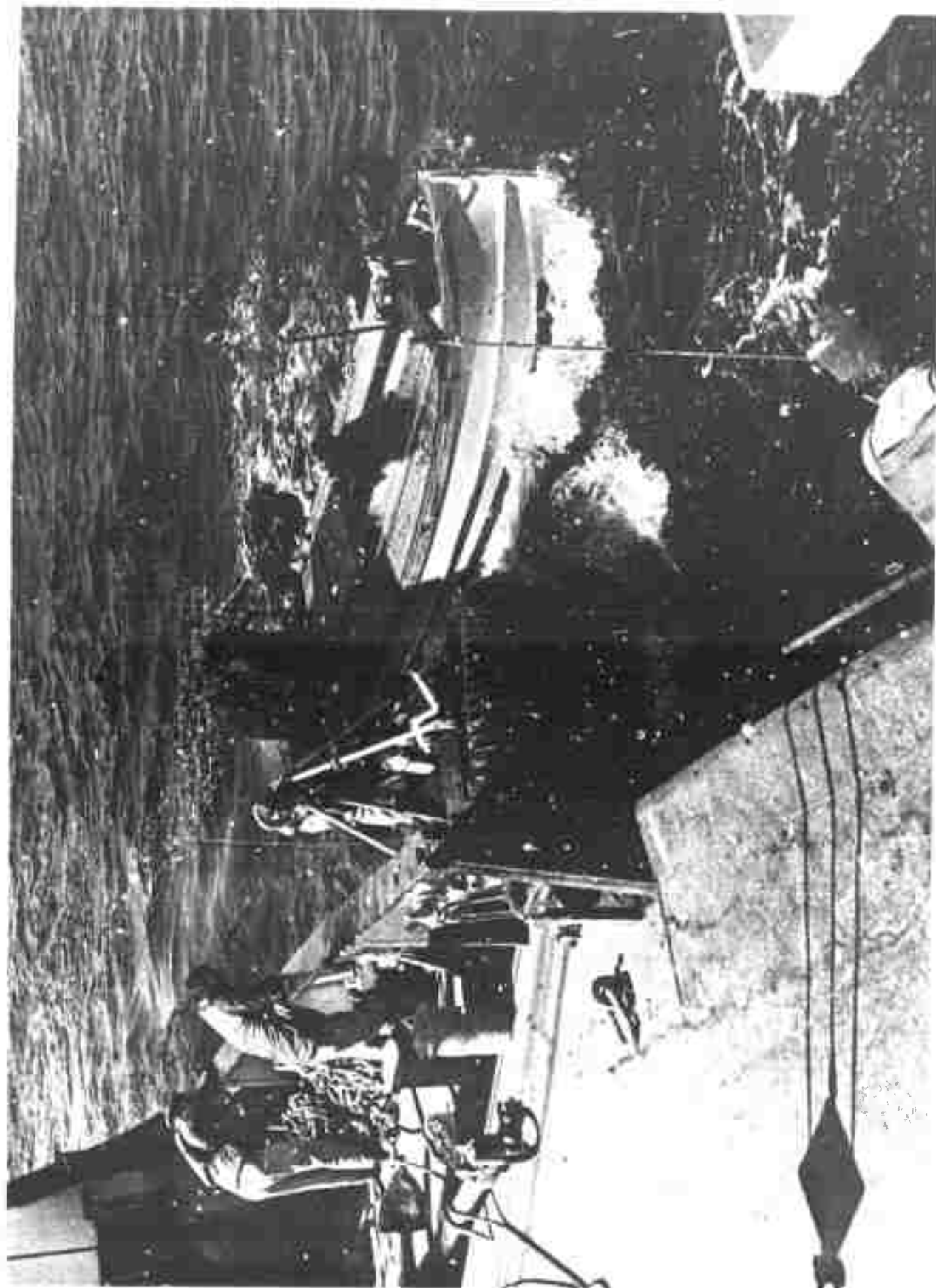


Figure 4.

13d

**Bottom Reconnaissance and a Detailed Site Survey
by Research Submersible**

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Bottom Reconnaissance and a Detailed Site Survey by Research Submersible

I. Project Summary

An integral part of the overall A.R.P.A. Geology and Geophysics program is the ability to properly define the structural framework of bottom environments in which specific studies are being conducted. If the direct sampling and indirect sensing systems proposed for development under the Geology and Geophysics program are to be evaluated in an effective manner, they must be paralleled by similar development programs in surface and subsurface mapping systems. For example, gravity and magnetic observations must be supplemented by information pertaining to bottom topography and subsurface structures. The rock drill likewise cannot be used in areas having a sediment cover unless the thickness of the sediment blanket can be determined, and the geotechnical probes cannot be properly utilized unless the basic configuration of the sediment body is known. Figure 1 illustrates the manner in which this task and its associated development efforts interface with other A.R.P.A. instrumentation programs.

Work during the first half of the contract year was broken into four sub-tasks; calibrated photography, submersible sub-bottom profiling, surface ship mapping, and geotechniques. A comprehensive study was made of a calibrated viewing and photography system for ALVIN. This study resulted in a report over 100 pages in length which is being prepared for publication as Woods Hole Oceanographic Institution blue cover report. A brief summary of this study is included in the technical report. Based upon this study a computer program was written which enables the scientific observer aboard ALVIN to obtain a grid overlay for pictures taken from either of the submersible's oblique-angle viewports when the submersible is in contact with the bottom. This calibrated system has already been used successfully during several cruises and has substantially up-graded visual observations (Figure 2).

The second sub-task of the program centers around the evaluation of a 5 kHz submersible sub-bottom profiler which was acquired from the Naval Oceanographic Office for evaluation under the A.R.P.A. program. The profiler arrived on loan from NAVOCEANO and the first half of the year was spent bench testing the unit and conducting limited harbor trials.

An important aspect of the surface and sub-surface program is to provide the overall A.R.P.A. program with a detailed dive site survey capability. The major requirement is to survey both the surface and sub-surface structure of bottom sites at which the gravity, magnetics, rock drill, and geotechnical probes are to be tested. To accomplish this supporting role, the R/V LULU was outfitted with a complete geophysical survey system including an Omega navigation unit, a seismic profiling system, a sonobuoy system, and an echo-sounder.

The fourth task undertaken during the first half of the contract year dealt with the design, construction, and testing of a prototype nuclear densiometer/penetrometer for use from ALVIN. This unit was

designed and built at Lehigh University in cooperation with the Deep Submergence Group and subsequently used to conduct a series of soil engineering studies of the Holocene sediments in Wilkinson Basin during ALVIN/LULU Cruise 3-71.

II. Technical Report

Calibrated Photography

The following discussion has been abstracted from a comprehensive study of over 100 pages which is presently being prepared as a W.H.O.I. blue cover publication.

The system of the Calibrated Grid which is discussed below has been developed specifically for a photographic study from a submersible, in particular, the DSRV ALVIN. By employing the submersible rather than a surface ship, the scientist has the option of selecting the seascape he wishes to photograph. In addition, ALVIN provides him with the facilities for collecting specimens related to his photographic study. In order to prevent the distortion incurred when a camera is tilted with respect to the plane surface of the viewport, a camera mount has been designed for the Nikkormat FTN camera to be removed and repositioned easily. (See Design of Camera Mount complete report). Then, once the dive is over and the photos are ready to be studied, the scientist needs to measure only two distances on the photo from which enough information can be obtained to provide him with an overlay grid for his photo. With the grid in place, he may obtain object sizes and distances which are pertinent to his study and necessary for relaying the findings of his research to others.

The grids to be provided for a series of scientific photos vary with every attitude and/or altitude change of the submersible. Therefore, the scientist must be able to determine both the altitude and attitude of the submarine at the instant the photo was taken. Insisting that this information be acquired at the scene rather than ascertaining the required data from the photo later, adds an unnecessary burden on the observing scientist.

C. Walker, who provides grids for use on the port for the simplest arrangement of submarine and ground, i.e. when the submarine is parallel to the sea floor in the field of view, has suggested a method for measuring height by means of a light. The following, complete with illustration (refer to Walker's diagram) is Walker's suggestion:

The 1000 watt mixed gas light is used for illumination of the area to be measured. A new light (#1) with a small angle conical beam is mounted alongside the 1000 watt flood lamp, and points almost vertically downward. Another new lamp (#2) is mounted in the A-1 battery door and beams out perpendicular to the vertical axis of the BEN FRANKLIN.

...The vertical beam calibrates height above the terrain with an elliptical area and the horizontal beam illuminates the terrain which is level with the BEN FRANKLIN's horizontal plane.

(Walker, 1969, pp. 1-2).

Illumination for the area to be photographed was to be provided by lamp #2. However, since Walker has assumed the ground and the submersible to be parallel, the light is positioned such that even on a "bottom-sit" the area illuminated is a space of sea water not terrain. As a means of calibrating height, Walker proposed to measure the elliptical area of light source #1. In order to calculate the area, measurements must be taken of the semi-major (b) and the semi-minor (a) axis of the ellipse. (Diagram #3). However, since the edges of the elliptical area are very fuzzy, ascertaining the correct lengths would be a problem and serious errors would be induced into the calculation of the needed height.

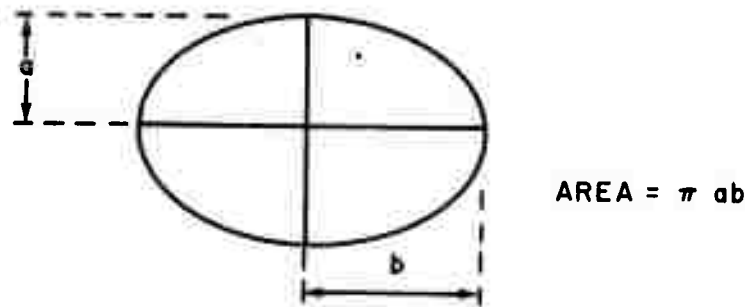
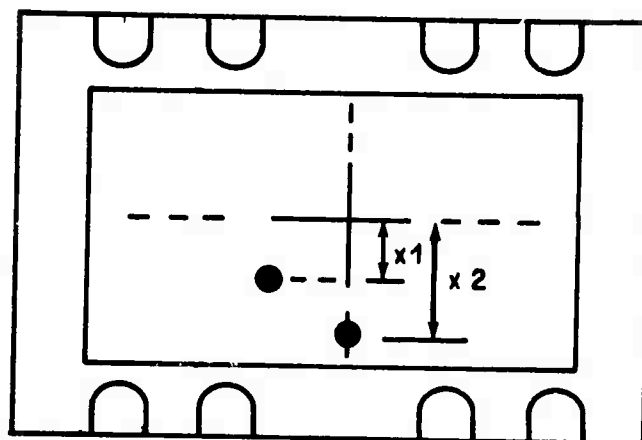


Diagram #3. Elliptical Area.

The principal of the Calibrated Grid allows the altitude and ϕ_1 , the fore and aft angle of slope of the ground to be determined by simply measuring the distance from the center of a photo to a light spot. The light source for this spot is positioned on the exterior of the submersible in a manner such that the spot will remain in an optimum portion of the total field of view of the port as the altitude of the port varies from 0' to 30'. (Note: The light source is in addition to those lights used for general illumination.)

Realizing the ground may be sloped fore and aft and/or port and starboard with respect to the viewport, this theory also permits the scientist to make an additional measurement of the distance from the center of the photo to another spot shown in his photo and have sufficient information to determine the port and starboard angle of slope of the ground. The distances X_1 and X_2 necessary for the scientist to measure are illustrated in the diagram below. (Note: These distances will vary with every change in attitude and/or altitude of the submersible.)



● LIGHT SPOT

Diagram #4. Light spot distances X_1 and X_2 .

Knowing these distances, the scientist may now enter a set of tables which have been developed and determine h , the altitude; θ_1 , the fore and aft angle of slope of the ground; and θ_2 , the port and starboard angle of slope of the ground. Once this data is fed into a computer program, enough information is provided to furnish the scientist with an overlay grid for his photo with which he can gage object sizes and distances.

"In underwater photography, light is transmitted through water and through a window into air where a camera is located." (Thorndike, 1967, p. 43.) Consequently, the image the camera perceives of the object exterior to the port is altered due to the light being refracted from sea water through plexiglas and into air. (Diagram #5.) How the image varies, then, depends upon the indexes of refraction of the substances involved.

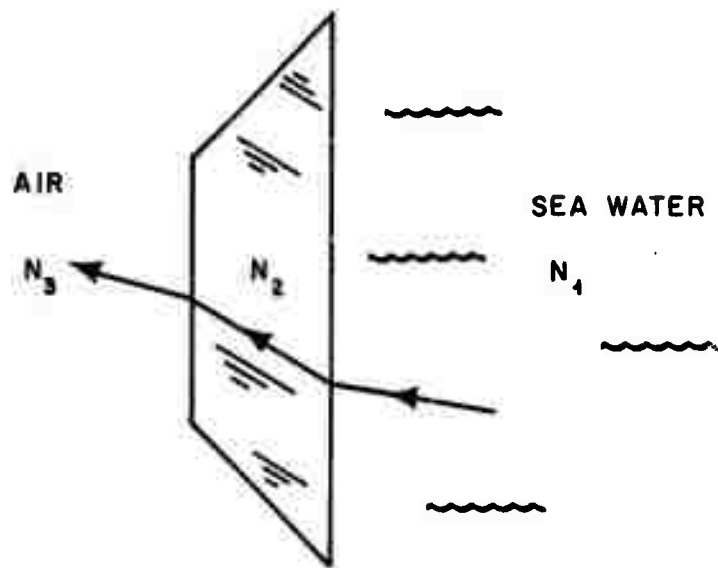
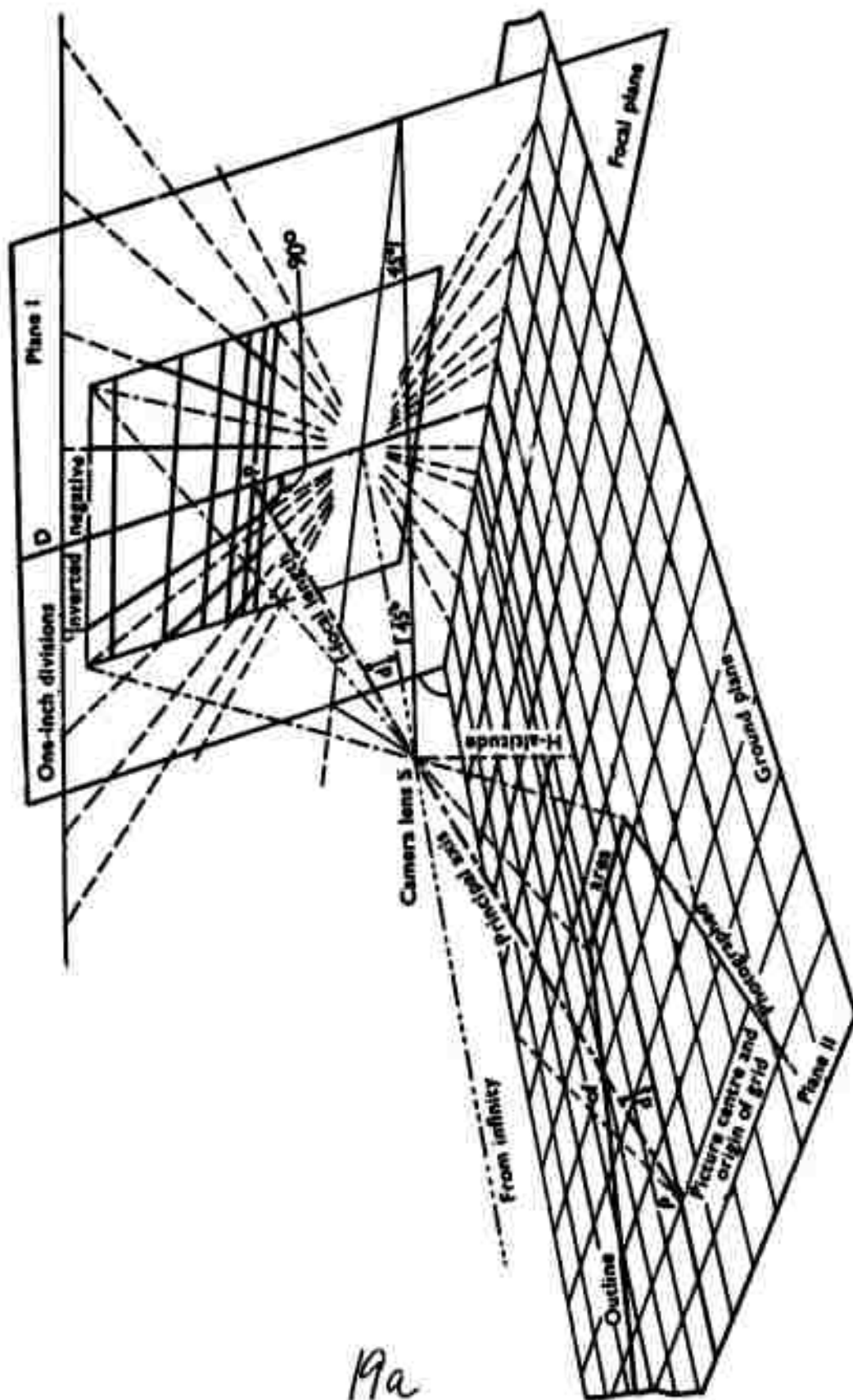


Diagram #5. Light ray passing through port into air where a camera is located.

If a photograph is taken (in air) of a horizontal grid with the focal plane of the camera tilted with respect to the grid plane, an inverted image appears on the negative which is a perspective projection of the grid located on the ground plane. Plate #1 illustrates a perspective projection image of a square grid. Since the camera (and thus the focal plane) is parallel to the plane of the viewport which is normally tilted with respect to the ground plane, perspective properties must be considered in a math analysis which calculates the image seen by the camera of an object located exterior to the submersible on the ground plane.

Once a light ray emerges from the plexiglas, it enters the camera lens where it is focused, then it continues on to strike the film. (See Diagram #6). Measuring along the inner surface of the port, "X" is the distance between the principal ray (or axis) and the incoming ray; this distance is recorded on the film as h. By knowing "X", one may calculate the distance h. h may be shown to be dependent upon a ratio of the distances L and f. L being the distance from the port to the point where the lens of the camera converges the incoming light rays, and f being the focal length of the lens. These distances are constant for a particular lens and a camera properly positioned at the port. For the 24 mm Nikkor lens available for use in ALVIN, $h = (.350)X$. (See Diagram #7.)



19a

Plate I.

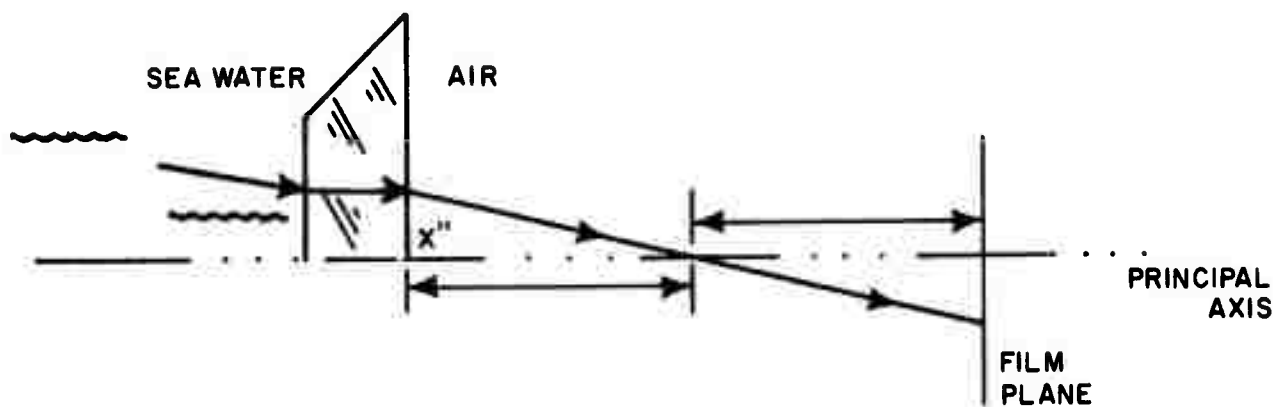


Diagram #6

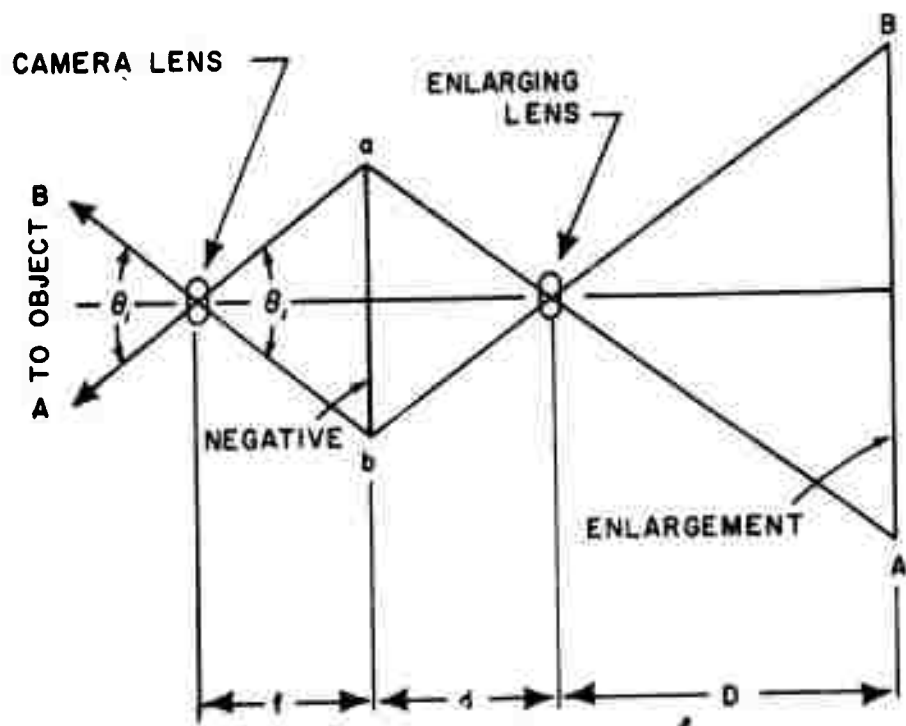


Diagram #8

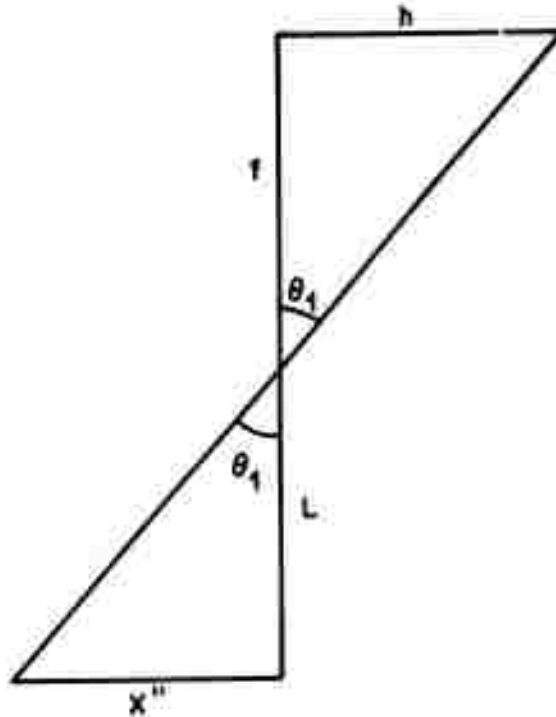


Diagram #7. Calculation of image distance h on the film.

The scientist, however, will be working with an image recorded on an enlarged photo (See Diagram #8.); this final image, X , may also be shown to be dependent upon a constant ratio times the distance X'' . (See Diagram #9.)

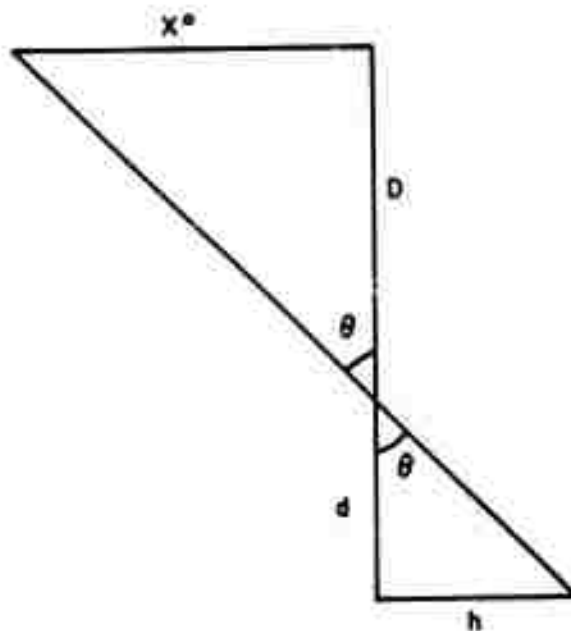


Diagram #9. Calculation of final image distance X after enlargement.

Note: The photos for analysis are to be enlarged consistently to the same size. Therefore, the distances D and d , as well as L and f , are constant.

Thus, once X is known; X is merely a constant magnification factor time the value X'' . However, X'' is dependent upon perspective projection and refraction from water through plexiglas into air. The following Mathematical Analysis Section develops the theory by which this distance X'' (measured in either the x or y direction) may be calculated for a given ground distance (in either the x or y direction) irregardless of the attitude of the ground plane. Although X'' may be calculated when the ground slopes fore and aft and/or port and starboard, X'' is dependent upon these angles. Consequently, one must be able to measure these angles in order to calculate X'' . Therefore, a process has been developed by which these angles as well as the altitude of the port may be obtained from a set of tables by measuring distances to light spots on the photo.

Submersible Sub-Bottom Profiler

Figure 10 is a photograph of the 5 kHz submersible subbottom profile which has been acquired on loan from the Naval Oceanographic Office. This profiler was originally developed by Ocean Research Equipment Inc. for use aboard the submersible BEN FRANKLIN during its drift mission in the Gulf Stream. Unfortunately this system failed shortly into the mission and its evaluation ended abruptly. When the Deep Ocean Survey Submersible program was discontinued within the Naval Oceanographic Office this unit as well as other instrument systems were loaned to W.H.O.I. with the hope that their evaluation would continue.

The subbottom profiler which arrived at W.H.O.I. during the first quarter of the contract consists of a series of four 5 kHz oil compensated transducers weighing 99 lbs. in air and externally mounted on the submersible. The internal electronics include an eleven inch wet paper recorder, programmer, and transceiver. This unit can be mounted in ALVIN's 19 inches science instrument rack and operates on 26 volts D.C. The programmer is similar to that manufactured by Giffit; the paper speeds are 50, 100, and 200 msec, and the pulse width can be set at 0.25, 0.5, 1.0, and 2.0 msec. The recorder also has a time variable gain which enhances internal bottom structures.

A considerable time was spent overhauling the internal electronics package which had been neglected since its initial use during the BEN FRANKLIN drift mission. The drive motor for the wet paper advance had to be replaced, numerous wires checked, and the entire unit cleaned. Time was also spent bench testing the unit with the transducer suspended from the dock during which W.H.O.I. personnel familiarized themselves with the profiler system.

During the second quarter the profiler was installed in ALVIN and preliminary tests were conducted in the harbor with the submersible operating at the surface (Figure 11). The external transducer package was attached to the standard sample tray which is mounted in front of the submersible below the forward viewport. This tray can be released from submersible by activating a solenoid mechanism. The profiler operated intermittently during this harbor test. Further bench testing in the laboratory indicates that the basic components are operating

satisfactorily but many of the interconnecting wires need to be replaced. A detailed summary of the unit's operating principles as well as its internal construction are contained in an operating manual which was written by O.R.E. It should be pointed out, however, that this unit is a prototype model and O.R.E. has not produced additional units nor is this company maintaining a history of the unit now used by W.H.O.I.

Shipborne Site Survey System

Figure 12 illustrates the site survey system which was placed aboard the R/V LULU to conduct detailed site surveys during the evaluation of the various A.R.P.A. instrument systems. The survey system consists of a continuous seismic profiling (Csp) system, a 12 kHz echo-sounder and recorder, a sonobuoy receiver and sonobuoys for seismic reflection studies, and an Omega navigation unit. The Csp system uses an air compressor operating at 2000 psi to supply air to a 10 cubic inch air gun. This gun discharges air at a six second rate producing a continuous series of low energy sound pulses. These pulses penetrate the bottom and reflect off of sub-bottom structures which are received by a 200 element hydrophone towed behind the surface ship. These signals are processed through a filter and preamp. and displayed on either a dry or wet paper recorder. The sonobuoy receiver system makes it possible to conduct one-ship seismic refraction operations. As a reflection profile is being made, sonobuoys can be released from the surface ship. After the critical angle is reached, refracted signals traveling along the rock unit interface will be received by the sonobuoys and transmitted back to the surface ship. These various survey systems permit the determination of internal bottom structures as well as sediment thicknesses over rock formations. This data can then be used to locate optimum dive sites for evaluating the hardrock corer, submersible sub-bottom profile, gravimeter, and towed magnetometer. This survey system was placed aboard the R/V LULU as supporting instrumentation and not as an instrument development program in itself. For that reason the major components of this system were borrowed from other projects and only minor support from A.R.P.A. was required to operate the system.

Nuclear Densimeter/Penetrometer

The final phase of work during the first half of the contract period dealt with the design, construction, and testing of a nuclear densimeter/penetrometer. Figure 13 shows the probe mounted aboard ALVIN during its field testing in the Gulf of Maine. The probe weighs approximately 400 lbs. in air and 300 lbs. in water. The units stand eight feet high and is mounted on a solenoid releasable science tray. The densimeter consists of a 12" forked probe having a 50 milcurie source of cesium 137 on one side and a gamma radiation detector on the other side of the probe. This forked probe is mounted on an eight foot long steel rod with rack and pinion arrangement. The wrist rotate on the mechanical arm of ALVIN is used to turn a reduction gear which drives the rack and pinion and forces the probe into the bottom. At various depths into the bottom a frequency counter is used to measure the amount of gamma radiation received by the sensor opposite the cesium 137 source. This measurement is then

related to the density of the sediment from which various engineering properties can be obtained. The forked probe contains a third leg on which is mounted a strain gauge which gives a measurement of the sediment's resistance to penetration. A more complete description of nuclear densiometer/penetrometer is being prepared by the Lehigh engineers who designed and built the unit. This report will be submitted to A.R.P.A. and O.N.R. at a later date.

INTERRELATIONSHIP OF SURFACE AND SUB-SURFACE STUDIES WITH OTHER A.R.P.A. TASKS

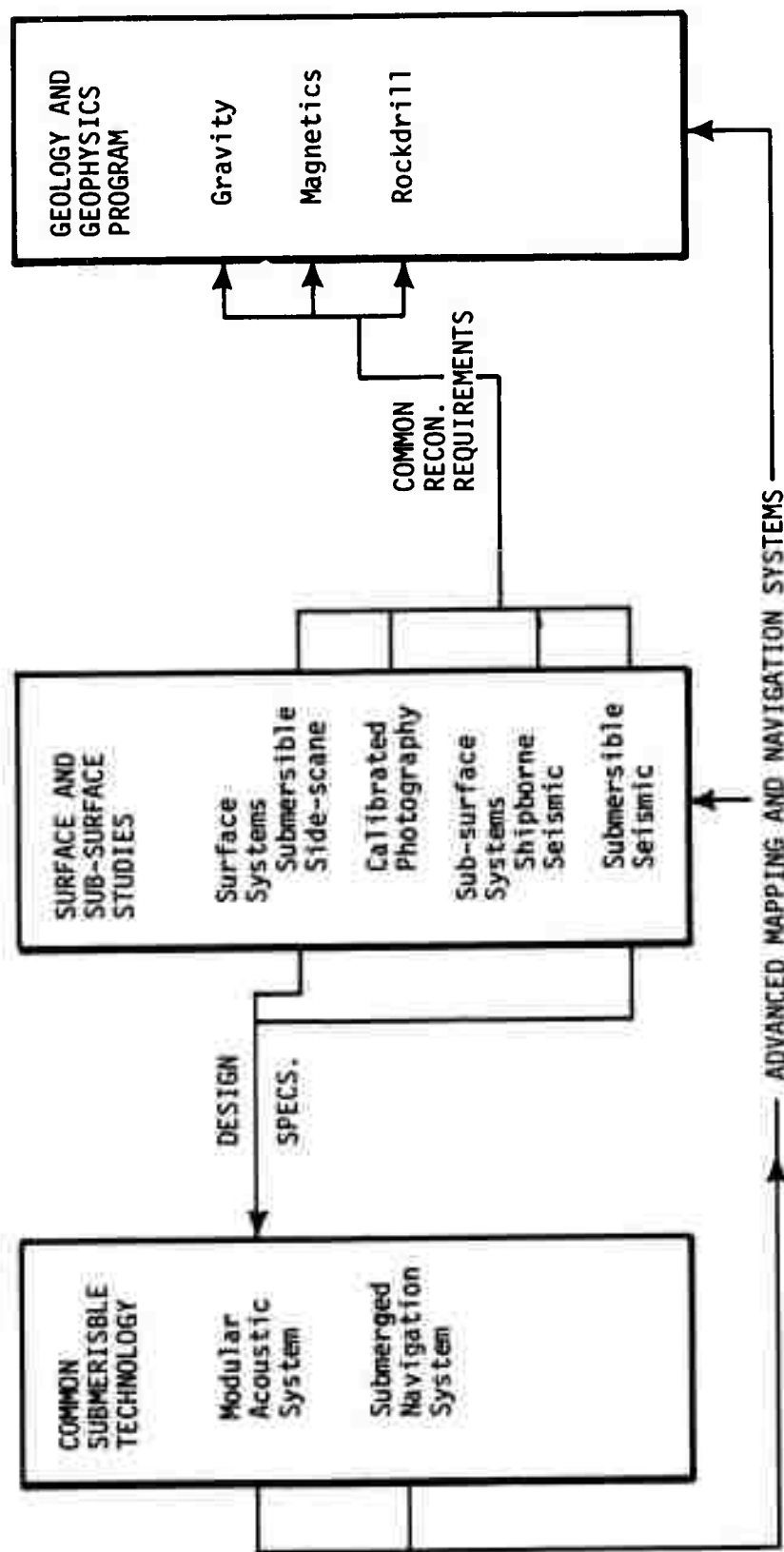
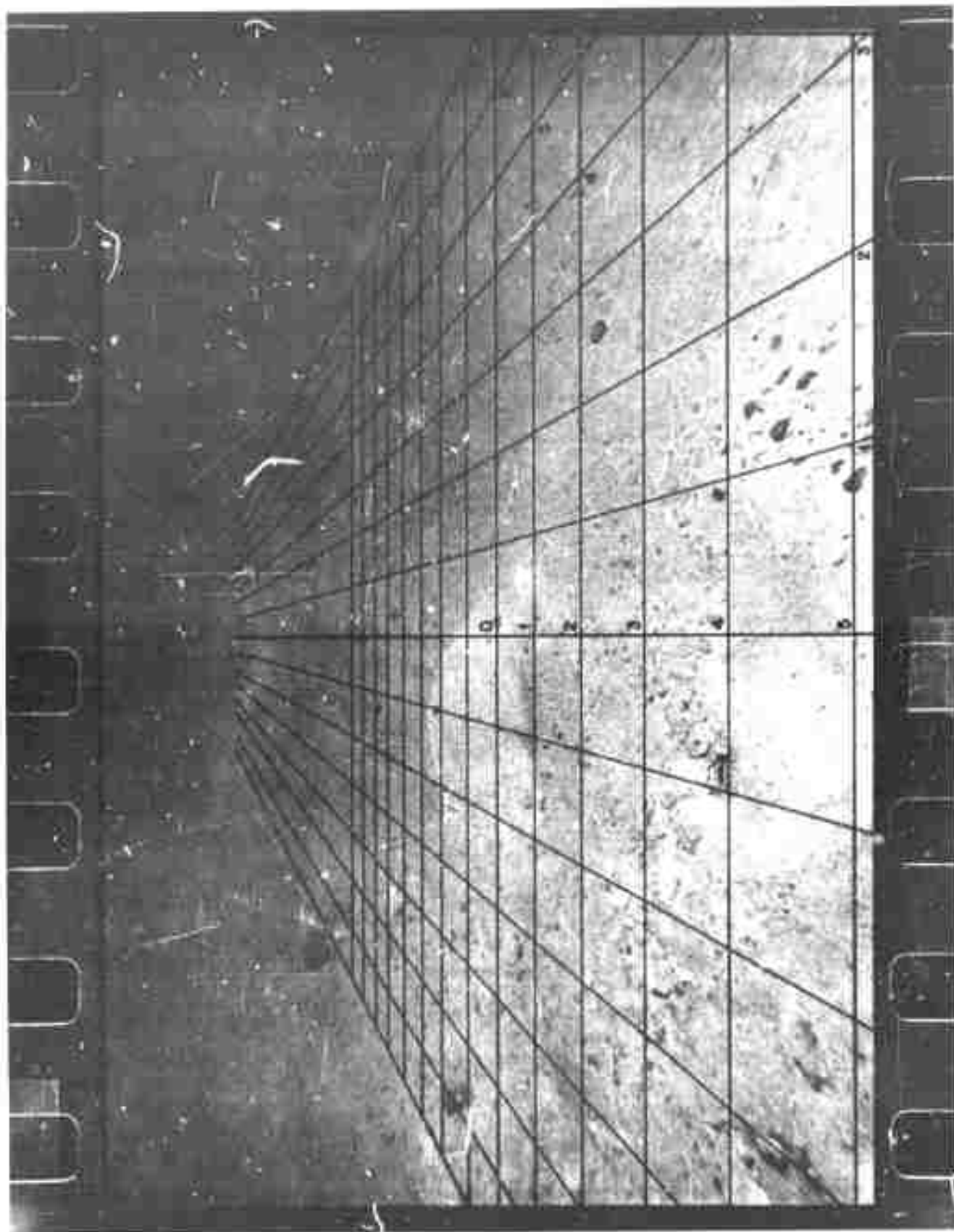
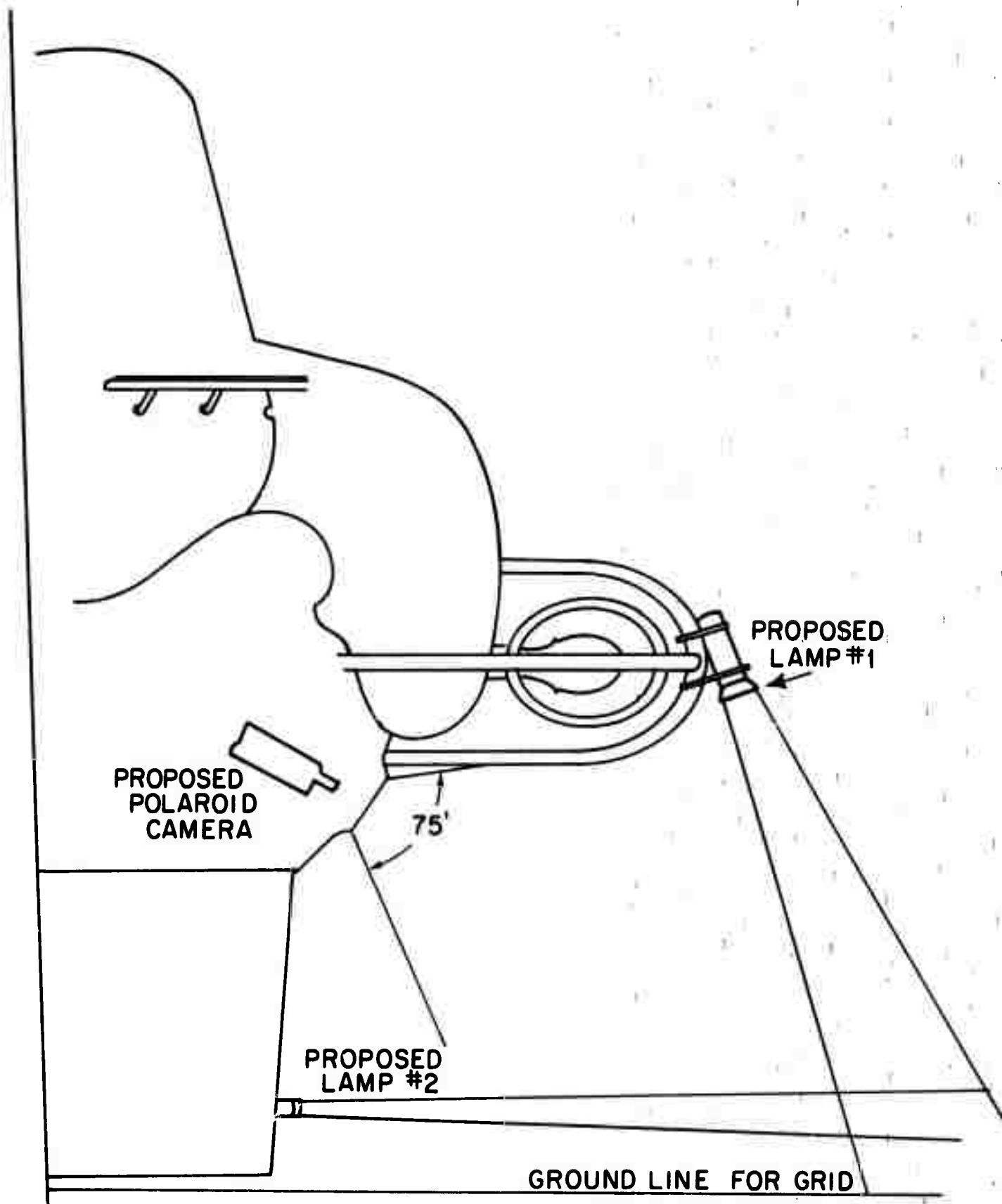


Figure 1.

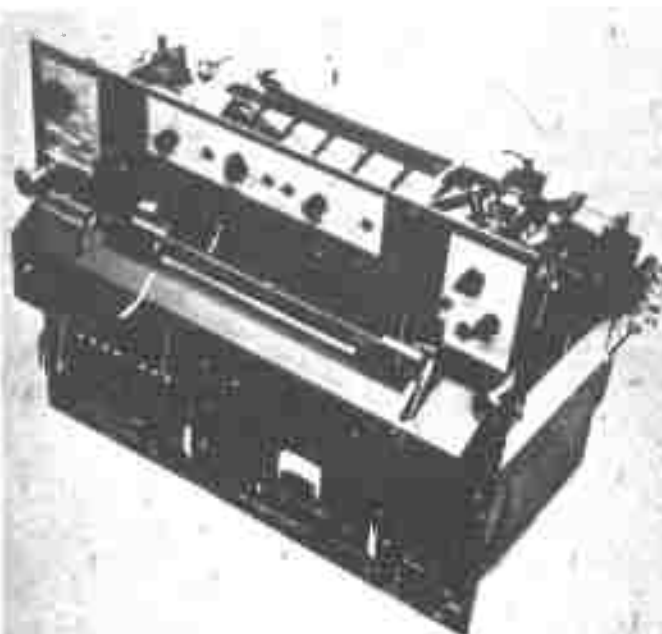


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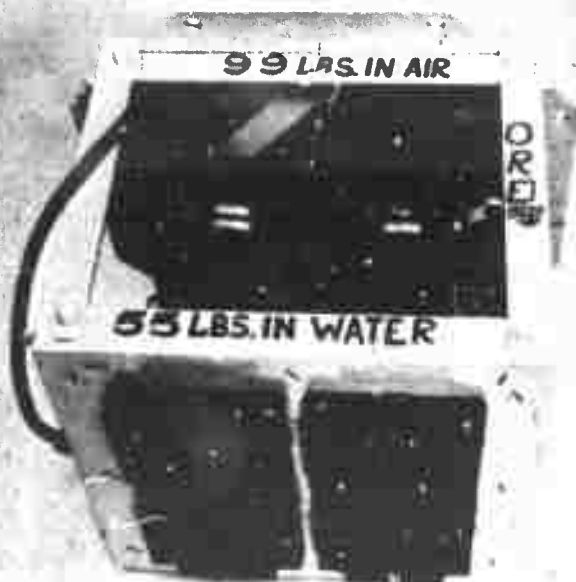
Figure 2.



23c
Walker Diagram



ELECTRONICS & RECORDER



TRANSDUCER ARRAY

ORE MODEL 1200
DEEP SUBMERSIBLE
ACOUSTIC SUB-BOTTOM PROFILING SYSTEM

23d

Figure 10.

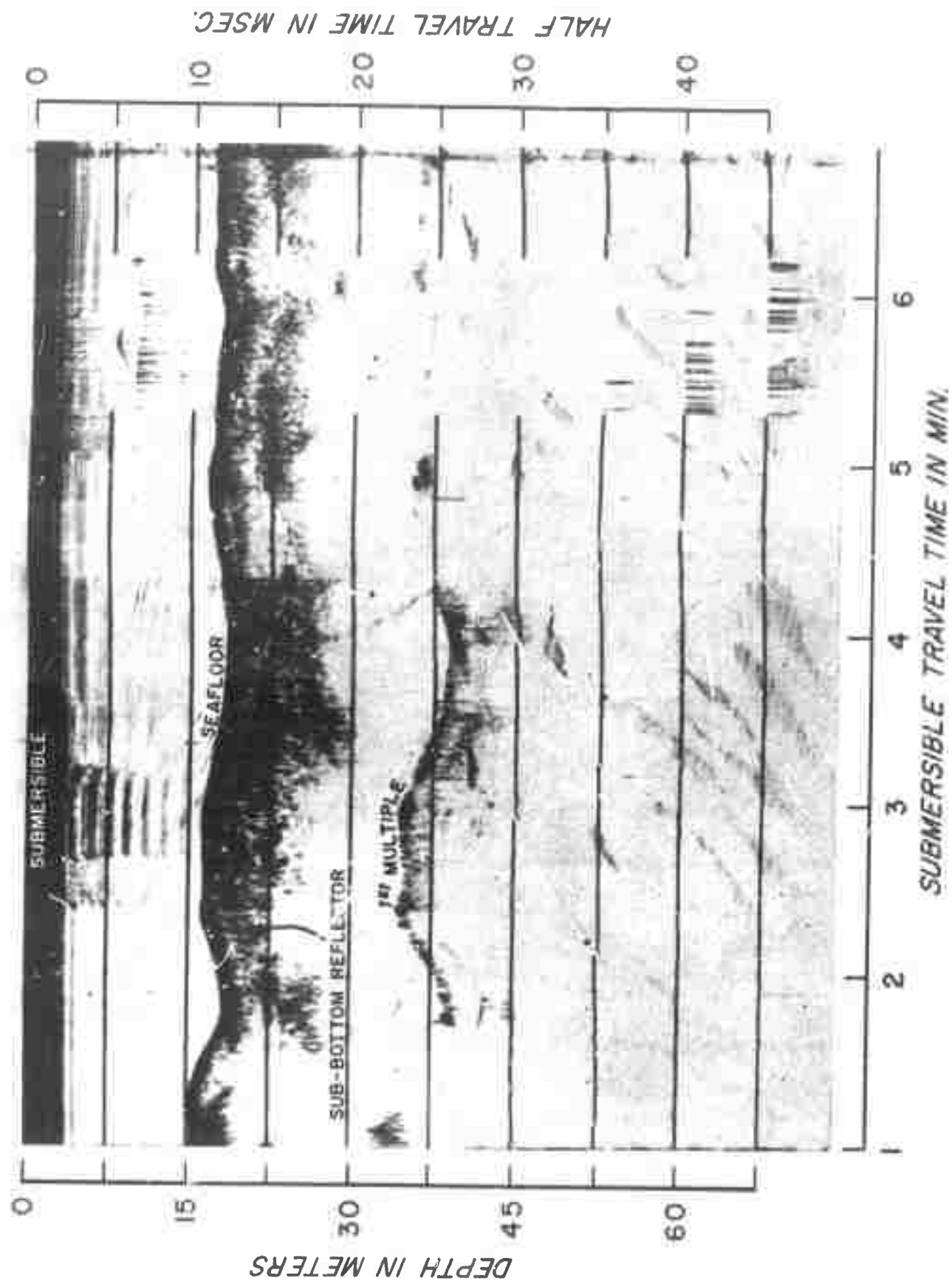


Figure 11.

LULU DIVE SITE SURVEY SYSTEM

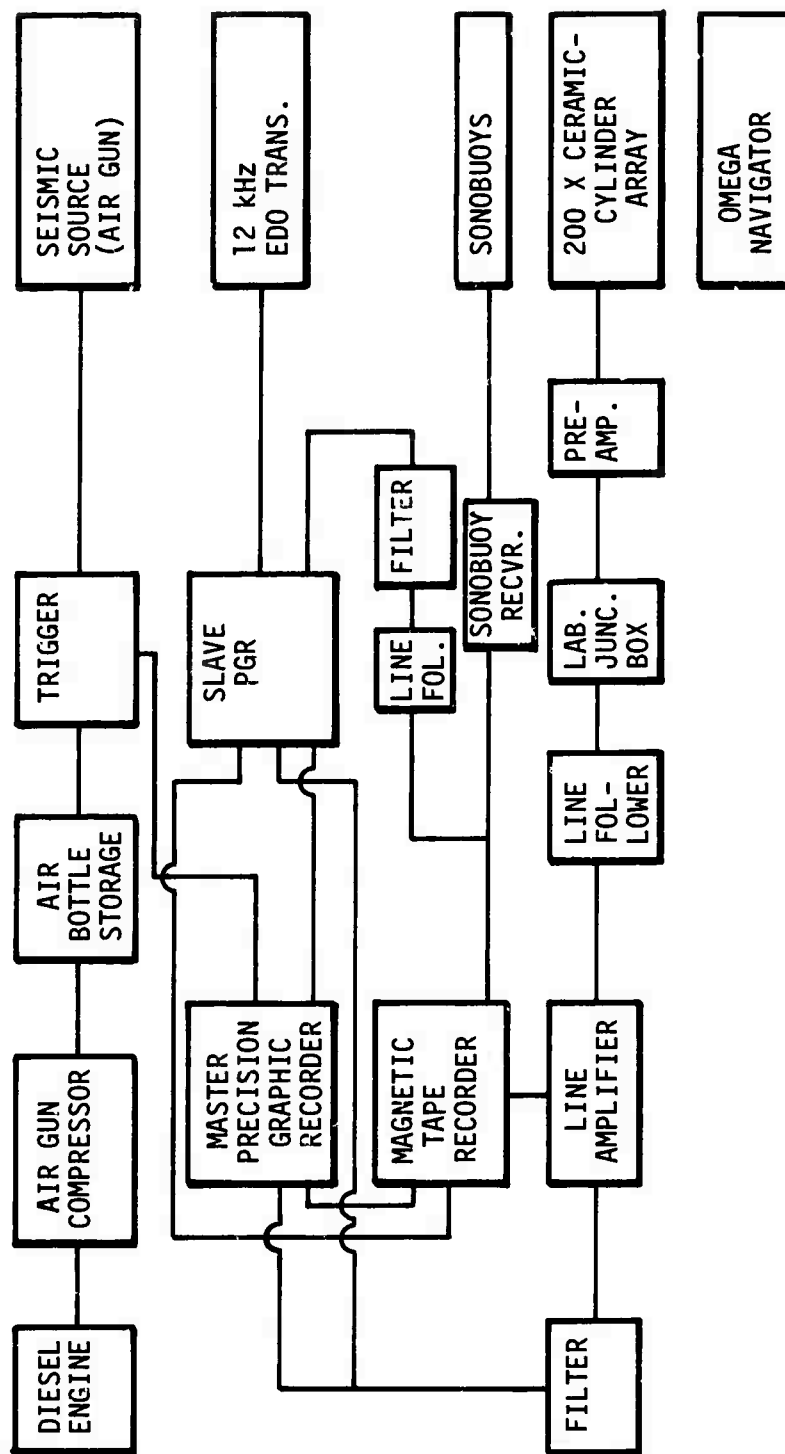


Figure 12.

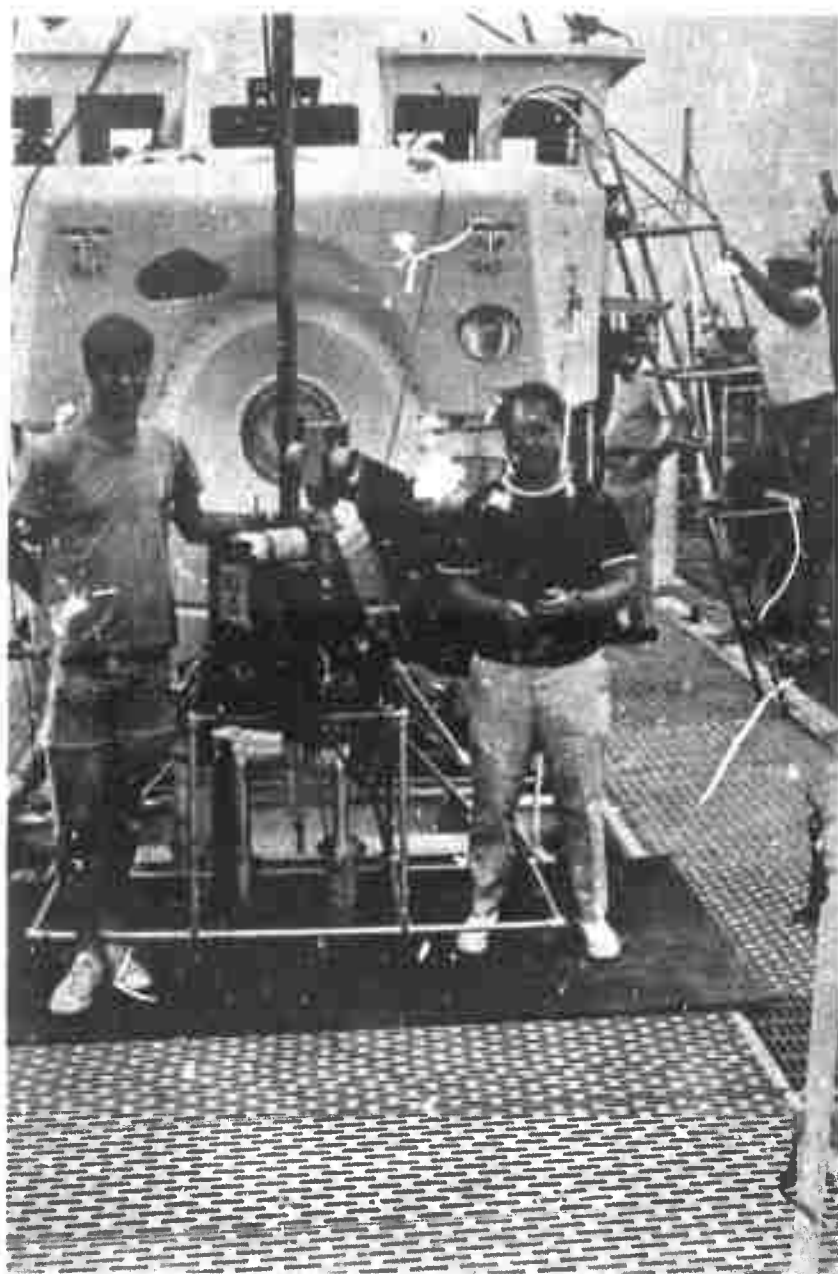


Figure 13.

238

**Near Bottom Magnetism Studies
Using A Deep Submersible**

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Near Bottom Magnetism Studies Using A Deep Submersible

Problem

The primary technical problem considered during this reporting period has been the design and procurement of an inexpensive prototype magnetometer system suitable for use with DSRV ALVIN. This system is to be used to determine the feasibility of performing near-bottom geomagnetic surveys during the planned November 1971 diving season in the Tongue of the Ocean (Nassau). To date magnetometers have not been towed from research submarines.

Methods

Two factors were considered in the magnetometer design. First, the large steel pressure hull of ALVIN precluded on-board installation of the magnetic sensor due to the inherent magnetic moment of hull. Calculations showed that a sensor/hull separation of at least 15 meters would be required for the magnetic field effect of the hull to be less than 10 gammas at the sensor. A rigid boom mounted sensor like that used on ALUMINAUT (Higgs & Carroll, 1967) was deemed impractical because of probable damage during launching and recovery operations. Accordingly, a towed proton precession magnetism sensor system was developed. It is not known whether such a towed system will interfere with submarine operations and safety. Sketches showing a detail of the sensor and the planned towing arrangement are shown in Figures 1 and 2. A similar towing arrangement has previously been employed with the Scripps Institution's DEEPTOW FISH (Spiess and Mudie, 1970).

A second factor considered was the on-board installation of the electronic signal processing equipment in ALVIN. The equipment used was an existing airborne proton magnetometer. Although this system is relatively large and heavy, and requires considerable power, it was felt that until it was clear that towed proton magnetometer operations are feasible from a maneuverability and internal electrical noise standpoint, major equipment miniaturization and/or procurement would not be justified. For data recording an existing analog strip chart recorder is to be used.

Results

- 1) Two standard VARIAN Model 49-843 observatory type sensor coils were modified for operation at pressures up to 8,000 psi. These units were completed, pressure tested and available for use by 15 August 1971.
- 2) A standard VARIAN 4937A airborne magnetometer presently owned by W.H.O.I. was modified for complete DC operation. This was a relatively simple procedure and was done to reduce use of the limited AC power available on ALVIN. The electronic counter (HP5512A) was the only unit requiring change.

Summary

An inexpensive magnetometer system was required to test the feasibility of making magnetic measurement from DSRV ALVIN, a steel hulled research submarine. Calculations showed that the sensor must be separated a distance greater than 15 meters from the vehicle in order to reduce the magnetic effect of the hull to acceptable levels. Accordingly a towed sensor system capable of operation at pressures up to 8,000 psi has been developed. It will be used in conjunction with an existing standard airborne magnetometer which has been modified slightly for use aboard ALVIN. This system should provide at minimal cost an adequate test of the use of submersibles with towed magnetometers for near bottom search and geomagnetic mapping purposes.

References

- Higgs, R. H. and J. C. Carroll, 1967. ALUMINAUT Magnetometer Operations, St. Croix, Virgin Islands, 1966. U.S. Oceanographic Office Informal Report No. 67-33.
- Spiess, F. N. and J. D. Mudie, 1970. Small scale topographical magnetic features, in The Sea, Vol. 4, Part I, p. 205-250.

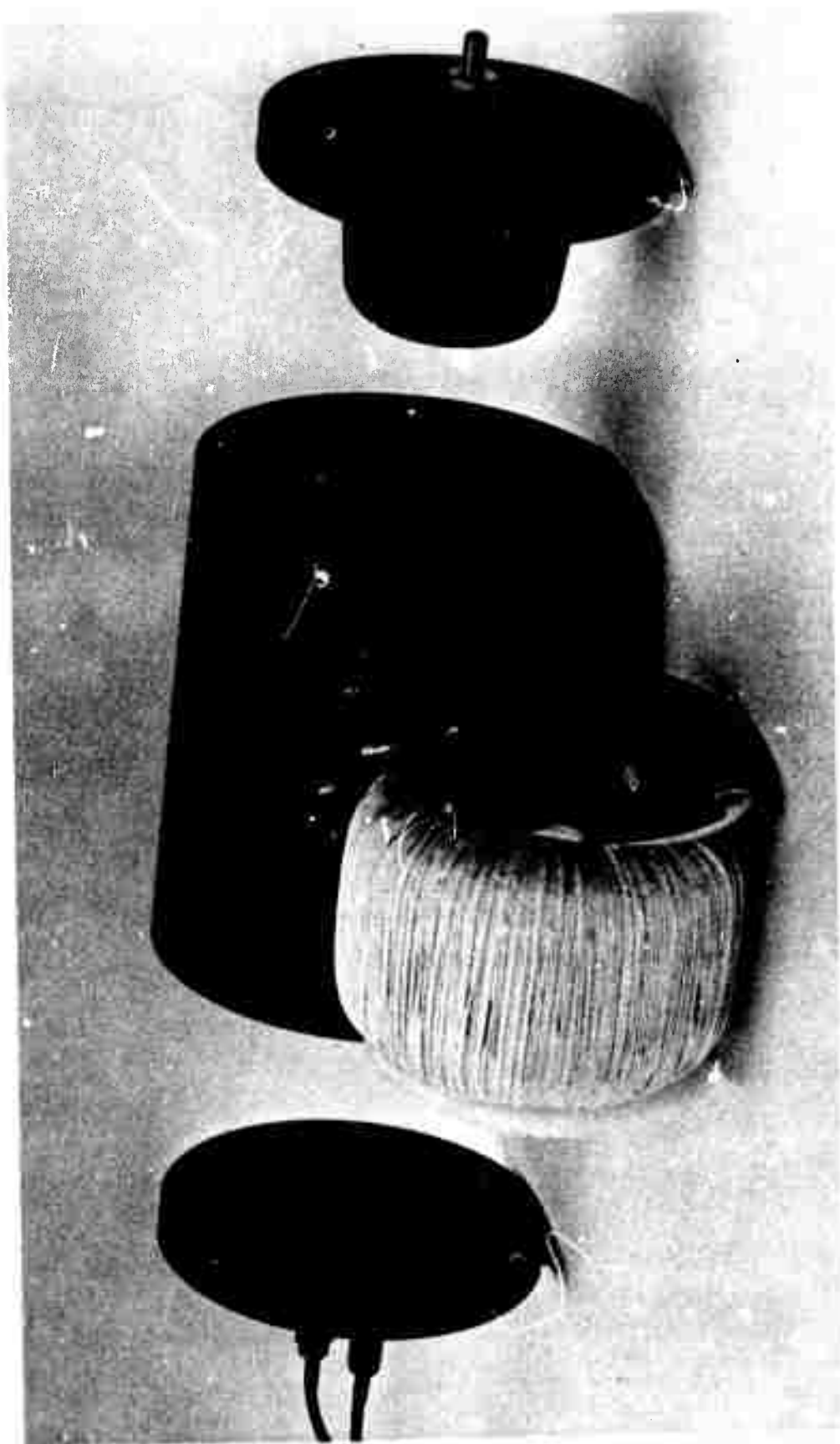


Figure 1.

27a

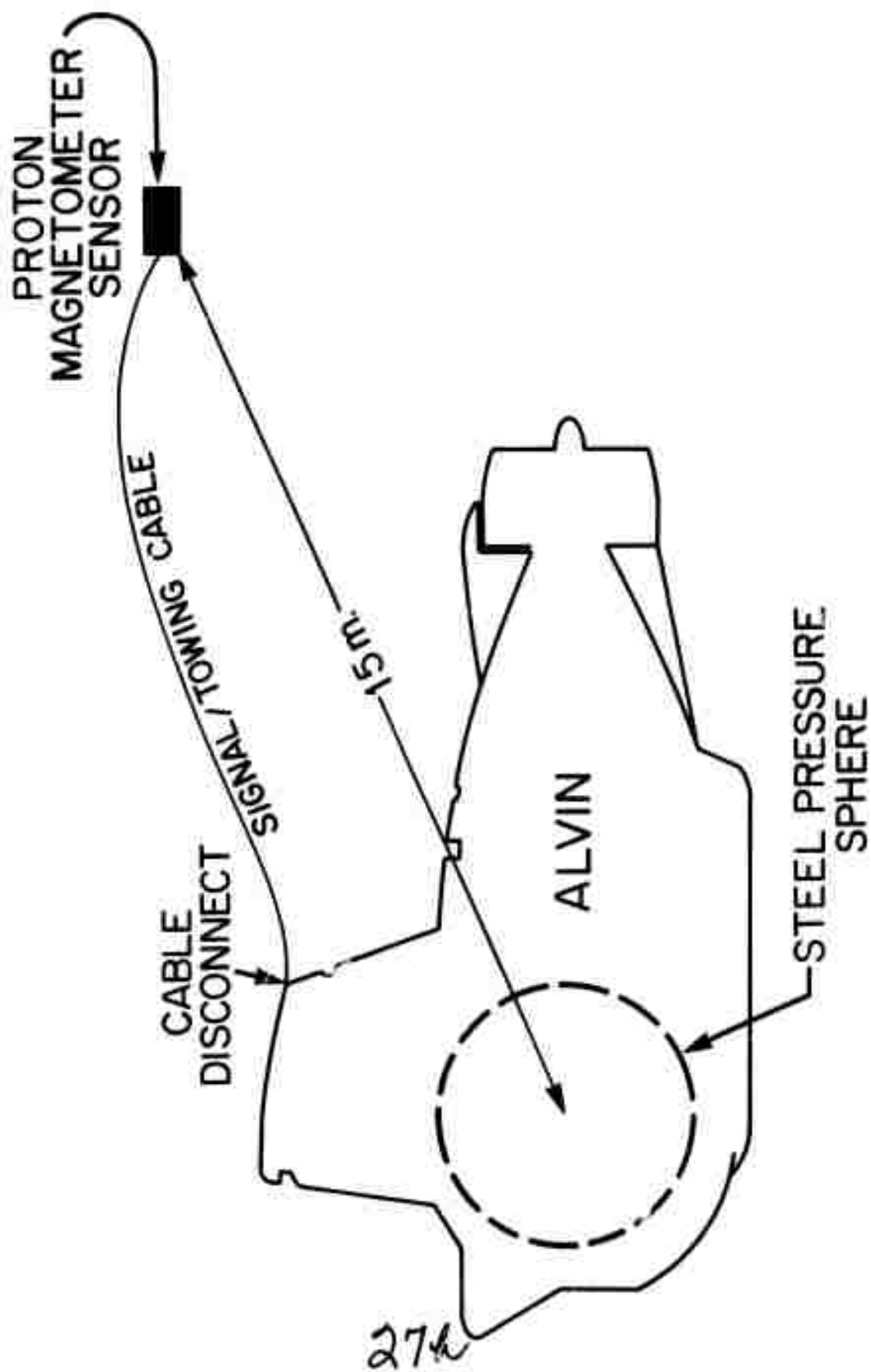


Figure 2.

**Near Bottom Continuous Gravity Profiles
From a Deep Submersible**

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Near Bottom Continuous Gravity Profiles From a Deep Submersible

As originally proposed to A.R.P.A., the Vibrating String Accelerometer (VSA) gravimeter for ALVIN was quite different from the instrument which has been evolved. Originally, the gravimeter was to have been built around the small version of the VSA accelerometer (D4E) to be obtained from the Massachusetts Institute of Technology. This small accelerometer was to have been installed in a miniature oven, and the string output frequencies, together with a precision time base reference were to have been recorded on a precision audio-frequency instrumentation tape recorder. The tapes thus recorded aboard ALVIN were at a later time to have been played back into a shore based computer for analysis. The VSA oven was to have been suspended in a gimbal system in ALVIN, the hope being, that the acceleration environment aboard ALVIN would be sufficiently inactive so as to allow the gravimeter to hang vertically, and essentially undisturbed during deepwater transits.

Early in the development of the gravimeter, it was discovered at M.I.T. that the miniature accelerometer (D4E) that had originally been intended for the ALVIN system had become defective and was no longer a viable instrument. As no other miniature accelerometers were available to us, we proceeded to utilization of the larger accelerometer (Lot D), a number of which were available to us. Subsequently, an oven, control electronics, and VSA oscillator-amplifiers, were built for the larger accelerometer. The preliminary version of this oven proved to be the best such oven we have seen to date, and work now is progressing in the final version of this oven for use with later gravity experiments. Although this oven proved to be considerably larger than that originally proposed, for use with the small accelerometer, it did prove workable, as shall be described later.

The readout and recording system did not turn out to be as proposed either. Early investigations showed the readout system as proposed to be an unreliable and difficult system to manage. Therefore, a digital readout and recording system was designed and built. This system is similar to those presently utilized on our surface vessels but with several important differences. The system is much smaller so that it will physically fit into ALVIN. It is designed to operate on the 28 volt DC power which ALVIN provides. The string difference frequency filter, which on our surface vessel system has a 3-minute period, has a 5-second period, and the digital accumulator of the filtered string difference frequency is designed so as to not miss any frequency counts between successive accumulations. The system designed in this fashion allows for recording of vertical acceleration of ALVIN which may, at a later time, when correlated with navigational information, be removed or filtered by digital processing techniques. The digital readout system also includes a digital real-time calendar clock. The gravity accumulator, clock, earth's magnetic field, and navigational information are digitally (BCD) multiplexed and recorded on cassette recording tape for later shore based computer analysis. The design of the digital multiplexer for the preliminary ALVIN experiment allowed for the recording of gravity, time, earth's magnetic field, and vertical pressure differences (to indicate relative vertical displacement for acceleration calculations) but the unit is expandable for installation of up to five more digital input channels so that for future

experiments, x, y and z navigational components as well as altitude above the sea floor and another parameter may be recorded. The cassette recorder utilized for the preliminary system was borrowed from another project because, with the change in the instrumentation from that which was originally proposed, funding did not allow for its purchase.

The most fundamental change in the instrumentation, from that which was originally proposed, should be replacement of the gimbal system of gravimeter suspension with a miniature stable platform. Attempts to measure gravity from a helicopter, utilizing a gimbal mounted VSA gravimeter, show that it is unlikely that ALVIN will be accelerationally "quiet" enough to allow gimbal mounted gravimeter operation.

Plans are made to test the system in ALVIN in the fall of 1971.

A Self Contained Deep Sea Rock Drill

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A Self Contained Deep Sea Rock Drill

In January of 1971, the Woods Hole Oceanographic Institution undertook the design and development of a deep sea hard rock core drill specifically intended for use with the DSRV ALVIN. The primary objective of the program is to concentrate efforts on developing a drill which can carry out its complete drilling operation as a self-contained unit utilizing the submersible only for site selection, emplacement and recovery. This proposed mode of operation for the core drill differentiates it from other existing drills which are either lowered over the side of the ship and controlled from the surface or are intended for light duty operation from a submersible and depend upon the submersible for power, control, and physical support while drilling.

The design criteria was established for the hard rock core drill as follows: The drill is to be interfaced with the submersible in such a way that after selecting a suitable site, the ALVIN can release the drill thus initiating the start of its drilling operation. The complete drilling operation is to encompass the following: The drill is to be capable of penetrating one meter of rock during its coring operation through a maximum sediment covering of one meter in less than twenty minutes. After a suitable time lapse, a series of heat flow measurements are to be obtained in the cored hole for geothermal studies. The drill is then to extract a three dimensionally oriented core at least one meter in length which is to be used for petrologic and paleomagnetic studies. Finally, after a total period of what may be five or six hours from initial emplacement, the ALVIN is to return to the drill, reattach and return it to the surface. The drill is to be designed so that it is capable of operation in water depths up to 12,000 feet.

Aside from the basic design challenge there are two important problems which result from this new mode of deployment for a rock core drill. First is the mating of the drill to the load carrying capabilities of the ALVIN and secondly is the development of a suitable power source since the drill is to operate with complete autonomy of the surface.

Since time and money are often the determining factors in the success of a project, much emphasis was placed initially on an extensive and thorough study of existing hard rock core drills prior to commencing with the design phase. By means of this procedure it was strongly desired to establish the most feasible and economic direction in which to proceed, by benefitting from the accomplishments of others and avoiding repetition of their mistakes.

The subsequent literature search involved two general areas; the study of those drills which were designed for use from surface ships and those which were designed for use in conjunction with submersibles. Included in the study of surface operated rock core drills were those developed or under development by Ocean Systems, Inc.¹, Lockheed Missile and Space Company², and the Atlantic Oceanographic Laboratory at Bedford Institute in Nova Scotia, Canada^{3,4}. In view of the fact that these drills require the direct support of a surface ship, they provided much information on the 'state of the art' of drilling which was directly applicable to the design of Woods Hole's drill.

The study of submersible operated drills included those developed or under development by the Woods Hole Oceanographic Institution⁵, Vickers Ltd. in England⁶, Ocean Recovery Corporation of America (ORC)⁷, and Ocean Systems, Inc.¹. Only a limited amount of useful information was acquired from these studies since the drills are more or less hand tools intended for operation from the submersibles' manipulator arms and are capable of obtaining relatively short cores in the order of one to two feet. The drill thought to be under development by Ocean Systems, Inc. showed the most promise, but further investigation revealed that their efforts had been discontinued as a result of the loss of their submersible due to financial problems.

The various rock core drills which were investigated were all similar in a very basic sense. They were designed for the express purpose of obtaining a core sample from the ocean floor. They are also dependent upon a source of power or continuous control which is external to the drill. A partial exception to this is Bedford's drill which will be discussed later.

It was found that the majority of these drills accomplish their drilling through the rotary motion of a diamond core drill bit combined with a continuous download applied to this bit. Two exceptions to this method are the resonant hard rock core drill designed by ORC, and the lunar percussion rotary drill designed by Martin Marietta Corporation⁸. For present design purposes the complexities of these latter mentioned drills did not warrant any extensive investigation, although the method of percussion rotary drilling showed the most potential for a future design alternative.

In general there are two basic methods of supplying a continuous download to the core drill bit. The first is through use of gravity. The weight of the core barrel combined with the dead weight of a carriage assembly provides the necessary download. This carriage assembly, which is free to move vertically enough to fully extend the core barrel, usually consists of the drive system, drill bit flushing system and other related components. The second method involves the use of hydraulic pressure which is used to vertically load the drill bit through some sort of piston-cylinder arrangement.

None of the drills investigated completely matched the design requirements of Woods Hole's proposed drill. The submersible operated drills were too small since their size and weight could not exceed the handling capabilities of the submersible's manipulator arm. The surface operated drills were too large and bulky since weight is not a prime factor in their design.

The closest drill whose capabilities were commensurate with the requirements of Woods Hole was Bedford's drill. To enable a more extensive evaluation of their drill, a trip was planned to visit their facilities in Nova Scotia. Since their work on a deep sea rock core drill commenced in 1965, it was felt that much could be learned from a closer look at their approach and accompanying difficulties. They had developed a novel drive system which employs a hydrostatic motor that derives its power from the differential pressure existing at depth between sea water and a series of low pressure reservoirs which are initially at atmospheric pressure. The use of this technique enables the drill to operate on the ocean bottom at great depths thereby eliminating the problems of power transmission and control over long distances. Its only

dependency upon the surface is for its lowering to the bottom and its subsequent recovery.

The necessary download in Bedford's drill is provided hydraulically. Sea water is used as the fluid medium in a piston-cylinder configuration, in which sufficient pressure is generated by a pump to provide a predetermined load to the piston. Attached to the piston is the core barrel which, as drilling proceeds, is extended out of the cylinder. This cylinder is referred to as a torque barrel since rotary motion and torque is supplied to the core barrel through the rotation of this torque barrel.

The primary outcome of the visit to Bedford Institute was a better understanding of the various parameters governing drill penetration. In addition, their method of supplying rotation and download to the drill bit was carefully scrutinized and due to its relative success was strongly considered as a possible design approach.

With a relatively good background on the subject of rock core drills, design procedures commenced with the subdivision of the proposed drill into five components which include the drive system, power source, drilling system, frame, and the ALVIN attachment. Of first consideration was the drive motor and power source. Due to the experience of the Ocean Engineering Department here at Woods Hole with the use of batteries for submerged applications, it was decided to use a DC motor powered by lead acid batteries. Both the batteries and motor would be encased in a pressure compensated, oil filled housing thereby eliminating the need for pressure containers.

The second area of consideration was the drilling system. Based on the studies of Bedford's work, it was decided to pattern our design in accordance with their method of rotating and hydraulically downloading the core barrel. This method was chosen due to the relative amount of success which Bedford has achieved. Other methods showed only limited promise since they had not been proven on a drill of our desired capabilities.

The frame and the ALVIN attachment are to be left until last since properly mating the drill to ALVIN requires a carefully designed frame. Since the weight distribution of the drill is a very important item, the drilling system, power source, and drive system would have to be developed first before the frame could be properly designed to effectively accommodate these components.

The ability to employ a deep submersible for the operation of a hard rock core drill offers a distinct and unparalleled advantage in the exploration of the deep ocean. The submersible offers a valuable means by which the scientist can selectively pick an area of interest to research and, through use of the drill, can very effectively supplement his studies. This proposed capability of obtaining a one meter long oriented core and subsequent heat flow measurements offers many advantages over present methods of the petrologic and paleomagnetic studies of the earth.

The efforts of such programs as JOIDES (Joint Oceanographic Institution Deep Earth Sampling)⁹ which have provided valuable contributions in these studies still possess intrinsic problems. Through the use of the Glomar Challenger, which serves as a floating drill rig, they have had much success

in demonstrating the capability of drilling and obtaining cores in 20,000 feet of water with a depth of penetration up to 2,000 feet. Although extensive core samples have been obtained, limitations exist which are inherent to their basic method of approach. They do not have the advantage of using a submersible for visually surveying the geological features of an area and the subsequent selection of a particular site to drill. In addition, rock formations which are exposed on the ocean floor cannot be sampled by this method of deep sea drilling since a sediment covering of at least 30 meters is necessary in order to stabilize the drill bit¹⁰. The existence of such limitations as these have provided the impetus for developing a rock core drill which can effectively be operated with a deep submersible such as ALVIN.

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Development of Equipment for Use
in Deep-Ocean Biological Research

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Development of Equipment for Use
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Introduction

The biological gear development program is directed toward both short-term and long-term biological studies of the deep sea floor. These will provide background knowledge of naturally occurring temporal and spatial variations resulting from interactions between the environment and the organisms living there. In developing such background information, specific well-defined areas of the sea floor must be surveyed from deep submersibles on a daily, seasonal and if possible yearly basis. This requires a capability of long-term monitoring and the establishment of deep sea monitoring stations which can be visited repeatedly to pick up instruments which have completed a task, to set down new instruments for continued data collecting and to carry out studies of the area which must be done directly from the DSRV.

Accomplishments to August 1, 1971

Design of all proposed equipment was initiated within the first six months of the contract year. The status of the units at the end of this time period is as follows:

1. Design of the Longhurst-Hardy Plankton Recorder System, LHPR, (Longhurst et al., 1966) for use with a DSRV was completed. Construction was approximately two-thirds completed. The sampling device is composed of the following units:
 - a) Two plankton recorders embodying the Hardy Plankton Recorder principle (Hardy, 1936), but which take a series of discrete samples (Figure 1);
 - b) Two nets with the cod end of each attached to a plankton recorder. A net has a rectangular mouth 62 cm x 32 cm and a length of 135 cm. The filtering surface (0.333 mm nitex nylon gauze) is zippered to a canvas collar which is mounted on a metal frame;
 - c) Two pressure cases, each containing an electronics package with circuitry to record water temperature, depth and number of net flow-meter revolutions, and to control the gauge advance time in the plankton recorder, a 12 volt power supply constructed of rechargeable nickel cadmium batteries and used to run a Rustrak chart recorder and the plankton recorder motor. Figures 2-8 give the circuit diagrams for the timing and metering circuits. The circuitry for recording temperature has three spans (5°, 10°, 25°C) and three zero points 0°, 5°, 10°C) thus providing a total of nine temperature ranges from which a given range can be selected for recording on a dive. In addition the metering circuitry allows the observer to change an initial temperature scale to another one during the course of the dive.

The aluminum pressure cases are designed for use to 4000 m (safety factor 1.5);

- d) Two control boxes (see circuitry Figure 8) which are operated by an observer from within the DSRV to turn the LHPR systems on and off. They also provide display units which permit monitoring of the LHPR while operating;
 - e) A supporting frame in which the nets, the plankton recorders, and pressure cases are mounted. Attached to the front of the frame are doors to open and close the mouth of the nets. The doors are manually opened and closed by the DSRV pilot using the mechanical arm. A TSK flow-meter, modified to telemeter propeller revolutions to the Rustrak Recorder, is centrally located in each net mouth.
2. A review of literature concerning previous sediment trap designs and related background material was nearly completed. A thorough literature search yielded little information concerning previous design or use of sediment traps. Berger and Soutar (1967), Fox, Isaacs and Corcoran (1952), Trevallian (1967), Brunskill (1969), and Moore (1931) have experimented with detrital or sediment collecting apparatus, but such designs have had accompanying operational difficulties. Moreover, the majority of the experiments employing this gear were conducted in relatively shallow water and are impractical for use in the deep ocean.

Evaluation of previous designs and the present research requirement that the trap minimally interfere with any naturally occurring processes resulted in the selection of a passive collection design. Design of a prototype has been started.

3. The design, construction, and testing of equipment for studying the functional ecology of the benthic community were begun. We were attempting to answer basically two questions; 1) what is the energetic requirements of the deep-sea benthic community and its component parts, and 2) what are the physiological effects of pressure and temperature on deep-sea animals.

To answer the first question we designed and constructed an in situ respirometer to monitor oxygen consumption by the bottom (Figure 9). This device consists of two plexiglas cylinders capped at the top to support the electronic recording mechanism housed in a glass sphere. A Ag-Pt oxygen electrode (Kanwisher, 1959) is inserted into each cylinder and is directly connected to an operational amplifier and a Rustrak recorder (6 v/100 ma) with a time sharing capacity to record the two electrode signals. Water enclosed within the cylinders is circulated with a motor and magnet arrangement. The motor (escape micromoteur/AR 601) and attached horseshoe magnet are packed in turbine oil and encased in a pressure compensated plexiglas housing with a perforated aluminum cap and a compensating neoprene gasket. The magnet on the motor rotates a bar magnet located beneath the housing in the cylinder, which circulates the water over the

electrode preventing oxygen stratification. A 4.5 volt battery source (3-C-cell alkaline dioxide batteries) powers the motor and are housed in the glass sphere. Connection between the motor and battery is through Mecca bulkhead fittings inserted into the stirring housing.

The glass sphere (OD-23.5 cm; ID-21.6 cm) consists of two annealed borosilicate hemispheres which are sealed with glue and adhesive tape. Ten electrical leads are inserted through the sphere to provide electrode and battery connections. Within the sphere is an operational amplifier and a Rustrak recorder which are powered by a 12 volt battery system (8-C-cell alkaline dioxide batteries). Operation time with this battery source is approximately 100 hours.

To adapt the respirometer for ALVIN use a steel strap arrangement made from hose clamps was secured over the sphere and a T-handle attached. This attachment can be removed to allow disassembly of the sphere. Counter weights were placed over each cylinder to compensate for sphere buoyancy.

One double bell jar respirometer was built and tested with ALVIN at the permanent station (70° 40'N; 39° 46'W). The first dive was made on 20 June 1971 at a depth of 1475 meters. One respirometer was placed on a fine mud bottom for a duration of 3.5 hours. Due to electronic malfunction a measurement was not obtained, but structurally the respirometer was adequately designed. A photograph of the respirometer on the bottom is shown in Figure 10.

The second test dive was made on 22 June 1971 to a depth of 1800 meters. One respirometer was placed on the bottom for five hours. Another electronic malfunction prevented a significant oxygen uptake measurement.

4. Due to the lack of engineering time the pressure retrieval system was not designed thoroughly or constructed.
5. In situ or submersible sampling of the benthos has been limited to small quantitative core tubes or to non-quantitative nets or scoops. Biologists using ALVIN have used arrays of polyethylene core tubes, sometimes as many as twenty, each having its own plastic quiver. These appear to work well for very small, infaunal species, but a larger sampler was needed to get better estimates of the abundance of less common, larger individuals. We also needed to be able to capture the larger, more-motile individuals that could easily escape the small cores.

Initially, we assumed a new instrument with the general design of an anchor dredge, to be used as a scoop, would have to be developed. Search of the literature, however, provided us with a Birge-Ekman box-core (Ekman, 1905). Used mostly in fresh water, this has been disregarded by marine ecologists because it is small and relatively light (2.5 kilograms). Anticipating that it could

save us valuable time in development, we acquired one and made some initial modifications for in situ use.

Conventionally, these have spring-powered jaws which, once cocked, can be triggered by sliding a messenger down the line to the box. The wire was removed and onto the plate actuated by the messenger, a brass nut was brazed. Through this, we screwed a threaded "T"-shaped aluminum rod. Screwed down completely, this prevents the box jaws from releasing, but with several turns out, the jaws can easily be actuated by depressing the T-bar aluminum rod serving as a handle (Figure 11).

Our first use of the instrument was in Woods Hole Harbor with SCUBA and in the Gulf of Maine with ALVIN. The only problem encountered was a loss or winnowing of sediments out the loosely-fitting flaps covering the box top. Not enough samples were taken to evaluate whether or not this sampler is actually big enough to get reliable estimates of the macrofauna.

6. Time-lapse photographic system. The purpose of this effort has been to explore the different avenues open for long-term visual records of biotic and sedimentary processes on the deep-sea floor. Photography was chosen over television initially because of clarity of the final prints and expense. First considered was a modification of a 35 mm bottom survey camera capable of taking 3000 exposures. This was abandoned in favor of an elapsed time motion picture for ease and convenience in analysis and a possible prototype had already been developed for shallow water (Edgerton, MacRoberts and Read, 1968). This system, in shallow water, made good records of animal movements for periods as long as 24 hours. Agreement was made with Dr. Harold Edgerton that we would furnish deep-sea housings, deployment frame, and flotation and deployment mechanisms, and his laboratory would modify the camera for taking photographs for a period of up to one week.

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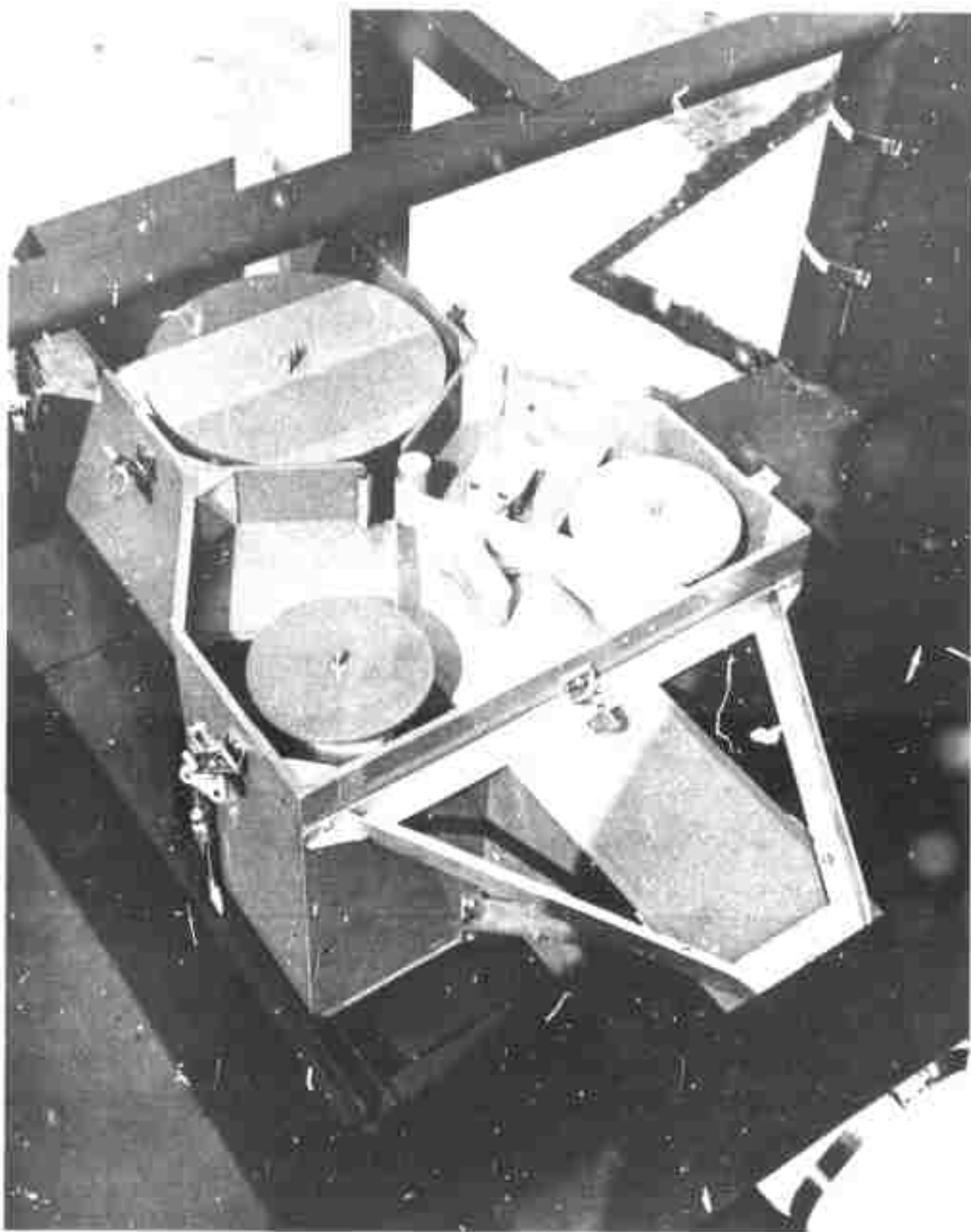


Figure 1. A single LHPR recorder unit mounted for use in a surface towed vehicle. Water enters the plankton recorder by way of the square tunnel at the lower right of the picture and passes out exhaust ports after the tunnel has divided. Zooplankton in the water are trapped on gauze filtering tape cutting across the tunnel. The tape is wound up on the large take-up spool behind the tunnel passage ways. The electric drive motor which is not visible is located behind the take-up spool.

40a

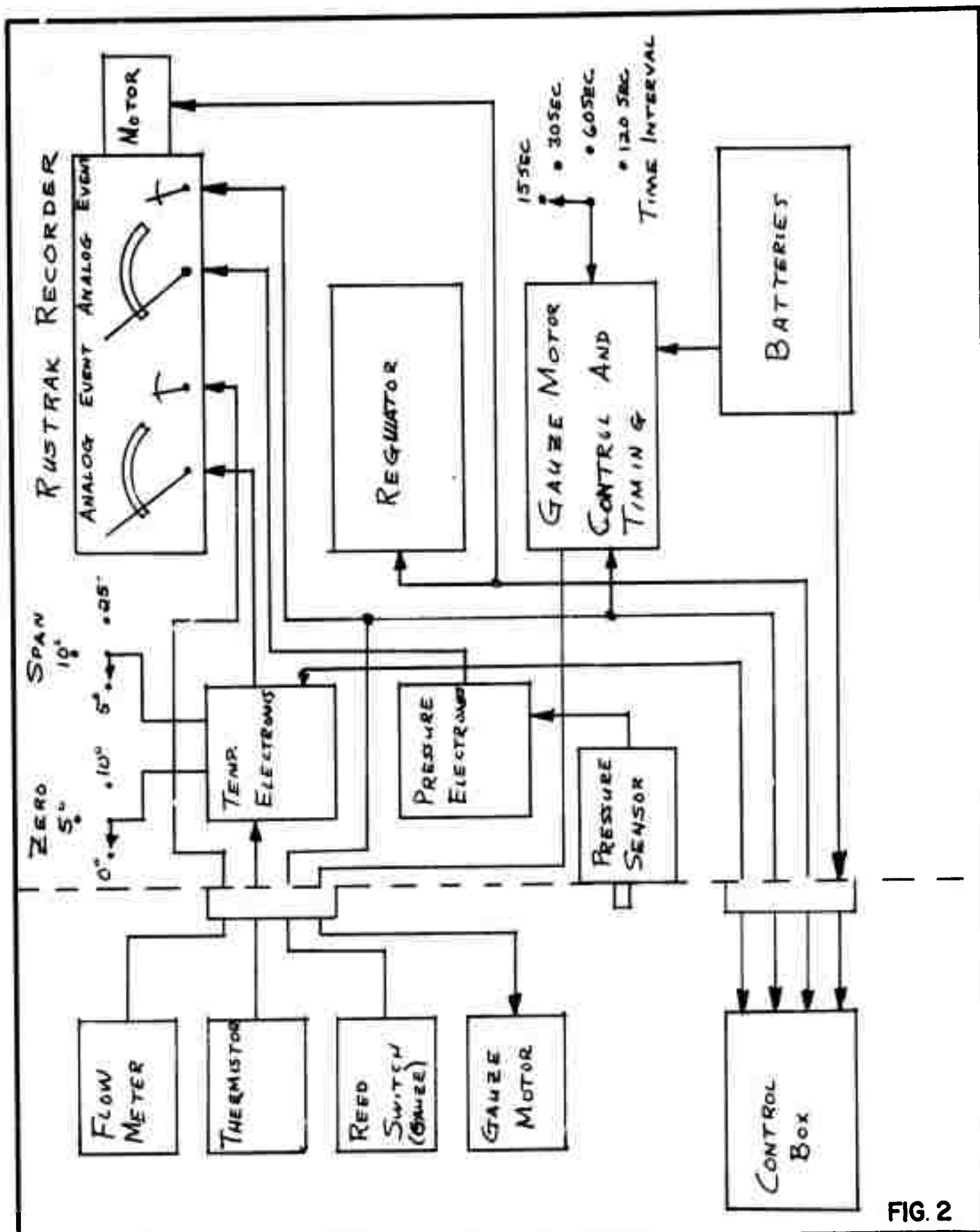
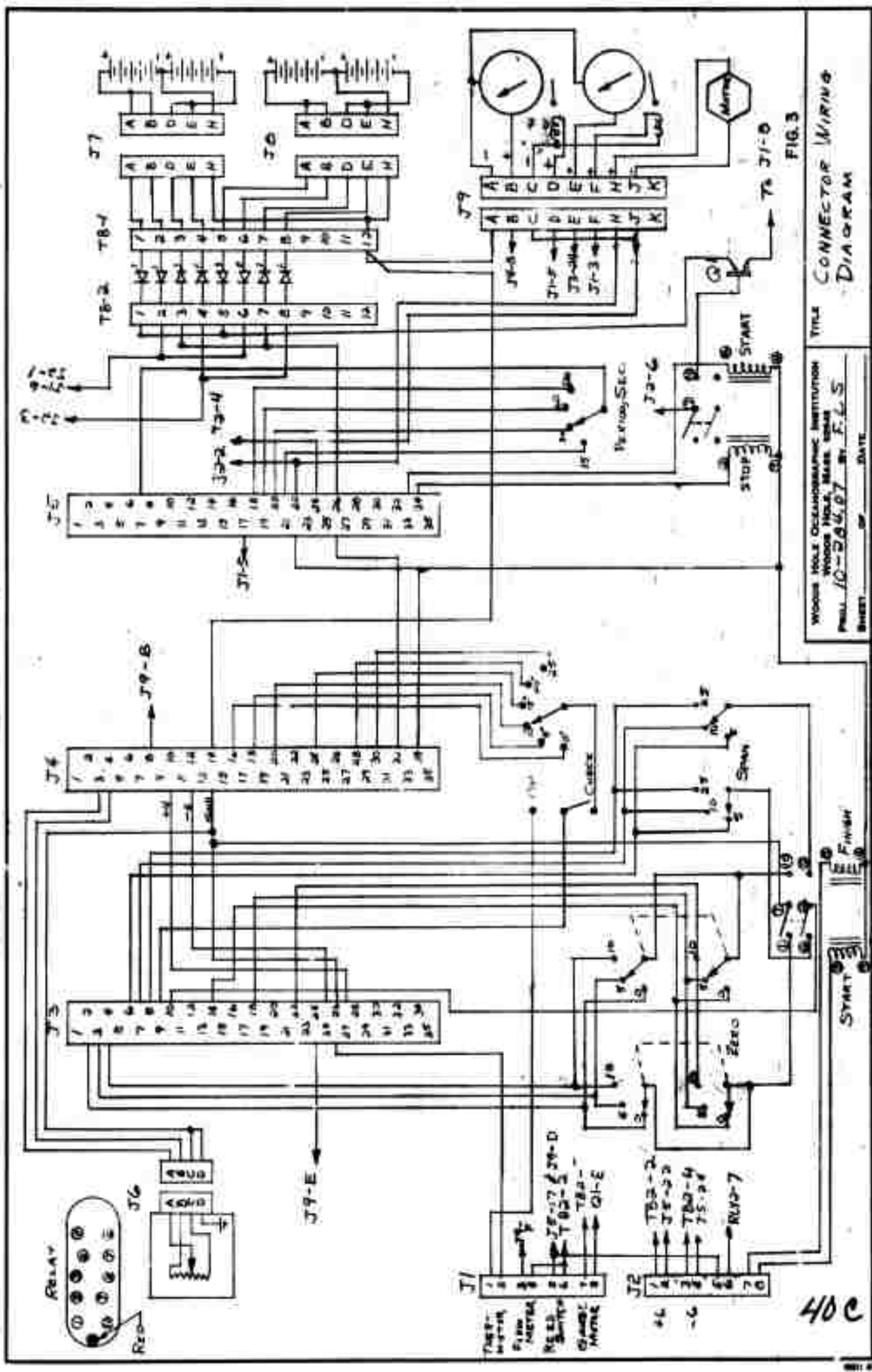


FIG. 2

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASS. 02543
PROJ. 10-284.07 BY F. STRIFFLER
SHEET _____ OF _____ DATE _____

TITLE L H P R
BLOCK DIAGRAM OF 40k
ELECTRONICS

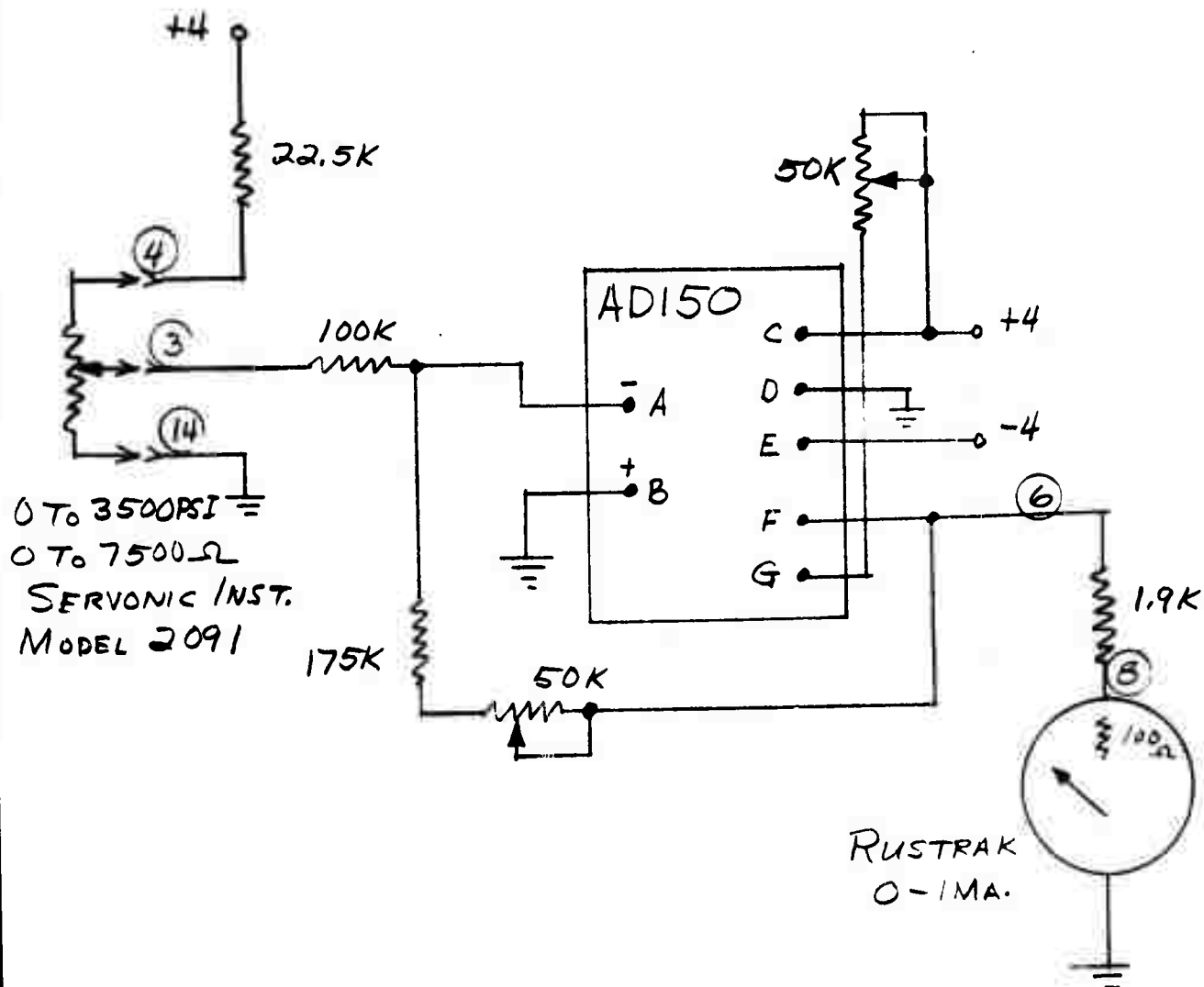


CONNECTOR WIRING DIAGRAM

TITLE
WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASS. 02545
PULL 10-20467 BY F.L.S.
SHEET 00 DATE

40C

⑩ ○ — +4
 ⑭ ○ — GND
 ⑫ ○ — -4



PIN CONNECTIONS SHOWN
 ARE J4

FIG. 6

WOODS HOLE OCEANOGRAPHIC INSTITUTION
 WOODS HOLE, MASS. 02543
 PROJ. 10-284.07 BY E. STRIFFLER
 SHEET _____ OF _____ DATE 16 JUNE 1971

TITLE PRESSURE CIRCUITS
LHPR

40f

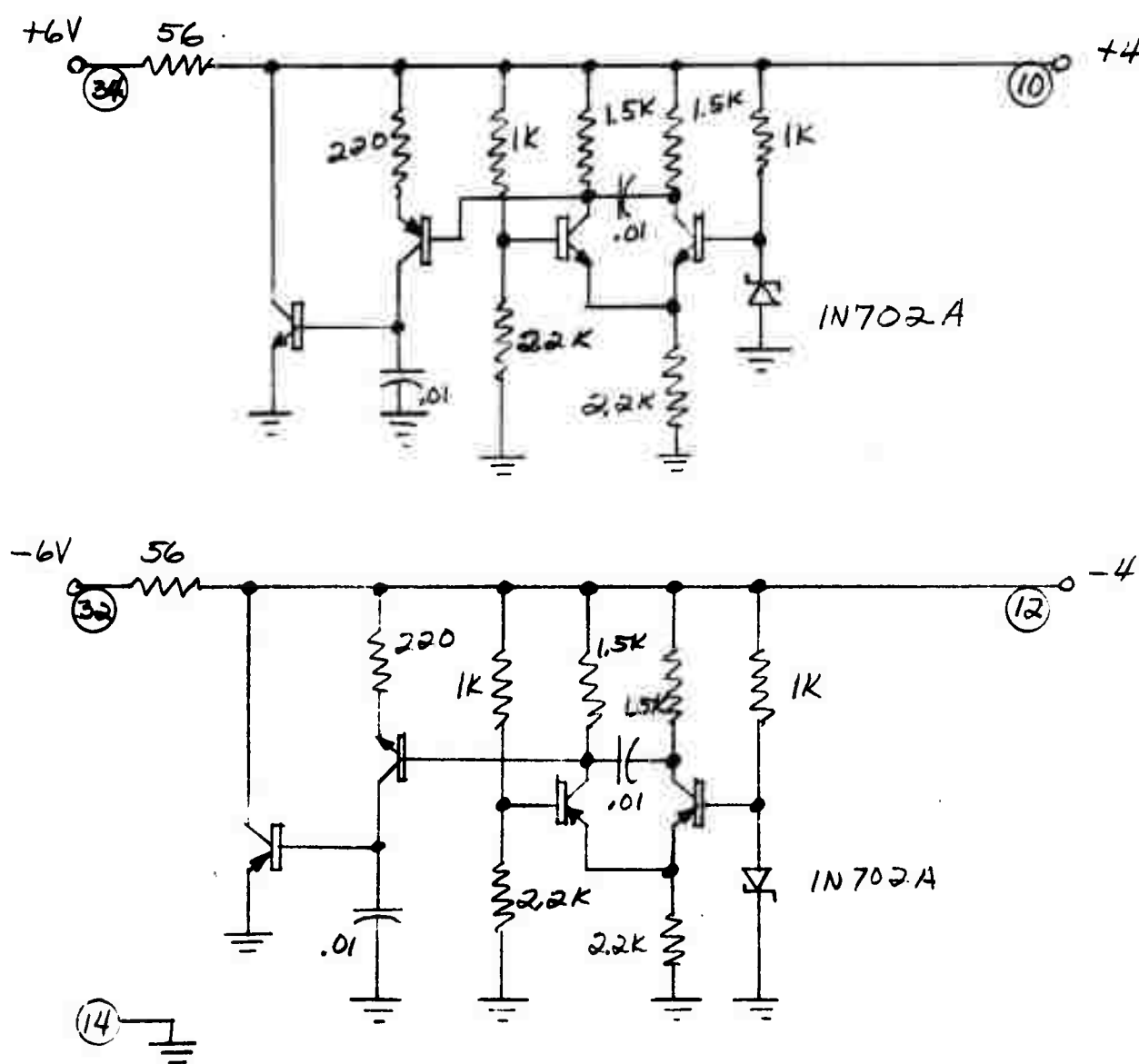


FIG. 7

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS HOLE, MASS. 02543
PROJ. 10-254.07 BY E. STRIEFLER
SHEET _____ OF _____ DATE 28 JUNE '71

TITLE ± 4 VOLT
VOLTAGE REGULATOR 409

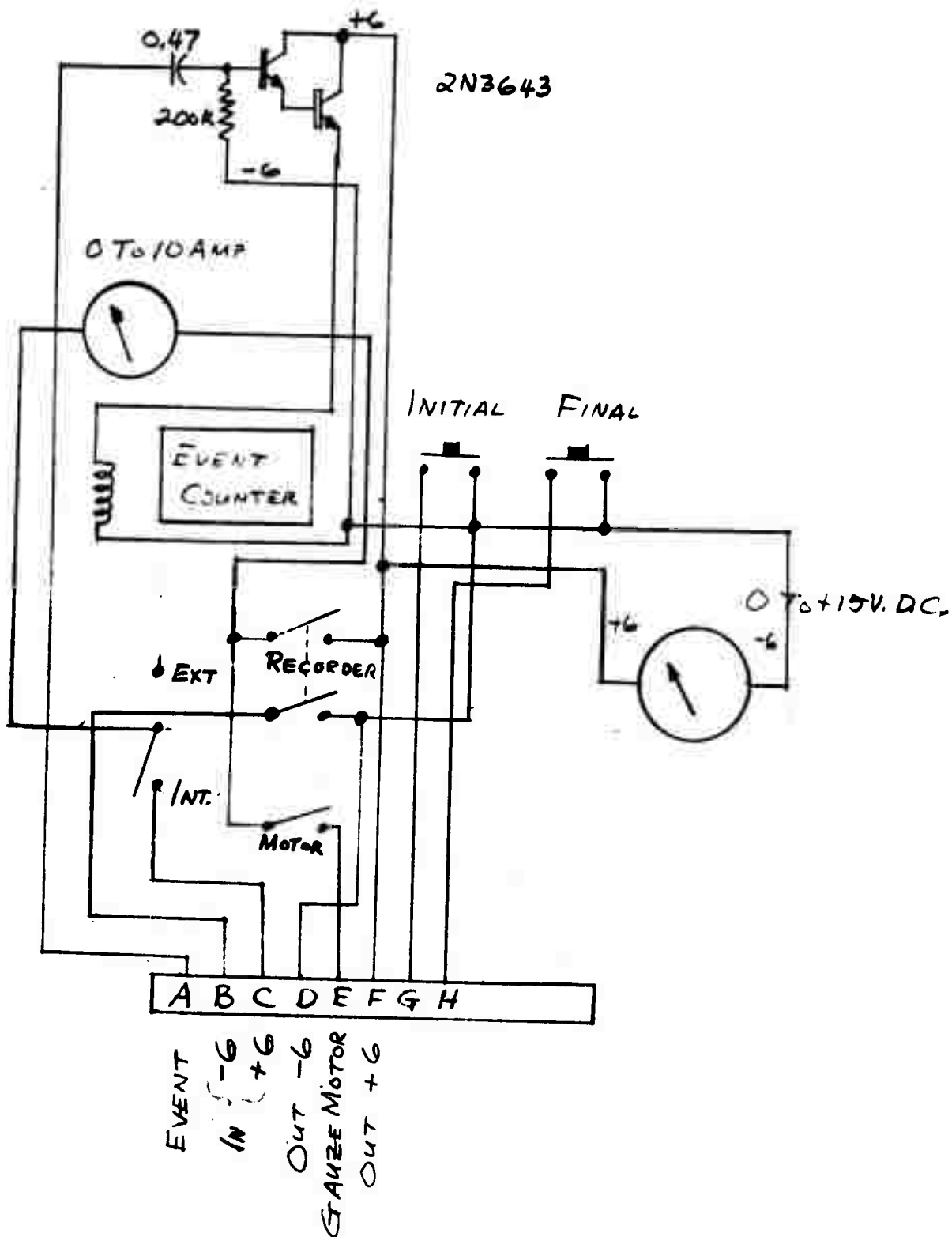


FIG. 8

WOODS HOLE OCEANOGRAPHIC INSTITUTION
WOODS, HOLE, MASS. 02543
PROJ. 10-264.07 BY E. STRIEGLER
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TITLE

CONTROL BOX
SCHEMATIC

40h



Figure 9. In Situ respirometer

40i

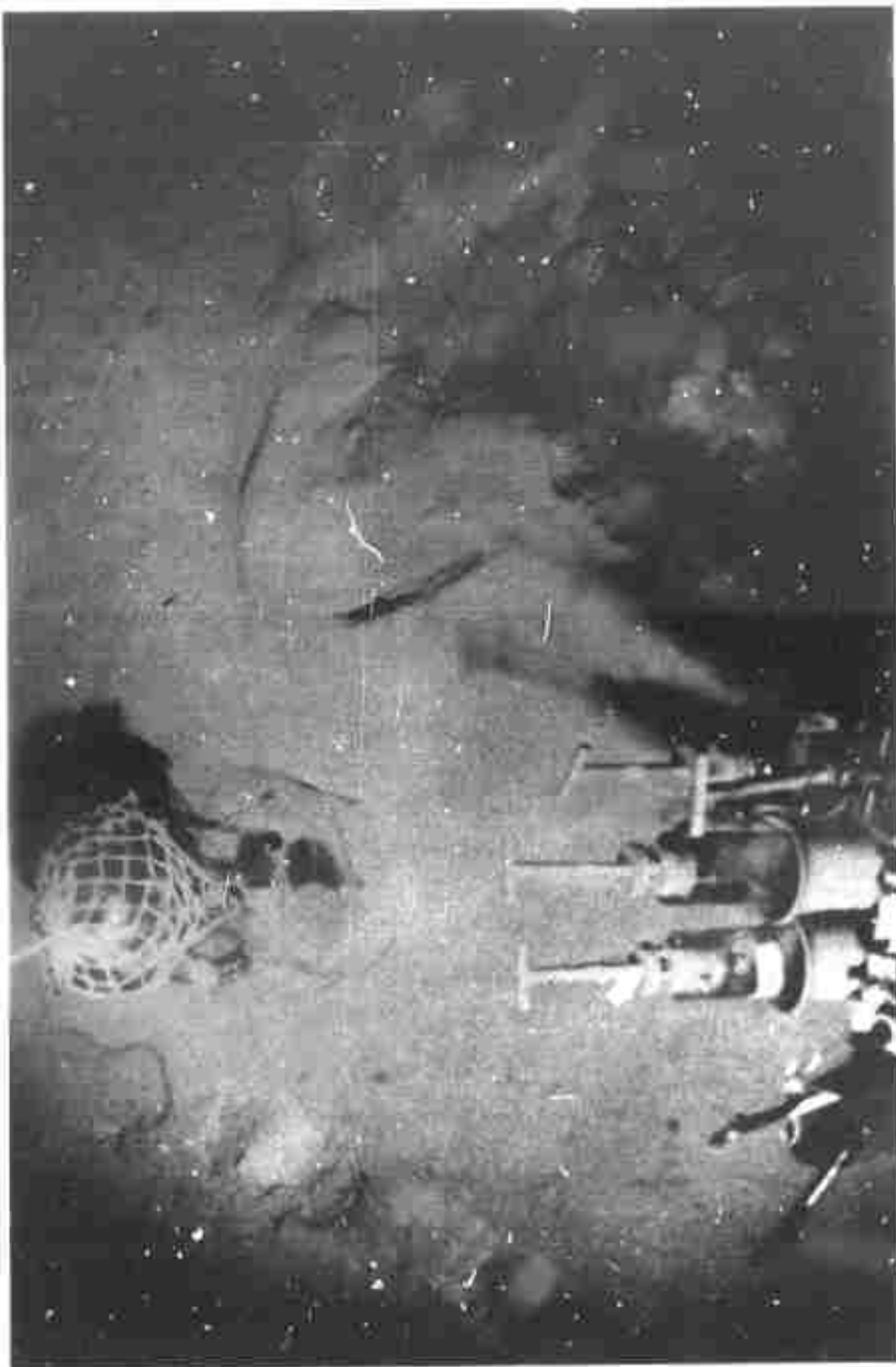


Figure 10. In Situ respirometer at 1700 meters with the ALVIN basket and cores in foreground.

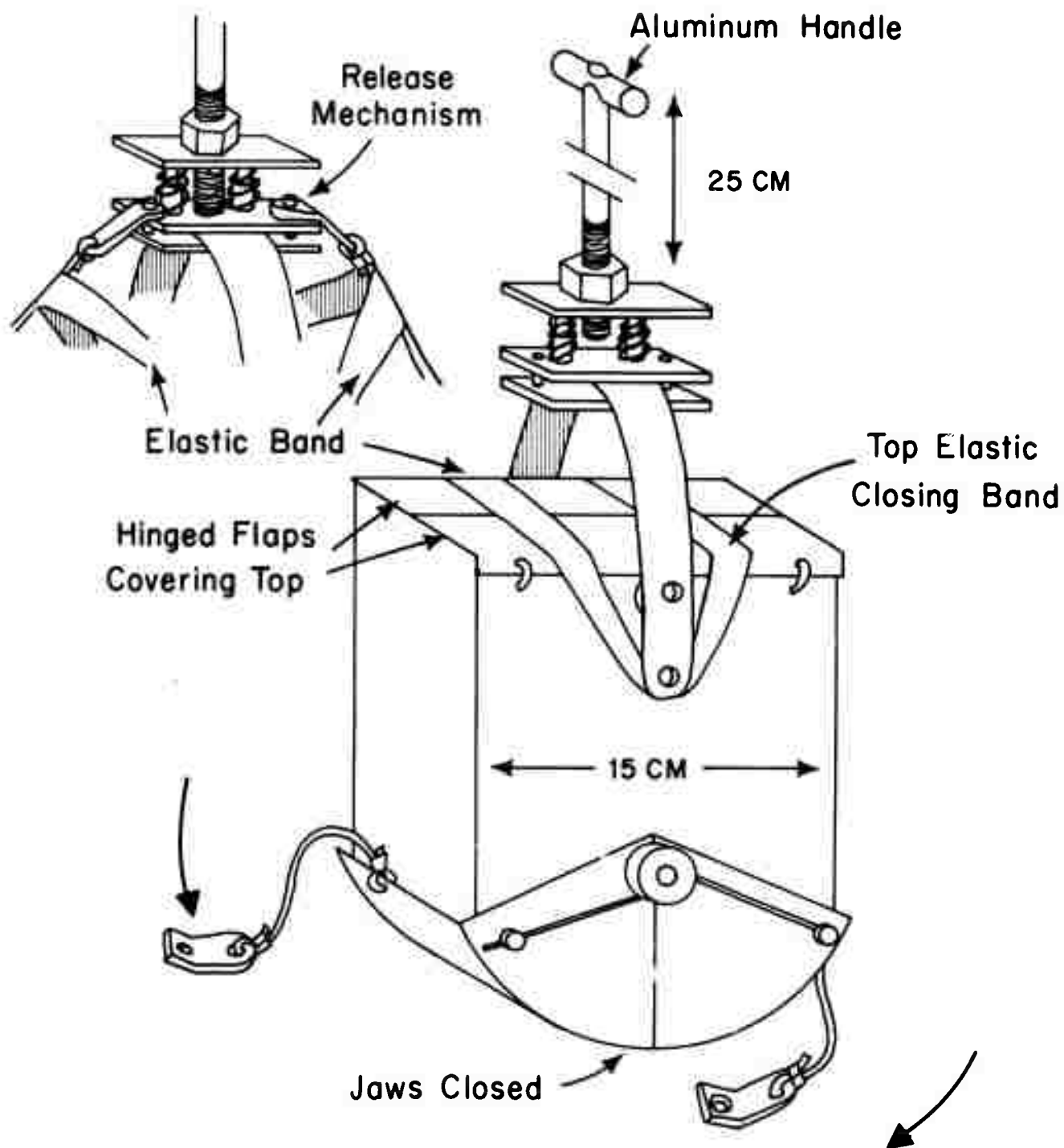


Figure 11. Birge-Ekman Box Corer for use from DSRV ALVIN.

40K

Offshore Monitoring of Industrial Waste

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Problem and Approach

The problem is to evaluate the feasibility of achieving practicable levels of sensitivity, resolution, and reliability in the chemical analysis of industrial wastes in offshore waters.

Budgetary limitations required that the sampling locations be near Woods Hole and precluded major advances in resolution of the analytical methods used or detailed investigation of their reliability. The problem was approached by obtaining a series of samples taken along a transect extending from mid-Buzzards Bay into New Bedford Harbor, where a variety of chemical-producing industrial activity (textile dyeing, golf ball manufacture, copper and brass machining, power generation, fish protein concentrate synthesis, and numerous very light industries) occur. These samples were analyzed by a modified method originally developed for the analysis of organic substances in natural waters (Blumer, 1970). The method is sensitive and free of contamination problems which are the major danger of artifact in this type of study.

Methods

1. Sampling

Water samples of approximately 20-liter size were collected by surface-dipping a stainless steel bucket from the windward side of a drifting small vessel and transferred to 20-l glass carboys which had been pre-cleaned ultrasonically with distilled water, distilled methanol and distilled pentane. Analysis of the last pentane washings of the jug before its capping was used to demonstrate low blank values. The water samples were returned immediately (within four hours) to the laboratory for extraction. Several sampling cruises were made, each sampling the stations shown on Figure 1 (Appendix).

2. Sample extraction and preparation for analysis

All materials and operations used in the following procedures were checked for purity and freedom of contamination as described at the end of this section, and many analyses were rejected because of these controls.

The samples, protected from light and less than four hours after collection, were gravity-filtered by siphoning through Whatman #54 filter paper into a second series of ultrasonically cleaned carboys and were agitated with 500 ml of pentane as extractant by a vibrating impellor positioned at the phase interface. The agitated phases were stored overnight in a freezer room for separation of phases and prevention of biological activity. The pentane extracts, recovered by siphoning and decantation, were dried over sodium sulfate and concentrated in vacuo to

0.1 ml volume, but not less, care being taken to avoid loss by evaporation.

The concentrated samples were passed through 1-ml chromatographic columns containing 90-120 mesh silica gel deactivated with 3% water. Elution with 3.0 ml of pentane was followed by reconcentration to 0.1 ml and storage at -20°C or immediate analysis.

3. Materials purity and procedural validations

The entire method depends on the availability in quantity, of a solvent which is sufficiently pure to give essentially a zero-signal blank analysis when it is used in 10^9 - fold or higher excess. Pentane of this quality was prepared by double redistillation through steam-cleaned all-glass 1-meter Widmer columns, and stored in dark all-glass jugs. The product (each jug as a batch) was tested for suitability by evaporating 500 ml of it to about 0.1 ml, and introducing the concentrate into the instrument just as samples were. Only batches which gave negligible signal were utilized.

All apparatus was cleaned with this solvent in multiple rinses, using ultrasonic agitation on glassware, before use. The last rinse from each piece of apparatus was added, in the successful versions of the analysis, to a procedural blank which accompanied each individual determination. If the rinses from all the glassware were clean before the piece was used, the analysis was considered valid.

Materials, such as filter paper, sodium sulfate drying agent, and silica gel, were purified by Soxhlet extraction with 1:1 benzene-methanol overnight and their cleanliness ascertained, batch by batch, by blank extractions with pure pentane, followed by analysis.

4. Gas chromatographic analysis

The samples were analyzed, using a total-sample injection method, at the maximum sensitivity of a flame-ionization detector analyzing the effluent of a high-resolution packed column of low polarity and bleed. Typical analytical conditions were: Single-column Varian Model 1700 gas chromatograph, injector, 200°C, column programmed 50-290°C at 62/min with 10 min post-injection isothermal segment; detector, 200°C; sensitivity 1×10^{-12} coul/g initially, with manual attenuation, carrier gas, 11 ml/min N_2 . Columns used were 6" x 1/8" ApL (pretreated on silica gel) 3% on Chromosorb W, acid-washed and silanized, 80/100 mesh. These columns typically had about 4000 plates of resolving power (normal hydrocarbons at 200°C) and bleed rates which were negligible at program start and about 16 x full scale sensitivity at the end of the program.

Sample introduction was by dousing a precleaned, etched glass rod with all of the extract pentane solution while holding it in the injection port opening, followed by rapidly inserting the entire rod with sample residue and closing off the port entrance. Sample analyses were recorded by 1-second response 1-mv Leeds and Northrup Model G recorder, and attenuation by Hewlett-Packard automatic attenuator in binary units.

5. Methods summary

The methods used strongly emphasize performance in terms of sensitivity and sample integrity at the expense of resolution (Blumer, 1970). Analytical reliability is high if one rejects all results invalidated by the "parallel control" technique, but many analyses are rejected. The method analyzes for the nonpolar volatile carbon-containing constituents of the seawater sample, and is capable of resolving completely about 100 components present initially in the 0.01 microgram or greater range.

Technical results

Over 150 gas chromatographic analyses were performed on samples from three sampling cruises and numerous reagent and method performance checks. Analysis of the complex results reveals the following major points:

- A. There are strong indications that the samples alter significantly between collection and the beginning of extraction in the laboratory. Clearly visible slicks were collected several times and were gone by the time the samples reached the laboratory.
- B. All natural samples successfully analyzed yielded large total signals.
- C. The material in these samples does not appear, on the basis of known biogeochemistry, to arise from natural processes (Blumer, 1970; Ehrlinton & Murphy, 1968).
- D. The samples are all extremely complex in composition and well beyond the resolving power of the instrument. All samples show a complex, partially resolved suite of peaks ranging from low to high molecular weights.
- E. A major contamination problem in analyses was traced to corrosion around threads of the agitator impellor used in the extraction procedure. This permitted access of extractant to a blind chamber containing some machine oil, and a few micrograms of it erratically contaminated and overwhelmed several samples.

The Appendix includes typical gas chromatographic traces relating to several blank experiments, calibration mixture, and the natural stations analyzed. Only typical examples are given in view of the

complexity of the results, which require extensive replotting to eliminate frequent attenuations.

DOD Implications

Chemical monitoring of industrial wastes utilizing the extractable organic fraction and analyzing gas chromatography and GC-MS is possible from the contamination point of view, utilizing the parallel solvent-rinse technique to validate sample authenticity. A much larger effort would be required to evaluate other aspects of feasibility. Biological alteration of samples after collection is an important negative factor.

Implications for further research

The analysis of samples filtered immediately upon collection should be pursued. Other data (Farrington, 1972) strongly indicates that much of the industrial wastes are precipitated in estuarine waters and not carried out to sea. Sediment samples should be analyzed to check this possibility; they might offer much more concentrated sources of material.

Special comments

This project cannot produce useful results of the current level of effort and funding, and should be considerably expanded or dropped completely.

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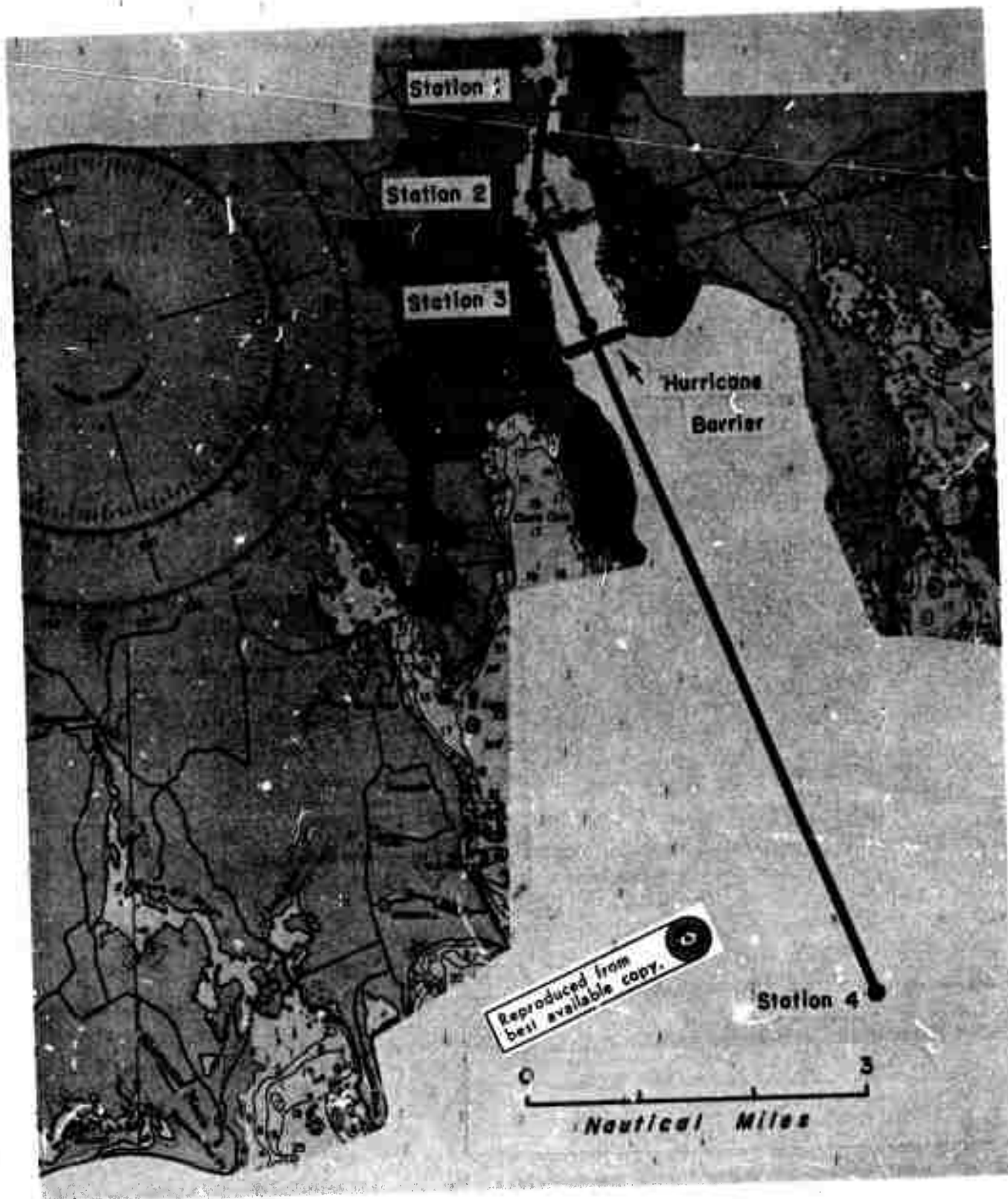


Figure 1. Location of Sampling Stations.

46a

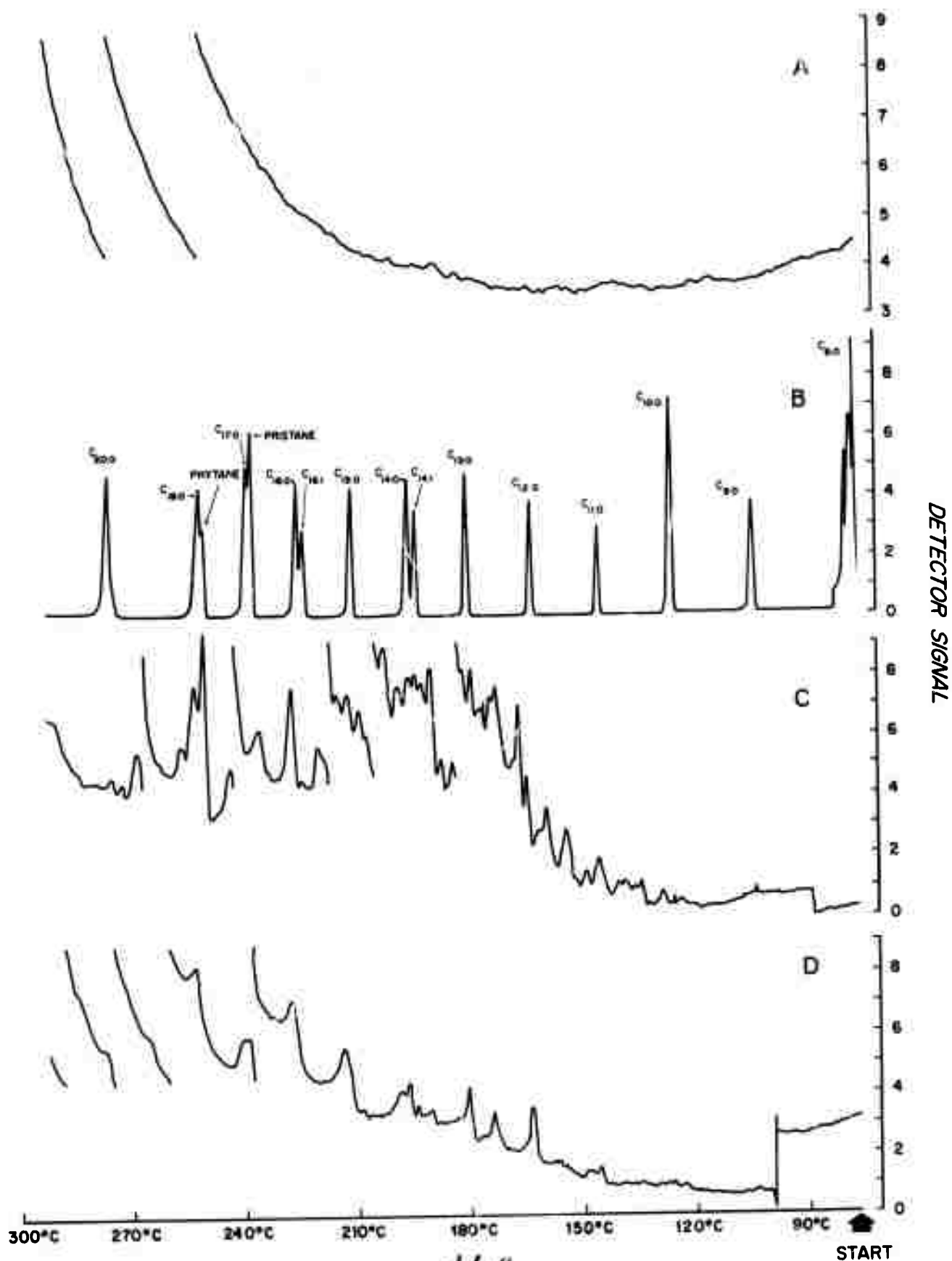


Figure 2. Gas Chromatographic analyses of Station 2 and 4 Hydrocarbons. 2a. Blank Determination. 2b. Standard mixture of saturated and unsaturated hydrocarbons. 2c. Hydrocarbons of Station 2 water. 2d. Hydrocarbons of Station 4 water. Recorder response is positive upwards. Gaps in pen tracing indicate halving or doubling of sensitivity to keep signal on scale.

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Ocean Engineering Department**

Air Borne Systems

Progress during the subject period was limited to planning of the preliminary experiment.

A preliminary experiment using 1500 foot (hydrophone depth) sonobuoys is planned. The experiment, using an aircraft of opportunity will entail the placing of ten sonobuoys on a line of bearing with approximately one mile spacing between buoys. The array thus formed will be used to monitor echoes from an assortment of explosives ranging from 1.1 oz. SUS signals up to 350 lb. aircraft depth bombs; the smaller signals being dropped along the buoy line mainly for determining the array geometry.

Larger charges (i.e. 1.8 lb. SUS fused for 1500 foot firing) will be dropped on the buoy line approximately midway between each pair of sonobuoys. These shots will provide the primary sound source for the ranging experiment. In addition, these spaced shots, combined with the array will provide a classic seismic refraction record allowing determination of bottom sediment thickness and sound velocity gradient.

The largest charges will be fired at some distance off the array line in a further long range experiment. Unfortunately, the large charges cannot be fired deeper than 125 feet somewhat limiting the energy available for echo-ranging. Communications have been initiated with the Naval Weapons Station, Yorktown, Virginia, to investigate the feasibility of fusing for the 1500 foot desired depth thereby placing the sound source at the same depth as the receiving array.

The experiment is planned to be conducted in April or May 1972, in order to give reasonable chance of good weather. The present plan calls for operation of the aircraft and of either Jacksonville N.A.S. or Roosevelt Roads, Puerto Rico. The array to be emplaced along a line roughly WNW from Latitude 24°N , Longitude 70°W . This area was chosen since a deep towed array track was run through the area on ATLANTIS II cruise 60 during August 1971. It should be possible to correlate echo returns received on both systems.