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**THE SEARCH FOR DEFENCE
and
OTHER OCEAN ENGINEERING PROJECTS**

1972 Student Summer Ocean Engineering Laboratory
Research Projects



Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

Report No. MITSG 72-20
Date: December 31, 1972

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Index No. 72-120-Noo

Administrative Statement

A fundamental educational experience for undergraduate students of Ocean Engineering is the opportunity to design, construct and operate equipment in the marine environment in a coordinated attack upon some real-world problem. This is the primary objective of the Summer Ocean Engineering Laboratory. The research objective is the location of the remains of sunken Revolutionary War ships in Penobscot Bay. In addition, the design and construction of individual equipment to support Ocean Engineering projects for both the 1972 and subsequent Ocean Engineering Laboratories are the objectives of the other individual projects described in this report.

A companion report, "Holbrook Cove Survey," (MITSG-72-19) describes the other major research undertaking by students during the 1972 Summer Laboratory.

Funding for the 1972 Summer Ocean Engineering Laboratory was provided by:

- The National Sea Grant Program, Grant No. 2-35150
- The Henry L. Grace Doherty Charitable Foundation, Inc.
- The St. Anthony Foundation
- The M.I.T. Undergraduate Research Opportunities Program
- The M.I.T. Information Processing Board
- The M.I.T. Freshman Advisory Council
- The Maine Maritime Academy
- The Massachusetts Institute of Technology

Alfred A. H. Keil
Director

December 1972

1972 Summer Ocean Engineering Laboratory

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The Maine Maritime Academy
The Massachusetts Institute of Technology

Equipment that was made available to the project at no cost included:

Equipment	Donor
Instruments for heavy metal analysis	Dr. Frank Aldrich and Mr. George Boylen, M.I.T. Environmental Medical Service
Polagraphic oxygen electrode	Dr. Frank Carey, Woods Hole Oceanographic Institution
Mechanical bathythermograph and Nansen bottle	Dr. Sloat Hodgson, Woods Hole Oceanographic Institution
Laboratory space and instrumentation for chlorophyll and heavy metal analysis	Professor Stephen Moore, M.I.T. Department of Civil Engineering
Research Vessel LOBSTER	Professor Damon E. Cummings, M.I.T. Department of Ocean Engineering
Various electronic components	SIGNETICS, Inc.

The individuals who donated their time to the projects without compensation include:

Individual	Organization
Professor A. D. Carmichael	M.I.T.
Professor Damon E. Cummings	M.I.T.
Professor Ira Dyer	M.I.T.
Professor Louis D. Braida	M.I.T.
Mr. Herman Kunz	Searle Consultants
Professor Dean Mayhew	Maine Maritime Academy
CAPT Willard F. Searle, USN (Ret)	Searle Consultants

Miss Anita Harris permitted the use of her properties and facilities on Holbrook Island without which the Holbrook Cove Survey would have been impossible.

The list of faculty and staff at both the Maine Maritime Academy and the Massachusetts Institute of Technology who contributed to the success of the 1972 Summer Ocean Engineering Laboratory would be lengthy and nearly impossible to compile without inadvertent omissions, so to these individuals the participants express their sincere appreciation.

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<u>Project</u>	<u>Student Participants</u>	<u>Results</u>
Lobster Behavior Study	Seo	Background research for a study of lobster behavior in the vicinity of traps was undertaken leading to some preliminary ideas for meaningful research projects.
Air Lift Pump	Parker Sawyer	An air lift pump was designed, partially constructed and tested. It worked satisfactorily although some detail design problems were encountered.
Underwater Power Generator	Benson McCarty	The design of a non-polluting, tidal-powered electrical generator was completed and construction started.
Can Buoy	Bartlett	A can buoy was designed, constructed and tested. It is available for the 1973 Summer Ocean Engineering Laboratory.
Stable Spar Buoy	Blackwood Bradford	A spar buoy that is decoupled from wave motions was designed, constructed and tested. It is available for the 1973 Summer Ocean Engineering Laboratory.
Nautilus Rock Tower	Campbell Devlin Libby	A tower for installation on Nautilus Rock was designed and constructed. It is ready for installation on Nautilus Rock during the 1973 Summer Ocean Engineering Lab.
Scallop Dredge	Labrecque	A new scallop dredge was fabricated in accordance with plans provided by the Maine Department of Sea and Shore Fisheries. It is to be tested subsequent to the Summer Ocean Engineering Lab.

2.0 SEARCH FOR THE REMAINS OF DEFENCE

2.1 Introduction

Ocean search and salvage is an important discipline of Ocean Engineering. Loss of property at sea is a problem which has plagued man throughout history and the prospect of recovery has motivated him to develop devices and techniques which better enable him to work in the marine environment. The serendipitous find of the treasure hunters is far overshadowed by the efforts made in rescuing men from sunken submarines or in the recovery of the hydrogen bomb in the deep waters off Palomares, Spain.

Search and salvage consists of several areas of interest. The search phase may consist of:

1. Historical research to determine what it is and where best to find it. This often determines whether the effort is worth undertaking.
2. Development of search methodology, including the determination of equipment and techniques that will be utilized in the search.

Technical competence is required particularly in the use of sonar, metal detectors, bottom profilers, and navigational fixing equipment. Knowledge of the locale and acquisition of data with regard to geology and oceanography are particularly useful.

Once the object of interest has been found, the operation shifts to the salvage phase. Certain legal permits or releases must be obtained before any salvage is undertaken. In the case of a historical antiquity, the state may have laws by which it takes possession of all objects recovered. Salvage is an engineering discipline in itself; hence experience will best decide what methods and devices will be used in the situation at hand.

Once objects of interest are recovered, they may require special treatment to allow them to be exposed to air without further deterioration after long immersion in sea water. Release to rightful owners is usually mandatory after suitable compensation to the salvors.

The search and salvage project was under the direction of W. F. Searle, Senior Lecturer in the Department of Ocean

Engineering at M.I.T. and former Supervisor of Diving and Salvage, U.S. Navy.

Considerable interest exists in the Castine area concerning the hulks of a fleet of American ships of the Revolutionary War period. Research into historical literature concerning this episode in naval history was undertaken to define areas of probable wreck locations. Conversations with local fishermen helped to determine search areas within these probable wreck locations, along with rumors of sightings as late as 1905.

Professor Dean Mayhew of the Department of History, Maine Maritime Academy, whetted the interest of project members by delivering a lecture concerning the history of this Revolutionary War fleet.

The historical research narrowed the search to two areas: for the privateer, DEFENCE, in Stockton Harbor, and the Massachusetts State ship, ACTIVE, on Sears Island Ledge. The search uncovered a wreck of the Revolutionary War period which is thought to be that of DEFENCE.

A recent and informative paper by a previous investigator in the search for the Saltonstall Fleet, "The Penobscot Expeditions," by John E. Cayford (1966) provided a recapitulation of previous search efforts.

2.2 Historical Background

The DEFENCE was part of a fleet sent by the State of Massachusetts to invade the British-held Bagaduce Peninsula and capture Fort George at Castine in what was then the eastern part of Massachusetts. The force was collected in Boston and sailed for Castine on July 19, 1779. The fleet consisted of three vessels of the Continental Navy, three vessels of the Massachusetts State Navy, one New Hampshire vessel and 12 privateers chartered in the service of the State of Massachusetts, of which the brig DEFENCE was one. Twenty-one transports made the fleet a total of 40 ships. Command fell to the senior Continental Navy officer, the captain of the 32-gun frigate WARREN, Dudley Saltonstall.

The force arrived at Castine on July 24th and lay siege. Several sporadic attacks on Fort George were made without success. On August 14th a British force of seven ships arrived and

the American fleet immediately took flight up the Penobscot River.¹

News of the discovery of DEFENCE rekindled an interest in the Penobscot Expeditions in both Maine and Massachusetts. Historians in Beverly, Massachusetts, provided evidence from the Massachusetts Archives that the brig was owned by Andrew Cabot and Moses Brown of Beverly. It was listed as a brigantine of 170 tons, carrying 16 six-pound cannon and 100 men.² It was a new ship, the Penobscot Expedition being her first major voyage. It is interesting to note that another DEFENCE of 140 tons was built at Newburyport, Massachusetts, by the same owners in late 1779.³

2.3 Search Methodology

Once the probable areas were defined, the actual search phase was begun. The two areas (one for DEFENCE and one for ACTIVE) differed in physical characteristics and made necessary different search methods. The flat, rock-free bottom of Stockton Harbor allowed use of a sonar search, while the irregular bottom of Sears Island Ledge made a visual search by divers necessary.

Sears Island Ledge is in a more exposed area and free of the accumulation of silt that is characteristic of the protected coves of the Penobscot Bay region. This affords comparatively better visibility (on the order of 10' to 12'), and a large area can be systematically searched by a group of divers. Herman Kunz, a professional diver with 30 years of experience in the U.S. Navy and an adviser to the diving program, organized and led a one-day search by divers on Sears Island Ledge with no indication of a wreck.

Stockton Harbor has a thick layer of sediment over the base rock on the bottom and was an ideal location to employ a sonar search. A Kelvin-Hughes Type MS 37 F/A MK 1 Echo Sounder System was employed. The general plan was to make a thorough sonar

1. Morgan, William James, Captains to the Northward, Barre Gazette, Barre, Mass., 1959.
2. Massachusetts Archives 170/229.
3. Howe, O. T., Beverly Privateers in the American Revolution, John Wilson & Son, Cambridge, 1922.

sweep of the area and mark all sonar contacts with buoys. When several contacts were marked, divers were sent down for a visual inspection. Two mornings were spent in Stockton Harbor utilizing the sonar in the depth sounder (downward scanning) mode. However, due to the extremely poor visibility on those days, on the order of two feet, no irregular features were observed by the divers.

These conditions made necessary a finer localization of the contact by the sonar before the diver check. For this reason it was decided to employ the sonar in the side-scan mode. A side-scan system for the Kelvin-Hughes was designed as part of the 1971 Summer Lab and a second transducer was utilized in that mode. The recorder console could be connected to either mode as desired. On the third day of search, a side-scan sweep was made, contacts buoyed, and a localization made by crisscrossing the contact area using the sonar in the depth sounder mode. Figure 2.1 shows the sonar trace of these contacts. The contacts are thought to be the same investigated on previous days; however, the localization effort proved fruitful since the divers immediately reported seeing several objects which later proved to be part of the wreck for which we were searching.

2.4 Wreck Survey

Objects identified were two cannon and a rectangular mortared-brick structure, probably the cookstove (see Figure 2.2). Other pieces of wood debris were scattered over and protruding from the bottom. Some pieces of wood were recovered to aid in identifying the wreck--on the first day, a long curved piece with two square holes which appeared to be a rib or buttock and a heavier wood object about three feet long. This latter piece was recovered next to the northernmost of the two cannon and contained several cannonballs of 3-1/4 to 3-1/2-inch diameter (see Figure 2.3). The dimensions of the shot indicated a six-pound cannon.

The first dive of the following day was with the underwater camera, a NIKONOS with a specially-made strobe-light attachment. Visibility was poor and the photographs were of inferior quality due to backscatter from suspended particulate matter. Visibility was noted to be a function of the tide and all subsequent photo-

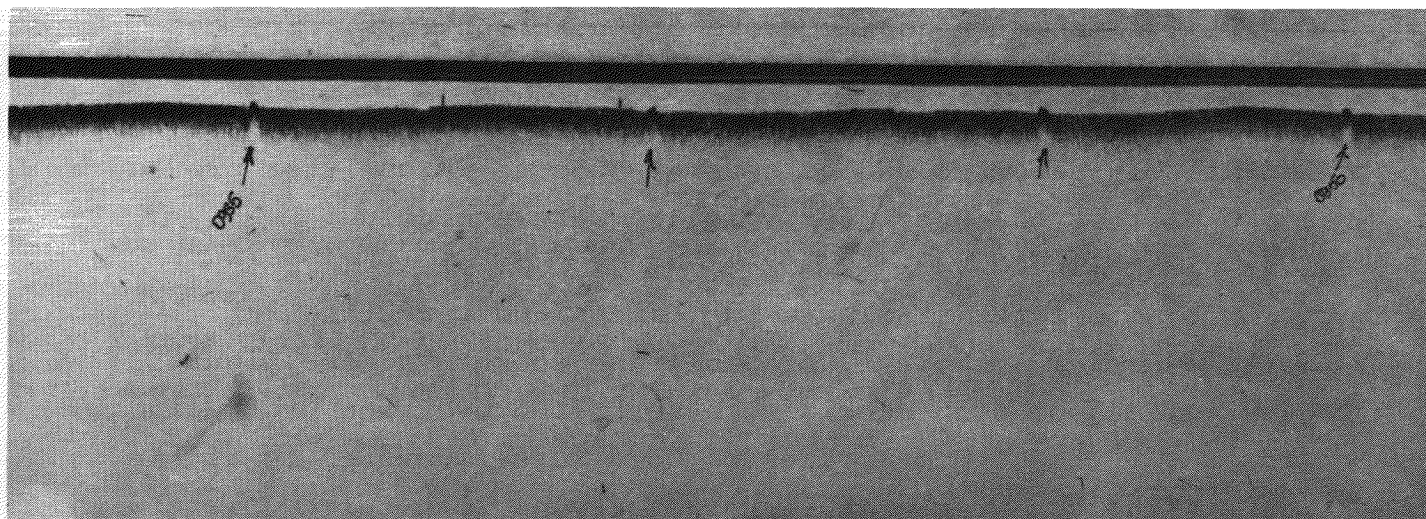
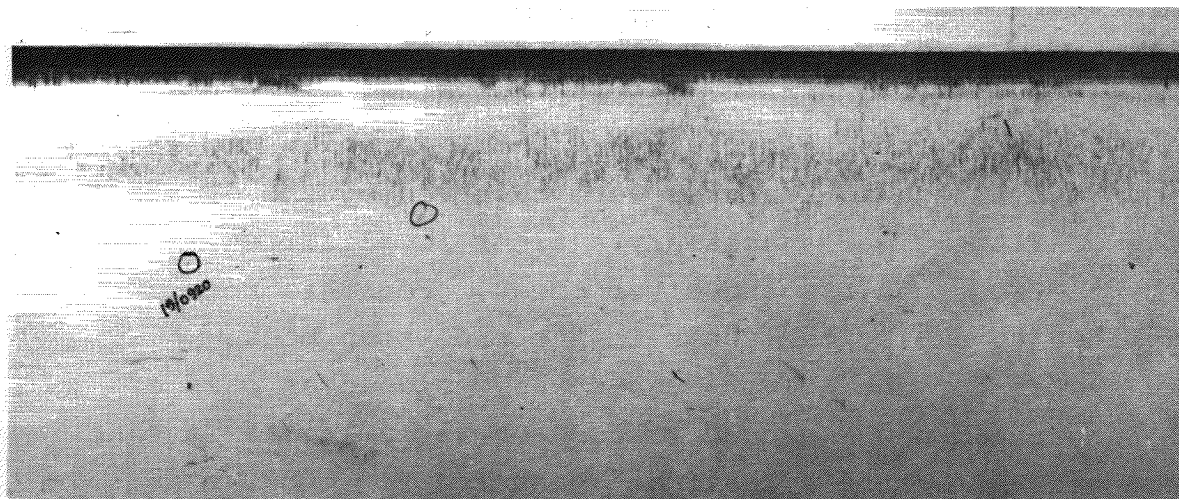
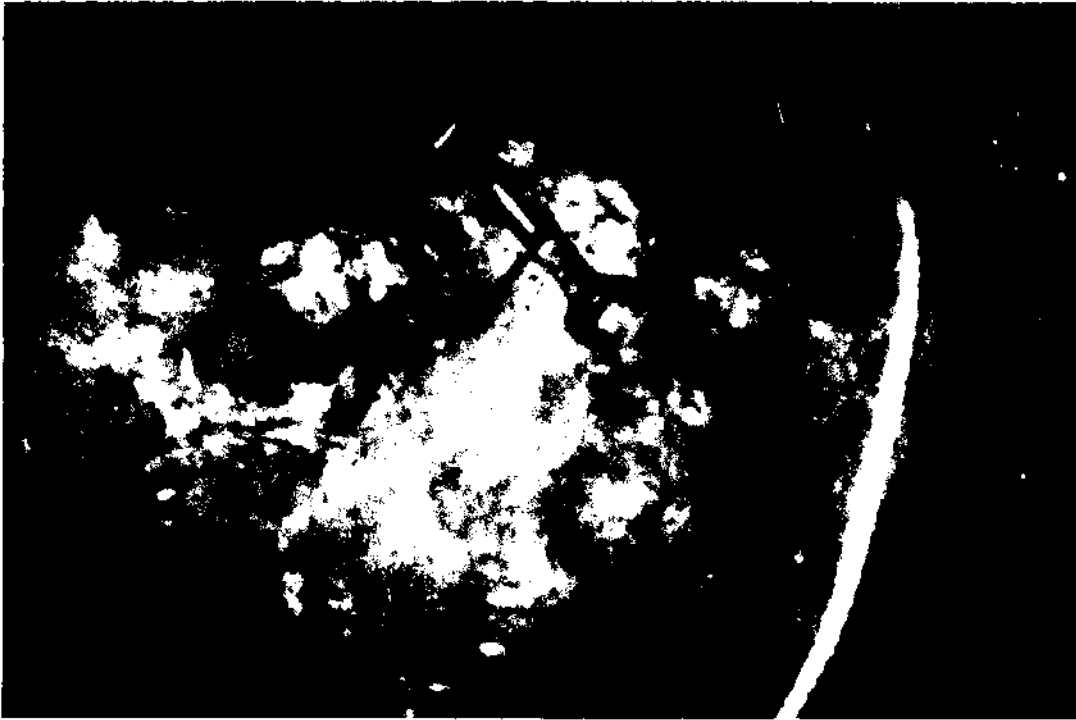
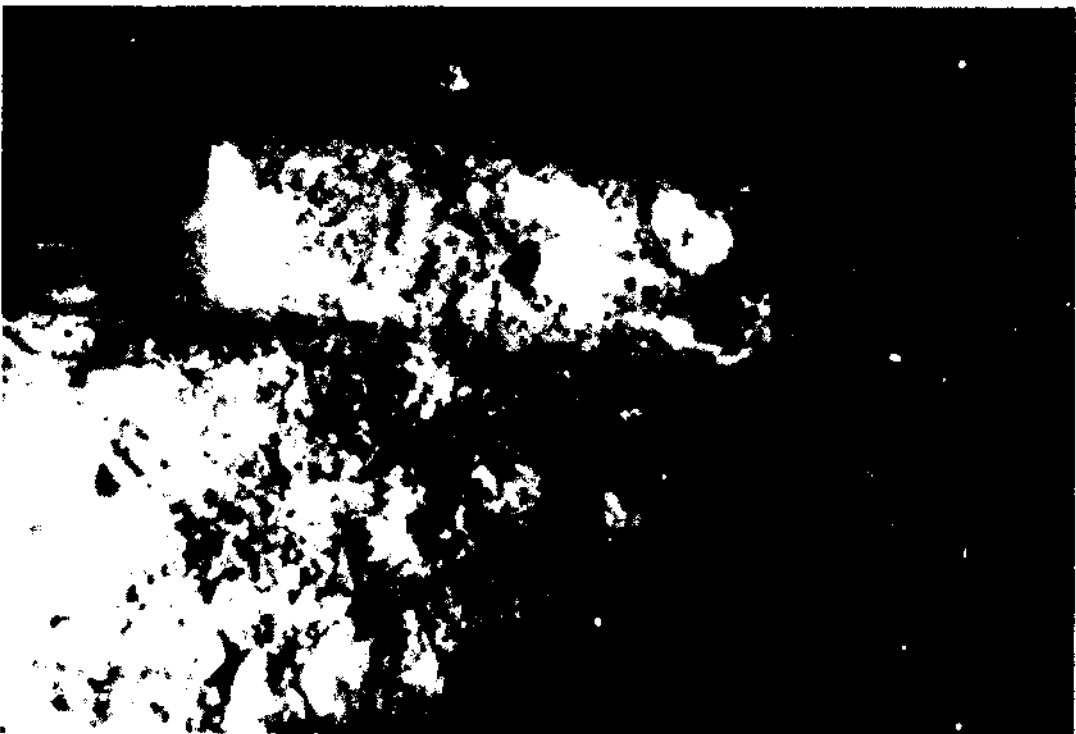


FIGURE 2.1 SONAR TRACE INDICATING INITIAL DISCOVERY OF THE WRECK, "DEFENCE"

The upper trace is in the side-scan mode, with the circles indicating echoes. Lower trace is depth-sounder mode with arrows indicating the four foot bottom relief of the wreck. Time marks indicate the relatively short time of the localization process.



South Cannon



Cook Stove Bricks

FIGURE 2.2



FIGURE 2.3

Professor Mayhew, Chertow, CAPT Searle, and Murphy with charred wood and cannon balls recovered from the wreckage site.

graphic efforts were conducted on a rising tide. All divers who did not have a chance to sight the wreck on the day of discovery were given the opportunity to survey with tape measures and compasses. More positive orientation of the several objects sighted was determined after many dives. The diving log, Appendix A, may be referred to for a detailed description of the diving work.

The only positive means of determining the heading of the wreck was by the cookstove, the only fixture attached to the hull. It was surmised that the opening, if any, would be facing aft. Careful survey was made and the wreck was determined to lie on a northerly heading. Curved planking and a standing rib were found under about one foot of sediment in an area at the suspected bow (see Figure 2.4). Probes through the silt found a hard substrate, presumably the bottom planking at a depth of about one foot beneath the water/sediment interface. If the DEFENCE was scuttled by burning as reported, it would have burned to the waterline, and the bottom planking would be relatively intact. A 50-foot-long straight log, broken at one point but without any fixtures or hardware, was found about 50 feet south of the wreck debris and is suspected to be one of the masts (see Figure 2.5).

The wreck was found in a location that suggests the captain was seeking to obscure his vessel using the surrounding land mass and hoping that the prevailing southerly breeze would allow him to escape under cover of darkness.

2.5 Salvage

Permission was granted by the State of Maine to raise two of the cannon to aid in positively identifying the wreck. It was decided, however, to recover only one. Of the two cannon discovered, the south cannon was in finer condition with what appeared to be remnants of the carriage still attached. The north cannon was heavily encrusted with marine fouling (see Figure 2.6). Since our salvage attempts were as yet untried, it was decided to salvage the less delicate, north cannon.

A sling of 3/4" manila line was rigged at two points around the cannon, and joined at about five feet above it so that it

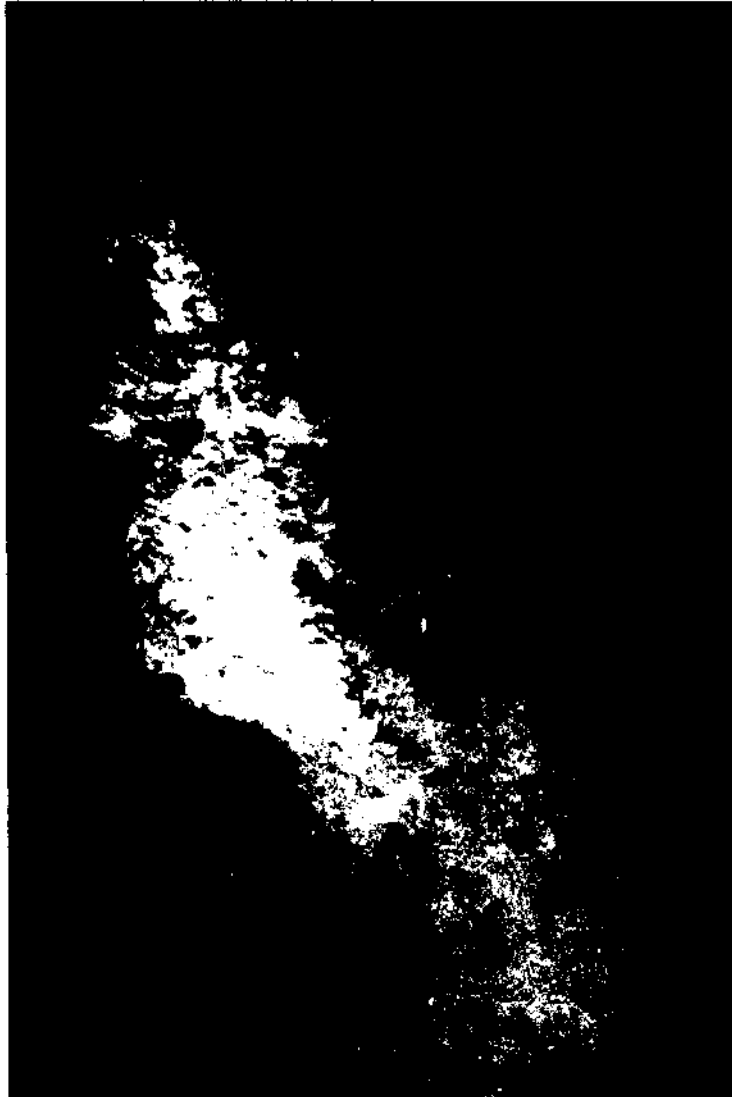


FIGURE 2.4
Standing Rib

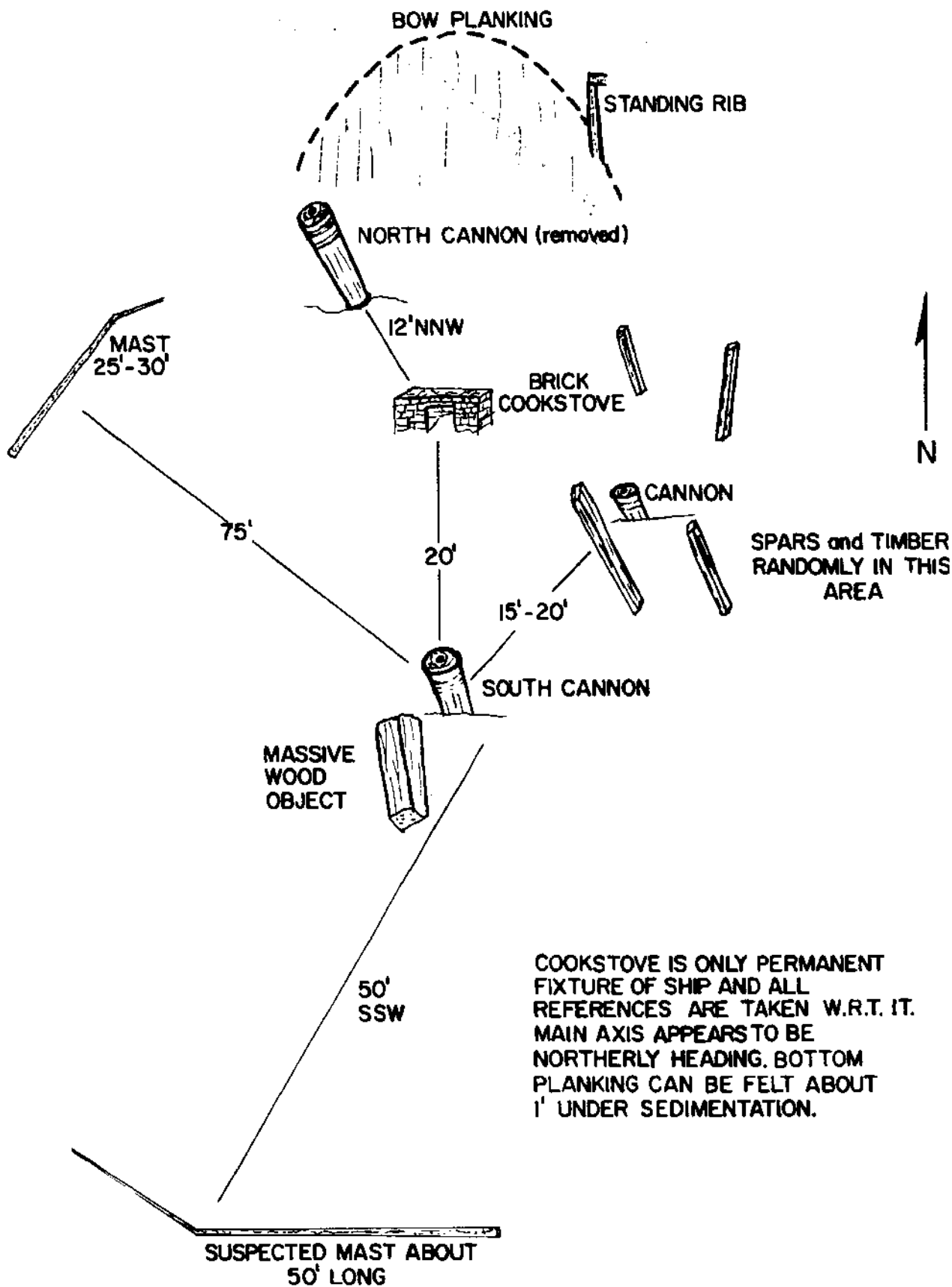


FIGURE 2.5 Composite artist's sketch of wreck site



FIGURE 2.6
Cannon before heavy encrustment removed

would be raised in a horizontal position with equal strain on each part (see Figure 2.7). The weight of a cannon firing six-pound shot was about 840 pounds, so the load calculations were made for 1,000 pounds.

A 6"x6" wood beam was rigged with a three-foot overhang over the stern of CHALLENGER, the MMA 54-foot launch. A double purchase block and tackle was rigged from the end of the beam to the cannon bridle and a strain was taken on the tackle by a crew aboard CHALLENGER. Communication between divers on the bottom and the surface was maintained by a taut line, with pull signals for "heave round," "hold" and "slack." The cannon broke clear of the bottom easily and was hauled up until the tackle was two-blocked. The load was transferred from the tackle to the two standing bitts on the stern of CHALLENGER by means of another 6"x6" beam lashed to the cannon and the bitts. The cannon was raised as far up the transom as it would allow using "Norwegian steam" and an even strain was taken on the bitts and tackle, suspending the cannon evenly at three points (see Figure 2.8).

In this position the cannon was transported over the five miles of open water back to Castine. A strong southerly breeze had by then raised quite a chop on the bay, but due to good seamanship on the part of CHALLENGER's crew the cannon rode easily on the trip home. As a precaution, a 200-foot light line was attached to the cannon with a buoy on the bitter end.

Other items recovered were several wood pieces which appeared to be part of the ship's hull, and a grinding stone with a square axial hole similar to the rotary type used for sharpening axes.

2.6 Preservation

Preservation of objects recovered from the sea must be undertaken immediately upon exposing the object to air. Dr. Mendel Peterson of the Smithsonian Institution was kind enough to forward processes for preservation of wood and metal recovered from sea water and are included in Appendix B.

The state of the iron objects recovered was very interesting. The shot was imbedded in the silt which probably acted somewhat as a preservative. The original dimensions were retained; however, the weight was on the order of one pound, one-sixth of its



FIGURE 2.7
Cannon being raised on timber over stern of CHALLENGER



FIGURE 2.8
Cannon being hoisted from its position on stern of
CHALLENGER. Note hoisting beam and beam used to
secure it on stern.

original weight. The material appeared to be a soft, carboniferous compressed powder. The cannon was covered by a heavy encrustation which from its bright red appearance seemed to have a high iron oxide content. The encrustation broke away from the cannon cleanly; however, care was necessary to avoid damaging the soft mass beneath (see Figure 2.9). A concrete burial vault provided the ideal container for the "pickling" phase of the preservation process.

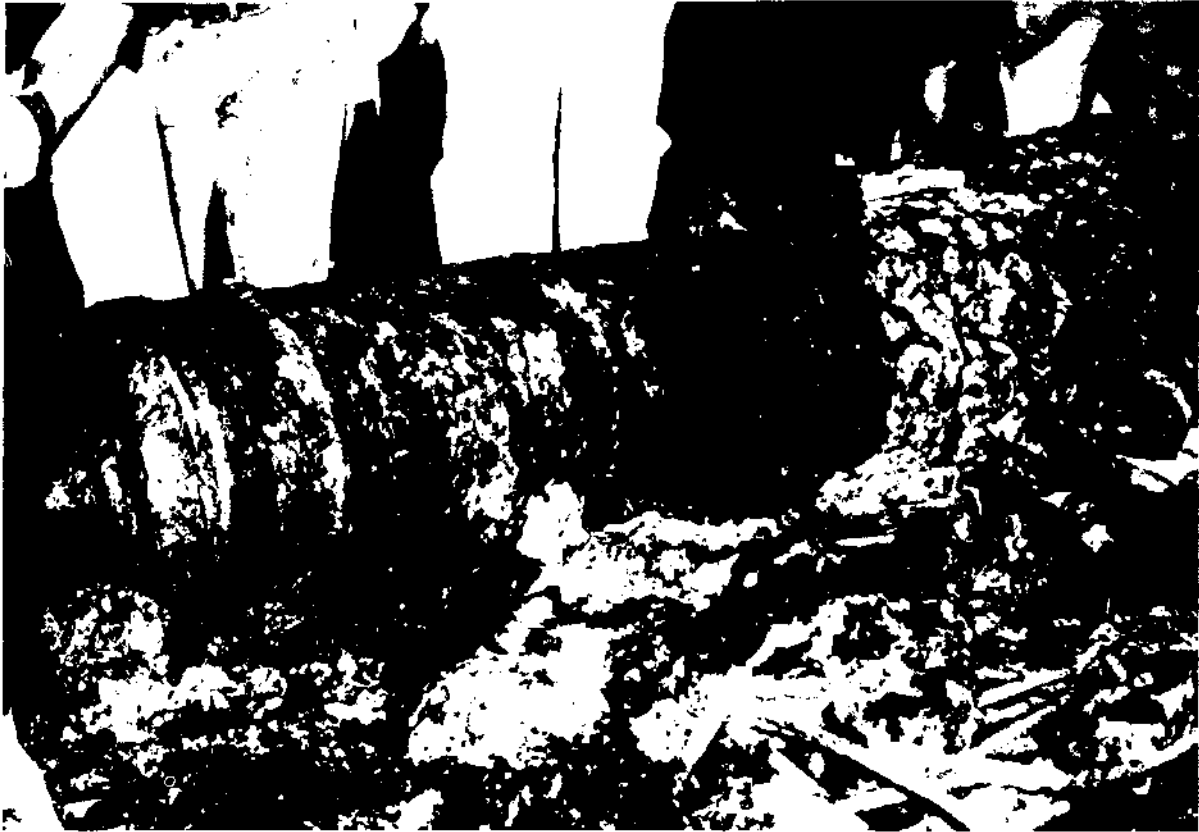


FIGURE 2.9
Cannon after heavy encrustment broken away

3.0 DIVING PROGRAM

3.1 Introduction

The diving program conducted in the Summer Ocean Engineering Laboratory had a twofold purpose:

1. To widen the experience of qualified divers in working underwater;
2. To certify new divers to enable them to take part in the program next year.

All dives in support of the Summer Laboratory were of an organizational nature and were conducted in strict accordance with the Standard Operating Procedures, included in Appendix C. Data concerning all dives were recorded in the Diving Log, extracts of which appear as Appendix A.

Legal aspects in conducting a formal diving operation made it necessary to determine certification and previous experience of all divers involved in the project, and to adhere strictly to the established procedures.

3.2 Diving Operations

The group project for divers was the Ocean Search and Salvage Project directed by Captain Searle. Before the search for an unknown wreck was begun, it was desirable to initiate the students in a near-ideal situation. A training site where a wreck could be found without difficulty, in medium depth water of good visibility, would present students with problems commensurate with the experience level of most members of the dive group. The wreck of the schooner ALICE B. CLARK on Isleboro Ledge was selected as a training site. This wreck was well known to divers in the area; it lies in 30-50 feet of relatively clear (10'-12' visibility) water on a hard bottom. The wreck is sufficiently broken up to present some difficulty in orientation. All divers were given the opportunity to survey with compass and retrieve any objects of interest. One of the few identifiable objects was the steering wheel. An attempt was made to salvage the wheel by sawing through the shaft.

One of the first problems encountered was that of contending with the weather. At an exposed position such as Isleboro Ledge the best time of day for conducting operations was at sunrise

when the wind and sea are generally calm. Since this work was also conducted by the same group searching in Stockton Harbor, the usual procedure was to get underway at 0500 and proceed to Isleboro Ledge. The training dive was usually secured by 0900 when the operation was shifted to the Sears Island Ledge and Stockton Harbor areas which were more protected from the wind and sea.

After discovery of the wreck in Stockton Harbor, diving operations were shifted to that site. There the limited visibility conditions made necessary the use of more advanced survey techniques.

Diving operations were also conducted in support of the work in Holbrook Cove. Inspection of current meters after placement enabled the experimenters to develop more effective mooring techniques. Light intensity data was recorded by divers. The outfall from the mine was traced and samples recovered by divers. Search techniques were utilized to look for objects lost overboard. The search effort was commensurate with the value of the object, which was generally a random search by one dive team and was usually not productive.

3.3 Diver Certification Program

There is no nationally recognized diver certification program available in the Castine area; therefore a course in SCUBA, administered by the National Association of Underwater Instructors, was offered to those students in the Summer Ocean Engineering Laboratory who desired to become qualified divers. The course included 30 hours of classroom and pool instruction and two open-water dives.

The following students from Maine Maritime Academy were certified as NAUI SCUBA Divers:

George R. Benson	Malcolm Cianchette
Garry D. Bartlett	Vincent Devlin
David P. Bradford	Dan Labrecque
William Blackwood	George R. Miller
Douglas B. Cameron	William Parker
Bruce Campbell	John Sautter

The boat used in the Ocean Search and Salvage Project was a Jonesport-type lobster boat of 36' length loaned by Professor Damon Cummings, last year's supervisor of the OESL (see Figure 3.1). The boat was modified to function as an oceanographic research vessel and diving boat by several student projects in the spring.

An aluminum diving ladder constructed such that it could fold flat on deck when not in use was mounted on the stern and performed beautifully in diving operations. The deckhouse was also enclosed on three sides and work tables installed so that sensitive gear could be used in foul weather. The low freeboard and large open areas provided ease when working over the side, and several operations such as sampling, acoustic measurement, etc., could be conducted at once with little interference. The superiority of using this type of boat in the project was acknowledged by all concerned.



FIGURE 3.1
RV LOBSTER

4.0 PROJECT ODYSSEUS

4.1 Introduction

During the 1971 Summer Lab it was determined that it would be useful to know the research vessel's position instantaneously and accurately. Therefore, in the first semester of the 1971-72 academic year a study of various methods of accomplishing this goal was undertaken. The first proposal was for a system similar to LORAN using hyperbolic coordinates. Other ideas included the use of sound, lasers, FM beat frequencies, and pulse-timing techniques.

The method which was selected, because of its relative technical simplicity and accuracy, was similar to a commercial radio location system, the Raydist DR-S.

4.2 Objective

The summer goal of Project Odysseus, a part of the total goal of designing and building an accurate, short-range radio location system, was to build a distance-measuring device with an accuracy of four feet. This goal was nearly, but not quite, realized this summer mainly because of problems in building suitable radio receivers.

4.3 System Description

A 3345 KHz signal, originating at the boat station oscillator, is transmitted to the shore station where it is mixed with the frequency-doubled oscillator signal (3344 KHz = 1672 KHz doubled) to produce a 1 KHz beat note. This beat note modulates the shore station's 1672 KHz transmitter. Back at the boat, the 1 KHz beat note is received and detected. The received signal's carrier is also doubled, and is mixed with the boat oscillator's output, producing a second beat note of 1KHz but differing phase. The phase relation of the two beat notes is a function of the distance between the stations (see Appendix D). The beat notes are phase-compared to measure the distance. In case the phase difference exceeds 360° , the phasemeter has an integral wavelength counter.

A complete system requires two shore stations to determine position. The effort this summer was to produce a boat station working with a single shore station. When a system with two

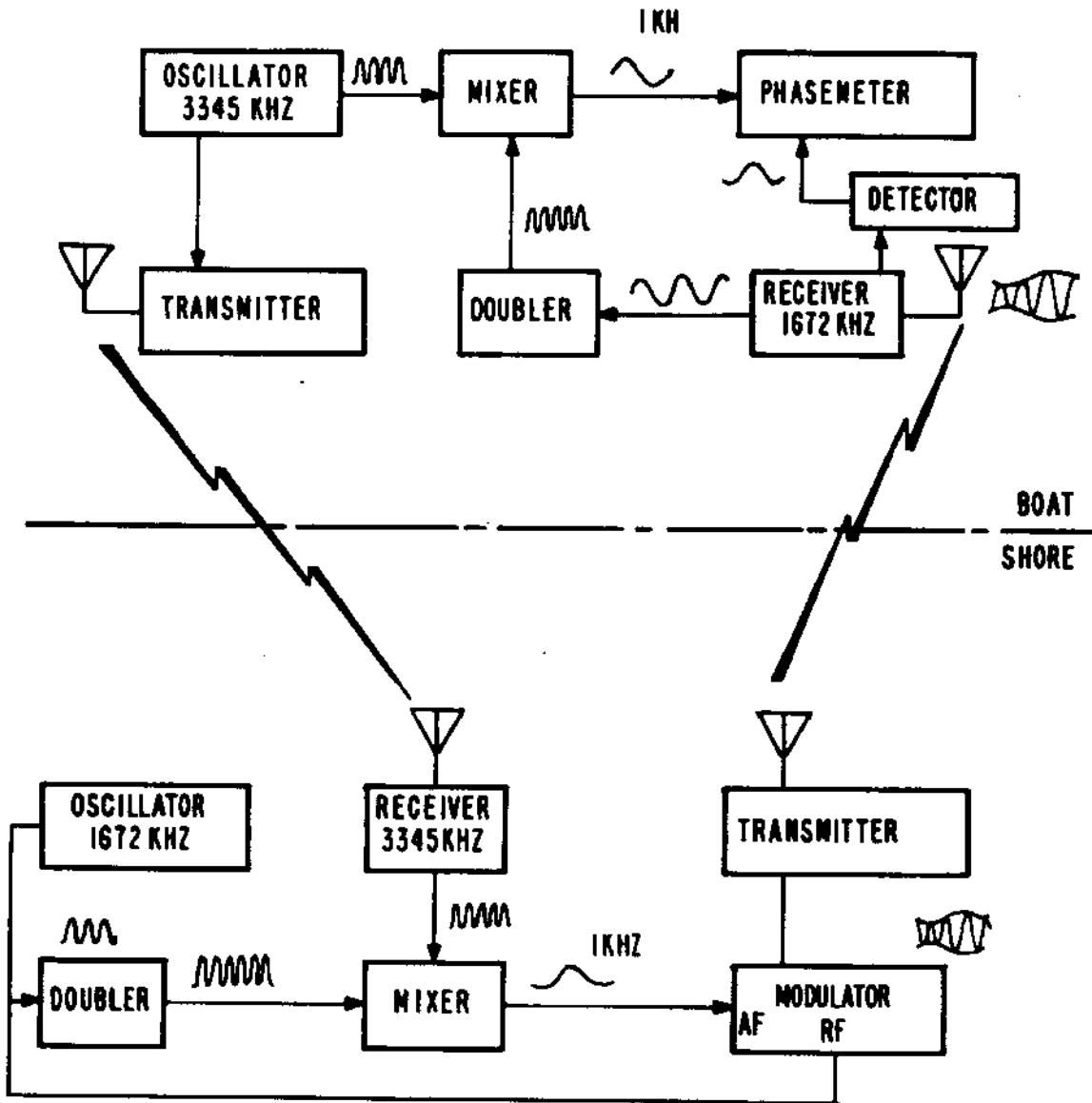


FIGURE 4.1
System Block Diagram

shore stations is used, they will be sampled alternately by the boat station.

4.4 Construction

The present method for radio location was decided upon in November 1971. Design and construction began almost immediately. A prototype of the phasemeter was begun in early December and the first oscillators were built around this time. As the second semester began, the phasemeter was redesigned to accommodate the change from two continuous systems to a multiplexing system. During the rest of the semester, February through May, the design of all parts of the system, except for the receivers, was completed. At the beginning of June, the idea of putting each of the functional blocks into one or more modules was incorporated into the design. This modular concept provided easy testing for each of the individual blocks. In June, the majority of the modules were built and tested; in July at the Summer Lab site the work was mostly on receivers, although some modifications were carried out on the transmitters and some system testing was accomplished.

4.5 Results

Before the end of July, each of the modules had been tested with success. During the last week of the Summer Lab some system testing was done inside the lab, with one station at each end of the room. Once everything was connected and tuned properly, the only remaining problem was that the 3345 KHz transmitter signal interfered with the 1672 KHz receiver and, due to nonlinearities, produced an output from the detector even when the shore station output was not modulated. Also, 60-cycle hum was very evident in the output. Subsequently, another system test was conducted outdoors with both stations powered by batteries. The 60-cycle hum problem disappeared, but for some reason the 1672 KHz receiver would not detect the modulation transmitted from the shore station. The entire shore station functioned well as a unit, and the boat station worked well except for the receiver.

4.6 Conclusions

The critical aspect of this project is the receivers. The

demands on their selectivity, sensitivity and the accompanying tendency for them to oscillate have been frustrating. With more help, time, and better references, the receivers can be made to work well without the critical tuning and adjustments which they now require.

With the receivers working consistently, the system should be successful. Only the question of ultimate accuracy still remains. The answer to this question can only be guessed. Considering the very crude case in which only integral wavelengths can be measured, the accuracy would be 165 feet. This case is too pessimistic. One-half of a wavelength and probably something less than one-tenth of a wavelength should be discernible if the beat notes are not grossly distorted. To attain an accuracy of four feet, $1/40$ of a wavelength, a change of 0.125 volts on a 5-volt sine wave must be discernible, which is easily accomplished. There are other factors such as drift, phase changes within the system, reflections and loading variations on antennas which would influence the measurement's repeatability. One cannot guess how drastic these variations will be, but a similar system, the Raydist DR-S, has an accuracy of 10 feet, so these factors may have only a small influence or can be circumvented.

The system needs to be tested more thoroughly to determine its linearity and isolate sections where problems may develop due to the rugged environment within which it must operate.

4.7. Detailed Description

4.7.1 Oscillator

The oscillator circuit is similar for both the shore and the boat stations; only the crystal, values in the tuned circuit, and the starting capacitor are different. The design is based on one shown in an article in QST, September 1968, but we used a different transistor and changed the base biasing. The circuit gave very little trouble, with one exception: Signal output varies considerably with changes in supply voltage. A change from a nominal 12 volts to 10 volts stops oscillation. Output with a 12-volt supply varies from 1 volt to 2.5 volts peak to peak depending upon the adjustment of the tuning coil. Frequency varies over approximately 1 KHz over the range of adjustment of

the coil. The power supply filtering for this module is standard for all others. Current drain is 4 milliamps.

4.7.2 Transmitters

This circuit, like the oscillator circuit, was taken from the September 1968 issue of QST magazine. Except for different tuning capacitor and inductor values, the same configuration is used for both boat and shore stations. Both transmitters are reasonably reliable, but somewhat difficult to tune. With no signal input, there is a tendency to oscillate. With an input of 1.5 volts peak to peak from the oscillator, the characteristic oscillation disappears and with a 12-volt supply a very clean 25-volt peak-to-peak output into a 45-ohm load is obtained. The 1672 KHz transmitter is normally operated with center supply voltage around 8 volts (see Section 4.7.3). The transmitters each draw about 250 milliamps at 12 volts.

4.7.3 Modulator

Our first modulator was designed to modulate the oscillator signal and feed it into the transmitter. This proved impractical because of the nonlinearity of class C amplification used in the transmitter. Therefore, the circuit shown here, which modulates the transmitter supply voltage, was designed. A maximum of 1-1/2 volts peak to peak of input modulates the transmitter supply voltage by 3 volts, about 30% modulation. The circuit is very consistent and stable in operation.

4.7.4 Doublers

This doubler circuit uses a Signetics 5596, a linear four-quadrant multiplier. The signal is introduced to both of the differential inputs and, doubled in frequency, is taken from one side of the differential output. Input and output emitter followers are used to provide easier interface with other modules, as well as ease in testing the doubler module. Three doublers were built, two of which work consistently; one never worked well, and we have never found the problem with it. For an input of 50 millivolts peak to peak the output is 150 millivolts peak to peak. The output is reasonably clean, with a small amount of undoubled signal in the output not removed by the balancing potentiometer. Current drain is about 8 milliamps at 12 volts

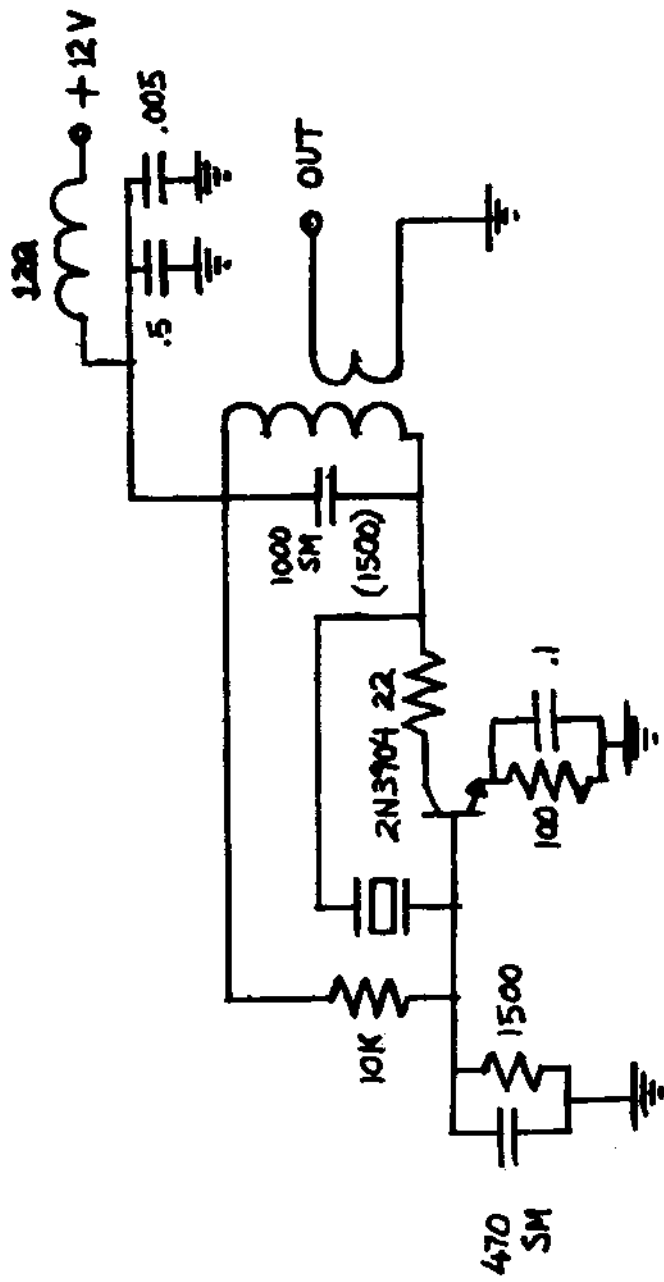
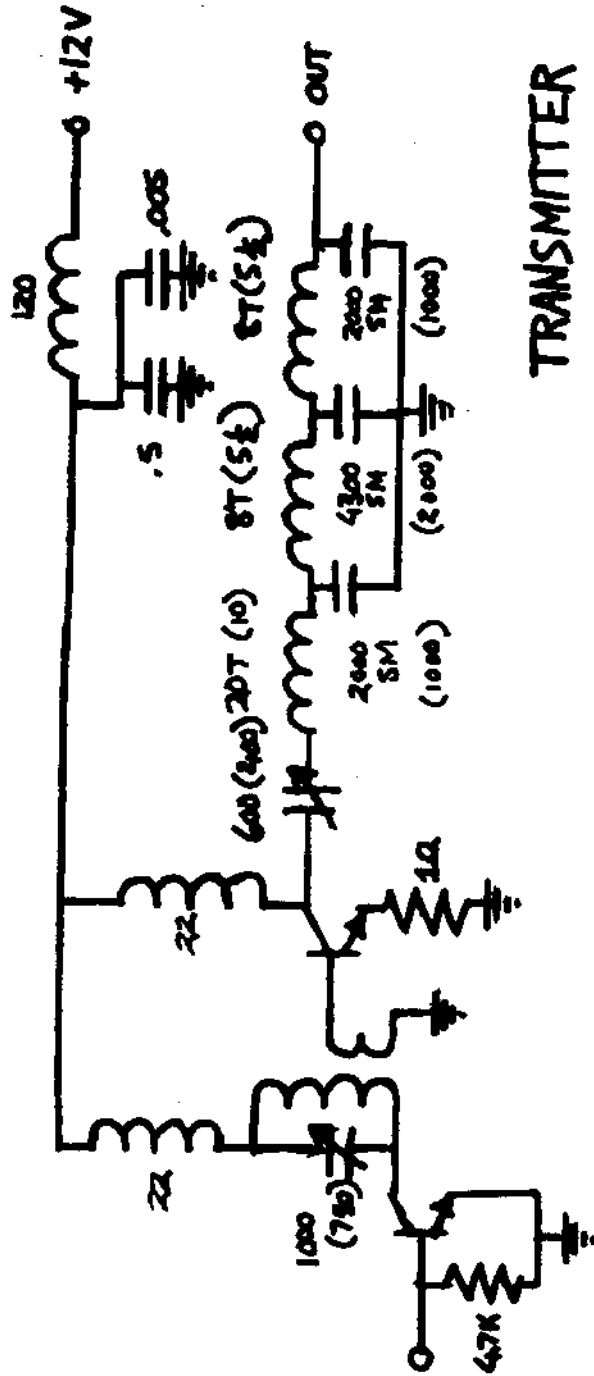


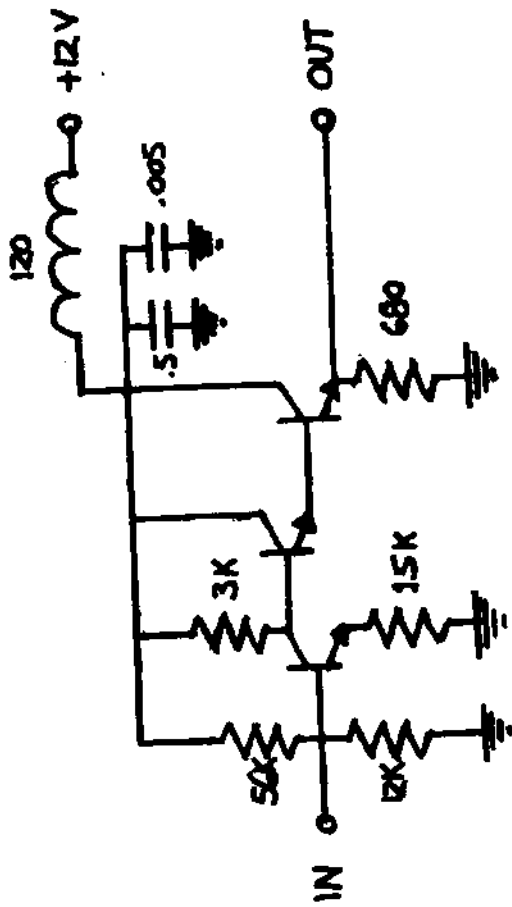
FIGURE 4.2

OSCILLATOR



TRANSMITTER

FIGURE 4.3



MODULATOR

FIGURE 4.4

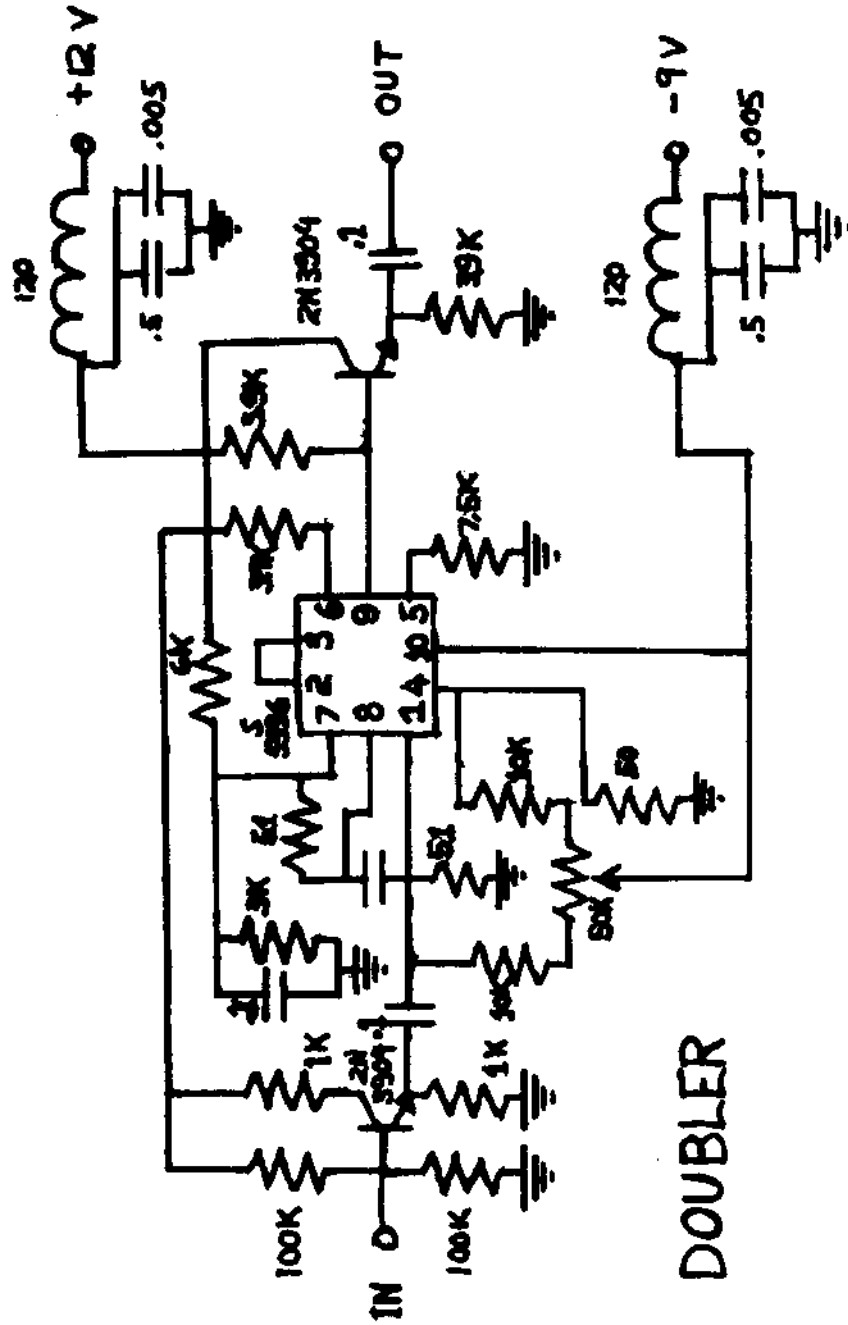


FIGURE 4.5

from the positive supply, and 4 milliamps at 9 volts from the negative supply.

4.7.5 Mixers

The mixer is similar to the doubler, also using a Signetics 5596 integrated circuit. Each of the signals to be mixed is fed into one of the inputs to the 5596 through an emitter follower. The resulting output is led through an RC low pass filter, producing a sinusoidal output at the difference frequency. The three mixers built work well and consistently. The maximum output of 2.5 volts peak to peak is obtained with 150 millivolts peak to peak from the doubler and 1000 millivolts peak to peak from the receiver (shore) or oscillator (boat). Current drain is 8 milliamps at 12 volts from the positive supply and 4 milliamps at 9 volts from the negative supply.

4.7.6 Phasemeter

The phasemeter generates a binary number relating the phase difference of two sinusoidal signals, X (the reference) and Y. The phasemeter also has provisions for setting initial values and multiplexing for dual channel (two distance) operations.

The following refers to Figure 4.7. The X and Y sine waves are squared by the μ A710 comparators with the transistion point being the zero crossing of each. The remainder of the circuits shown are concerned with timing generation. A duration pulse which starts at the negative transistion of X and ends at the negative transistion of Y has a length proportional to the phase difference between X and Y. The signals, pause and reset, are used for clocking, initialization, and to prevent race conditions in later logic. The squared X is sent to the X1000 frequency multiplier (Figure 4.8) whose signal output is used to time the duration pulse's length.

The time multiplex generator's (Figure 4.9) switches between channels 1 and 2. With the switch in the "auto" position, the oscillator (which has not yet been implemented) would alternate between channels, otherwise the function of the oscillator is assumed by the momentary toggle switch. The purpose of the monostable multivibrator is to allow the present measuring cycle to run to completion before the channels are switched, thus

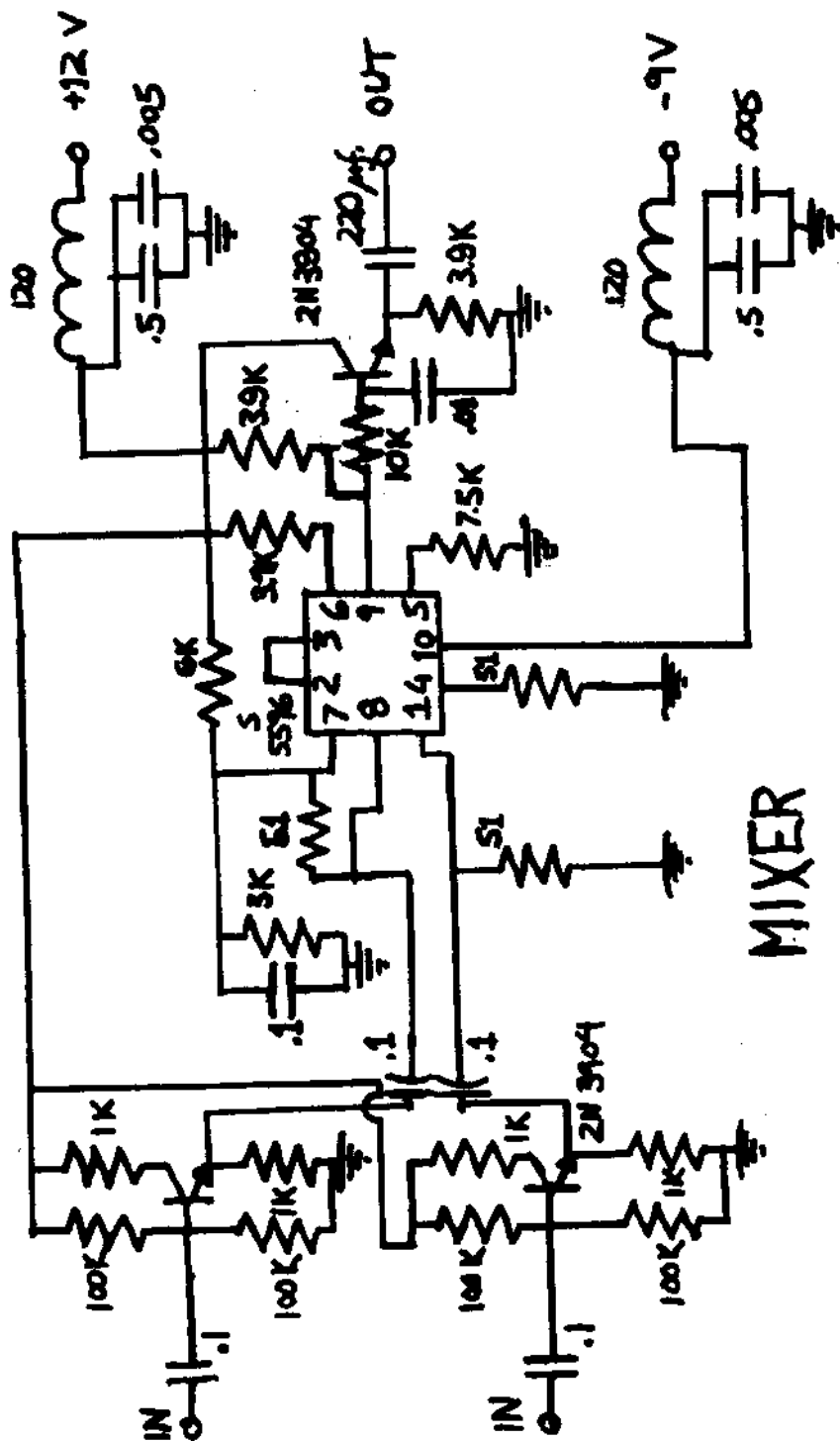
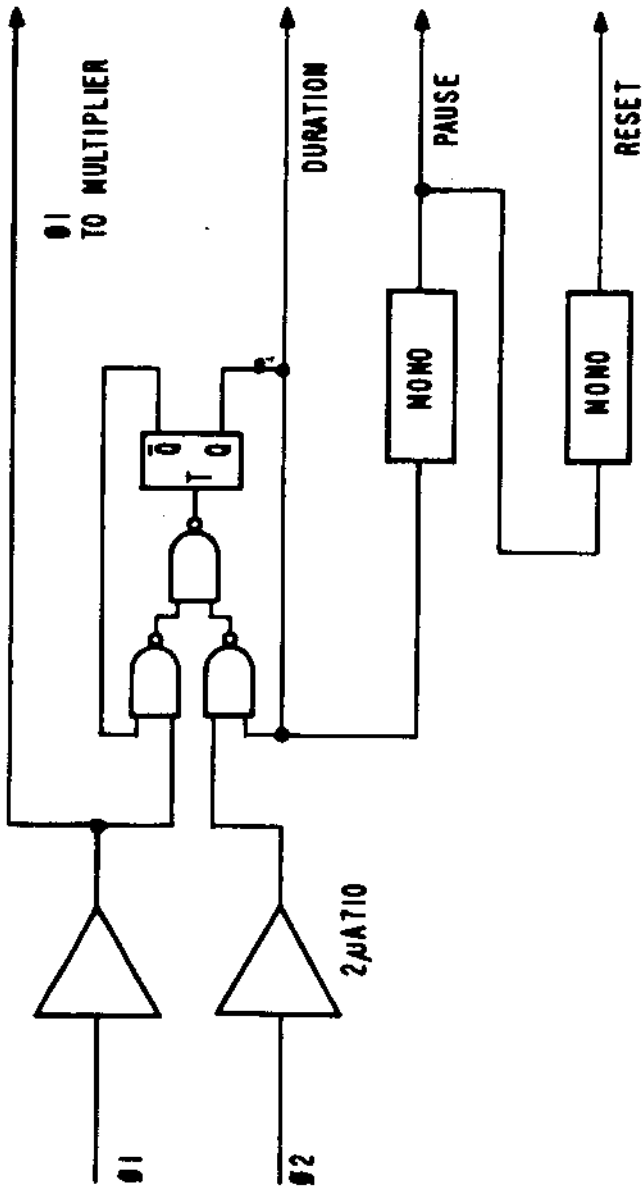
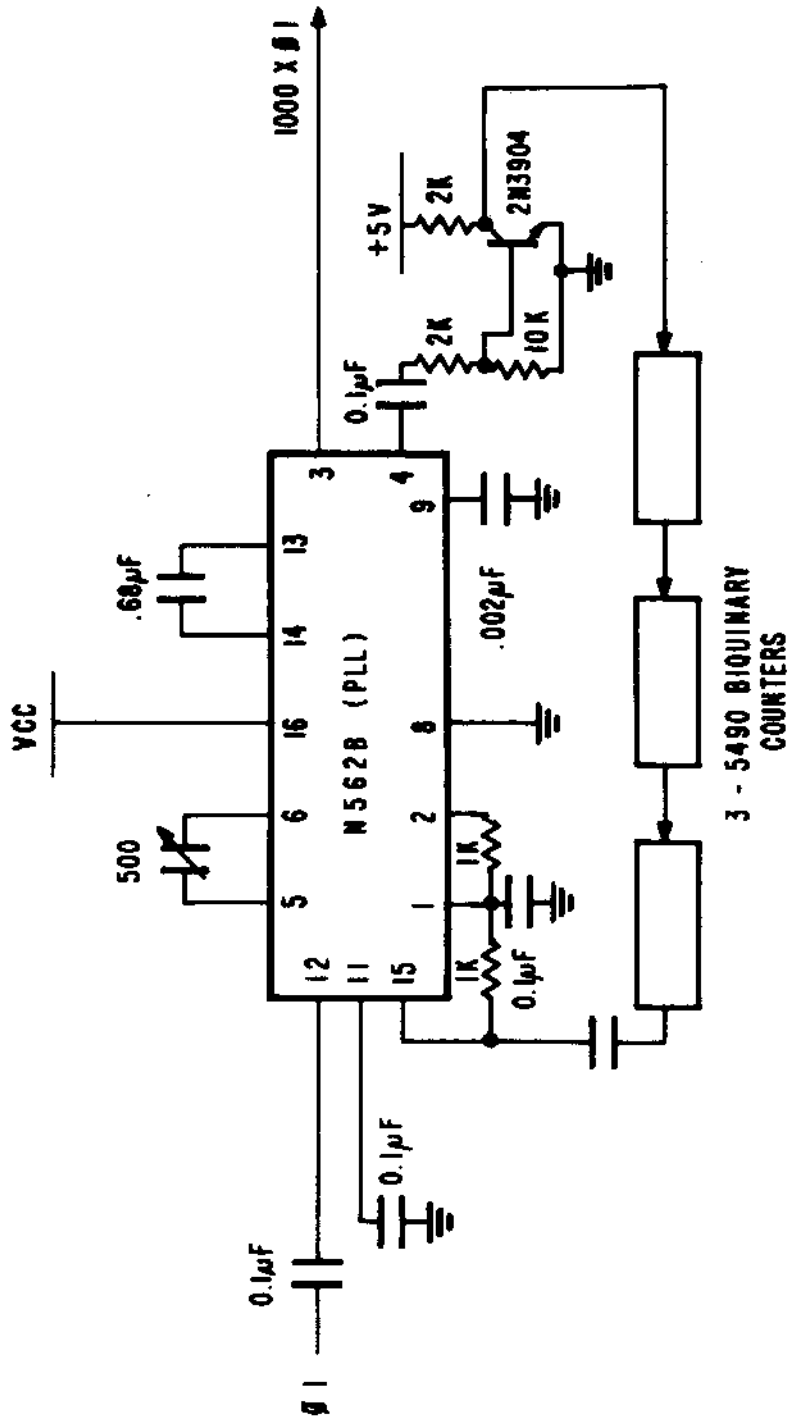


FIGURE 4.6



SQUARING AND TIMING

FIGURE 4.7



FREQUENCY MULTIPLIER

FIGURE 4.8

avoiding an interruption at an inopportune time, causing a false increment in an up-down counter. The output signals (channel 1, channel 2, channel 1 pause, channel 2 pause) are used in selecting and strobing the channel-dependent sections of logic.

The measurement section of the logic is shown in Figure 4.10. The reset pulse clears the counter which then counts the $\times 1000$ X frequency (from the multiplier) for the width of the duration pulse, therefore obtaining the fractional wavelength. The two nand gates and the inverters decide if the fraction is less than .1 or greater than or equal to .98 of a wavelength. The results of this evaluation for the last fractional wavelength have been stored in one of the dual-D flipflops. Comparisons of the new values and the old values inform the up-down counters (Figure 4.11) that they should count up (new less than .1, old greater than or equal to .98) makes (up=1), count down (old less than .1, new greater than or equal to .98 makes (up=0), or not at all (enable count=0).

Pressing the reset button clears the current channel's up-down counter. The increment switch sets the "increment" flip-flop which increments the current channel's counter by one. In this way, any value may be placed in the up-down counter.

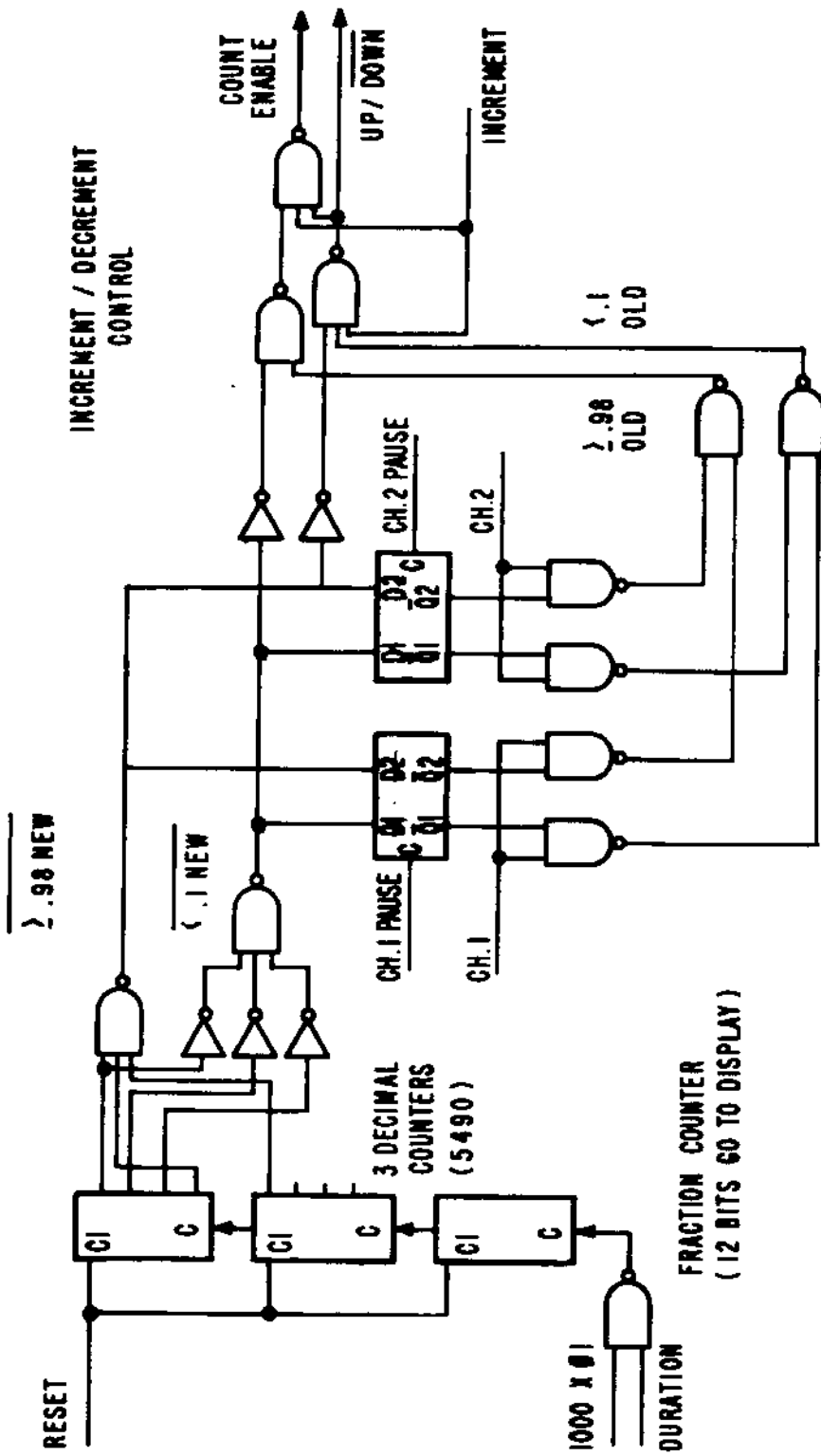
The outputs of fractional counter (Figure 4.10) and the up-down counters (Figure 4.11) go to 7 segment decoder-drivers 8T04 which drive the RCA numitronTM digital display tubes for direct readout.

This circuit is the second model of the phasemeter, the first did not include multiplexing. The tests on the first phasemeter revealed a race condition in the wavelength counter which would incorrectly increment the counter every few seconds. This problem was eliminated in the second design.

The second model is complete except for the circuitry of Figure 4.1. Some memory is needed for flicker-free operation of the digital display. The meter was not completed because other parts of this project (receivers), lab equipment and space and other projects were more pressing in Castine.

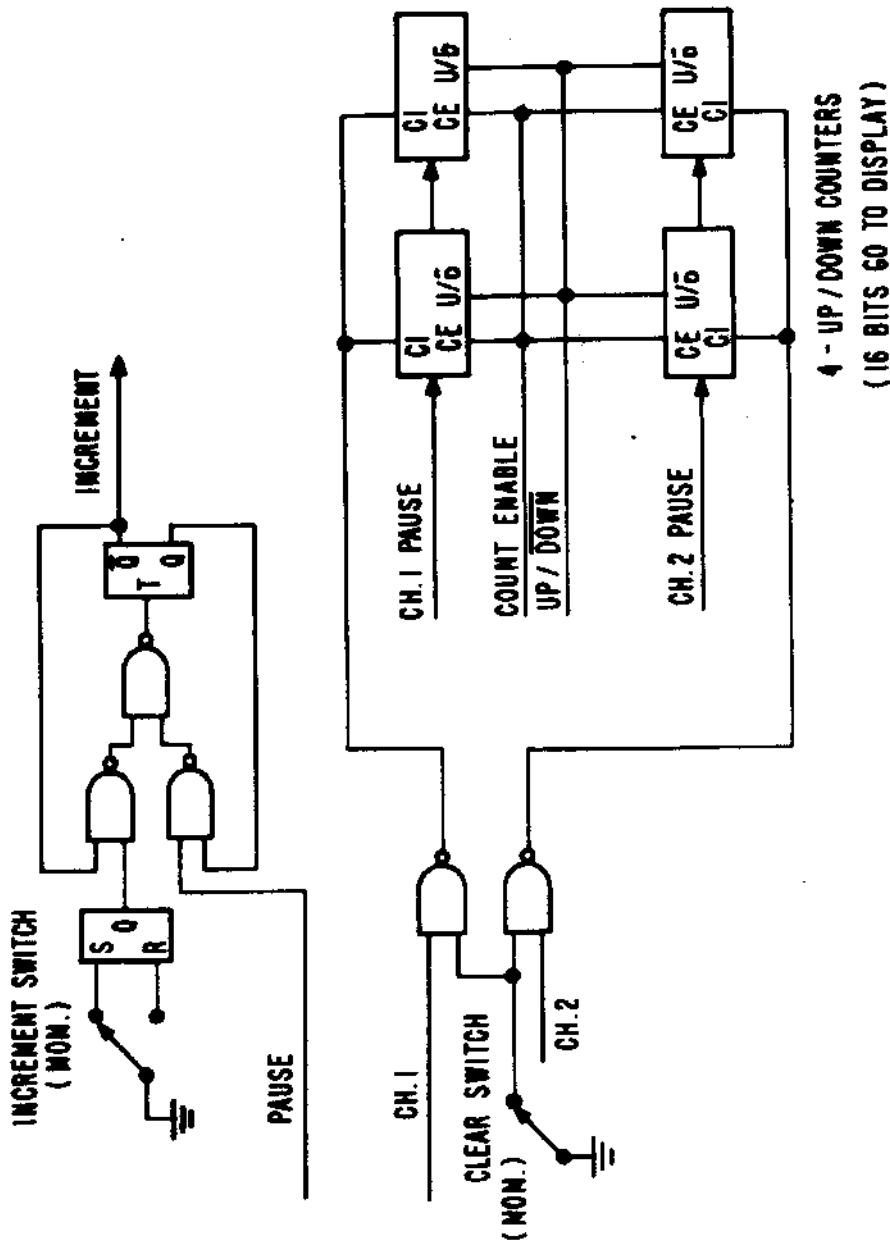
4.7.7 1672 KHz Receiver

This receiver is substantially the first one that was built for this frequency, though it has undergone several important



MAIN CONTROL

FIGURE 4.10



UP-DOWN COUNTERS

FIGURE 4.11

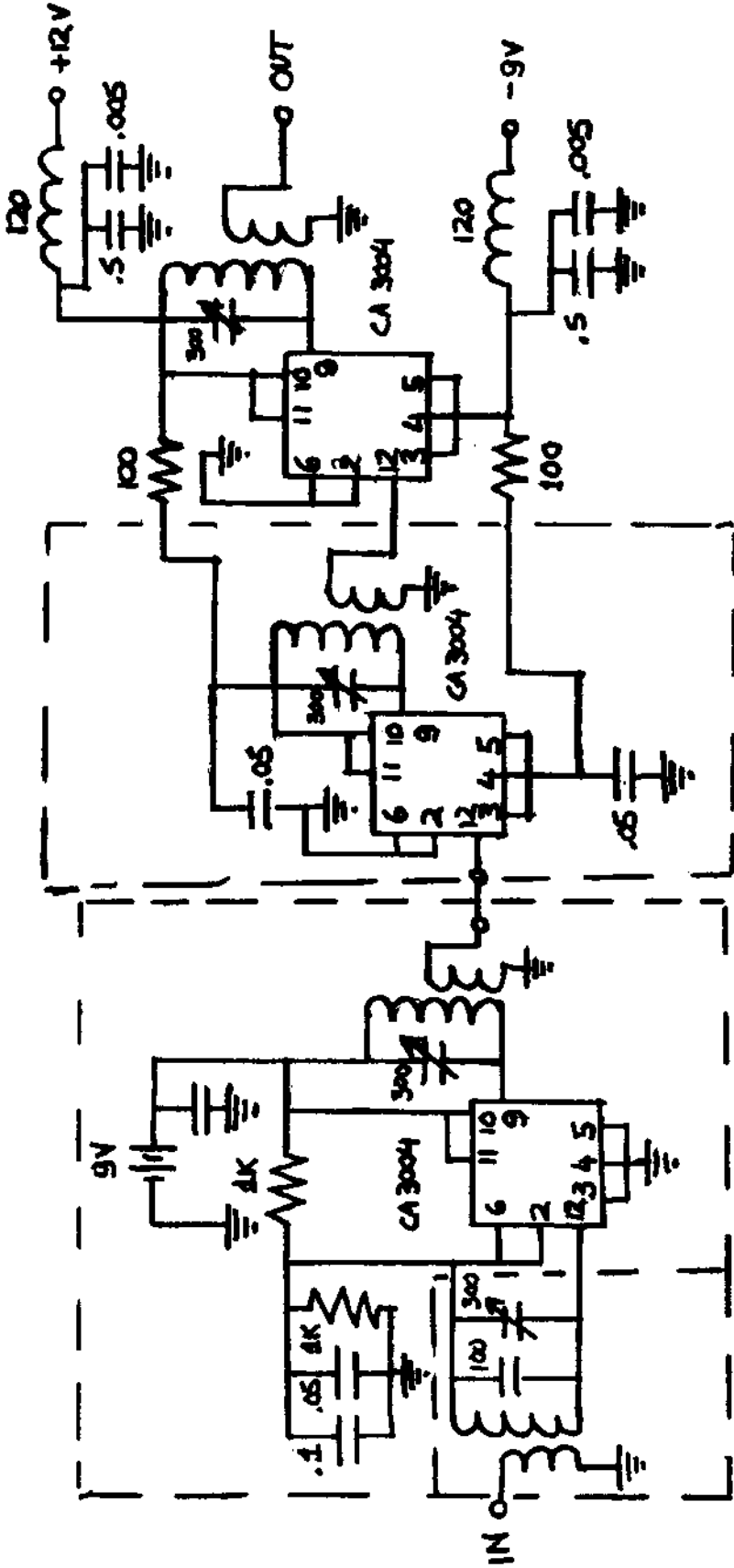
modifications.

In its present state it has two stages, each in a separate box. The first is battery-powered to eliminate coupling through the power supply. Each stage uses a differential amplifier--the first, a Motorola MFC 6010 integrated circuit; the second, a similar circuit constructed from discrete components. There are three single-tuned transformers--input, interstage, and output; the output transformer has an extra winding to drive an AGC circuit which controls the gain of the second stage. The receiver showed adequate gain and selectivity.

4.7.8 3345 KHz Receiver

This receiver, the result of three time-consuming attempts, consists of three stages, each using an RCA CA-3004 integrated circuit connected as a differential amplifier. Four single-tuned transformers are used, each wound on a Q1 ferrite toroid core and tuned with a variable capacitor (the variable capacitor placed in parallel to one of fixed value to bring the total capacitance to its required value) to improve stability in tuning. As in the 1672 KHz receiver, the first stage is separated from the rest of the receiver to decrease unwanted interstage coupling. This receiver does not incorporate AGC, as none is necessary. The three integrated circuits provide progressive limiting and, since the receiver is not required to pass modulation, only a CW carrier, the limiting has the added advantage of eliminating interference and noise from the output.

The first stage provided approximately 30 dB of gain; the second and third stages together, approximately 50 dB for a total of 80 dB. Due to limiting, total gain could not be measured through all three stages using the signal generator. Selectivity is approximately ± 10 KHz at 6 dB down. The receiver, after proper adjustment, performed satisfactorily in the system as part of the shore station.



3345 KC RECEIVER

ALL TRANSFORMERS: 3T-10T

FIGURE 4.13

5.0 LOBSTER BEHAVIORAL STUDY

5.1 Objective

The objective of this project is to set up a research project dealing with lobster behavior, specifically involving observational biology and observational psychology. Originally it was hoped that their actions around traps might be studied by use of time-lapse photography.

5.2 Background Investigation

At the beginning of May the possibility of working in this program first came up, thanks to Valery Lee. Several talks followed with Mr. Keatinge Keays, Professor Damon Cummings, Walt Lincoln and Robert Dwyer. Essentially a biology project was preferable not only from interest in that direction, but also because any engineering project would require a technical skill not possessed by this investigator and probably would take more planning and time than was available. Simple observation with available equipment might be possible with a biology project. The subject of such scrutiny should be of fair size, i.e., not microscopic, both for ease in observation and because a larger, more advanced animal might be more interesting behaviorally. Not too many marine creatures seemed available in Castine--a few large fish, osprey, occasional whales and seal, all of which would be very difficult to observe due to their mobility and scarcity. Finally Mr. Keays suggested that lobsters might be worth studying. Any information might be of potentially practical value (the lobster industry being worth millions) and, of course, lobsters are definitely available in Maine. Study by camera seemed the simplest most straightforward method. Field work would eliminate lab conditions which might cause artificial reactions in the lobsters. In addition, time-lapse photography would remove the need for another possibly disturbing element--the diver.

On May 31st background investigation was begun by a visit to John Hughes, Director of the Lobster Hatchery and Research Station, Department of Natural Resources, Commonwealth of Massachusetts. He is interested in a practical method for commercially raising lobsters. As a result of years of working with lobsters, he was a source of both practical knowledge and

interesting possibilities for research related to lobsters.

Mr. Hughes keeps egg-bearing females in hatching tanks; when the eggs hatch, the lobster fry drift in the circulating water into a screening box. Normally, about one in a thousand survive, but by placing the larvae in cylindrical tanks with circulators, the accumulation of larvae in groups, and therefore cannibalism, is prevented. This technique, plus sufficient food and the lack of predators, results in up to thirty percent survival. After fourth-stage molt, each lobster is kept in a separate container.

In nature it normally takes almost six years to reach marketable size. At stable optimal temperatures, about 60° to 68°F, this size can be reached in approximately three years. Mr. Hughes was also conducting some experiments with special diets--he was trying to develop food of a consistency like chewing gum and shaped like spaghetti (to lower waste involved when the lobster "bites" the food).

Equally interesting were the studies of genetic characteristics. Lobsters come in bright red, blue, albino and the usual brownish red. Mr. Hughes found that progeny of albino parents retain the odd color (incidentally, blue coloring is produced in hatchery-raised animals by some diet deficiency). Also some lobsters come with two crusher claws which offers extra meat. He had a male with this quality and hoped to breed for a strain. This, plus the possibly inherited characteristic of faster growth rate, would make selective breeding very worthwhile. He was also experimenting with optimal environments, size of container, with or without refuge. Salinity ranges were from 30 to 31 percent. When Mr. Hughes demonstrated his pump system, he warned about the dangers of air leaks, which lead to dissolved nitrogen and gas disease, copper poisoning from either metal parts or paint, and, of course, insecticides.

On June 1st an investigation of camera equipment was made with the assistance of Michael Kennedy. At Professor Edgerton's Laboratory, Mr. Charles E. Miller was very helpful. Apparently a great many people are interested in underwater time-lapse photography. Professor Edgerton at one time manufactured such

equipment, but discontinued the line. The lab is presently building a \$10,000 camera for NOAA for work at depths of 10,000 feet. A man named Doubliet was renting closed-circuit T.V. equipment apparently in conjunction with some offer by National Geographic for films of lobsters entering traps. Mr. Miller suggested adapting a Nizo S-56 (\$450). It contains a time-lapse mechanism and the electronic hookups necessary to attach a strobe. The strobe would be necessary in Maine's murky water (filming was planned at about 50 to 60 feet). There were also problems associated with a power supply and housing, anchoring the system, etc.

In New Jersey some lobstermen offered insight into defining what aspects of lobsters would be worth studying. They came up with several interesting ideas. They displayed their traps and explained how they worked. The traps are boxes made of wood creosote slats. A funnel of netting is contained in one end and farther in there is a second funnel. The second funnel is narrower and has a greater vertical slope than the outer funnel. The bait is placed between the two funnels. The lobster enters the first funnel, eats the bait in the space between funnels, and then backs up the second funnel toward the darker end (that end is darkened by having no slat openings) to rest and digest the food. Lobsters are almost always caught in this second compartment. The slope is much steeper and the hole smaller, so that it is much more difficult to get out than it is to escape from the first entrance.

One lobsterman said that in Massachusetts no one uses bait because only crabs would be caught. However, in New Jersey, if no bait is used, there would be no lobsters. Fishing is usually conducted on the rocky bottom from 3 to 20 miles offshore from May to December. When there's a warm water current, there are lobsters; when there's a cold water current, nothing. Traps are normally left out two or three days. One fisherman said he'd heard that lobsters crawl all over the trap before entering (the first funnel is too deep for the lobster to simply reach in).

On June 13th at the Sandy Hook Labs, one of the behavioral psychologists, Mr. Olla, explained the necessity for good experimental techniques. There are too many poor scientists who don't

know their methods for experiments, especially behavioral observation. On hearing my vague ideas, he offered some more concrete detailed plans. He cited Talbot Waterman on vision and Stanley Cobb on habitat selection. He outlined four parts of a project. First, vary which end of the trap is light and which is dark. Is it more comfortable (i.e., phototactic response) or is it easier to escape from light to dark or from dark to light? Second, use starvation as a stimulus to see escape reactions. Fright would cause unnatural "panic" response, probably headlong rushing about. There are clear liquids commercially available as lures. Measure the success of each with lobsters. Third, what is the actual process of trial and error used by the lobster. Fourth, what is the process of entering? Lobsters swim backward in escape, but probably explore while moving forward.

On June 14th at the library of the Sandy Hook Labs, articles from various research magazines were found and mimeographed.

While in Maine, my project was discussed with Dr. Barlow of Maine Maritime. He said that first there were observations, which in turn lead to a hypothesis. Then tests were made of the hypothesis to define any problems. He felt that it would be best to take one aspect with a yes-or-no answer (rather than randomly observe), and then design all equipment for this one point. As a result, regardless of what occurred, there would be some answer either in support or negation. If one were testing to see what percent of entering lobsters actually remain in the trap, i.e., the number of entries and exits, then one could design a counter. He suggested that perhaps 15 seconds would be too big a time lapse; he felt that maybe all that would be on film would be a series of lobsters jumping around due to the time lapse. Once again, methodology was stressed--the importance of picking out an answerable hypothesis that could be handled simply in the short span of a few months.

A couple of weeks later a call to Dr. Richard A. Cooper, National Marine Fisheries Service, Boothbay, produced a marvelous invitation to visit him. His research had concerned lobster migration and he had been working with the inshore and offshore populations. Apparently in an effort to stay in the best avail-

able temperatures, the offshore group migrates and as a result grows faster (lives under optimal conditions). His group had been using a Nikonos 35 mm with strobe to do a certain amount of underwater photography. In response to questions about conditioning and behavioral experiments, he pointed out the difficulties of filming and suggested several things in the line of lab research, most especially underwater acoustic studies. He felt that a good idea would be to record the sounds lobsters make under varied conditions, for example, when predators were near. He remarked that lobsters make a humming vibration and indicated that sound tapes of some of their natural enemies might be available at U.R.I.

Concurrently, reading through different books and mimeographed articles (see References) added to the general information obtained. Facts on lobster biology, especially those concerning the best holding condition, and, of course, what is known about their habits and life cycle were amply covered.

5.3 Conclusions and Plan for 1973 Lobster Research Project

First, lab experiments offer the simplest, most readily manageable environment. Second, some single question or aspect should be studied. The idea of learning about the sounds lobsters make appears attractive. Additional study might show how sounds affect lobsters, and whether it can be used to attract or perhaps herd them. Acoustic analysis might also prove to be useful in determining the animals' "emotional" and physical state. Third, external factors should be minimized and the study designed so that either the unnatural lab setting has no significant influence or its influence can be taken into consideration, perhaps by comparable field study. In the latter case, the Summer Ocean Engineering Laboratory would serve well as an opportunity to eliminate artificial factors. However, once again the problems of working in the ocean would be encountered. A lobster pound has been suggested, or maybe tape-recording trapped lobsters for additional data. Therefore, a plan for a 1973 lobster project calls for two phases. First, lab experiments during the school year and, second, field experiments during July. The basic equipment would be hydrophones, tape

recorders and some sort of machine for acoustic analysis. In the lab situation, filming might be useful. First, a control set of recordings, taken under as natural conditions as possible, should be made at different times of day; males and females should be used and, if desired, different age groups. Once normal sounds have been identified, conditions can be varied to see if any changes occur in the sounds emitted. Possible situations might include: physical stress--heat, cold, hunger (food could be introduced or tapes of food sources like fish played)--presence of predators, out of water, in light, in darkness, after just molting, etc. Tape recordings of boats, divers, other lobsters could be played. Tests might be conducted with individuals and groups. Incidentally, if tapes are being used to simulate certain conditions, some sort of filtering would be needed to leave only the lobster sounds on the new tape. Tests should be made several times with the same lobster under the same conditions to see if his reaction to a given stimulus changes. Perhaps gradual acclimatization would occur.

Later, in Maine a hydrophone could be attached to traps and recordings made and compared with those of the laboratory specimens.

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6.0 AIR LIFT DREDGE AND CATCH BASIN

6.1 Objectives

The purpose of this project is to design, build, and test a system for dredging sand and silt from relatively shallow water.

6.2 Background

The project was started after a Revolutionary War ship, the DEFENCE, was found in about 20 feet of water. A lift pump was needed to clear away some of the mud and silt that covered the vessel.

6.3 Results

The lift pump and catch basin were tested on a limited scale in sand, and worked satisfactorily. The connection between the air line and the PVC tube failed.

6.4 Conclusions

The lift pump and catch basin built are probably satisfactory for dredging mud and sand in up to 25-30 feet of water. The connection between the air line and the PVC tube needs to be redesigned.

6.5 Recommendations

Another valve should be placed in the air line at the exit from the compressor for topside control.

A 90° elbow should be installed in the air line at the bottom of the lift, and the air line attached to the PVC pipe above this elbow. This would eliminate the strain on the connection that failed.

6.6 Detailed Procedure

6.6.1 Screen

This project was divided into two parts. One part was the dredge and the other was the catch basin. The first part worked on and completed was the catch basin. It was needed in order to keep objects dredged up from going right back into the water. This would be done by making a floating platform which would keep out objects wanted and let the mud and silt fall back into the water.

The materials used on the catch basin were 1/2" plywood,

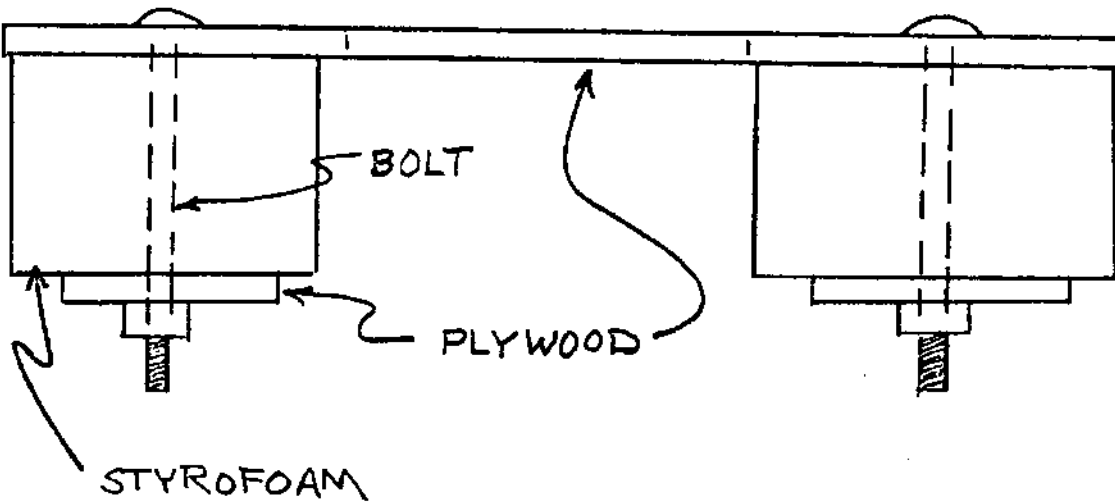
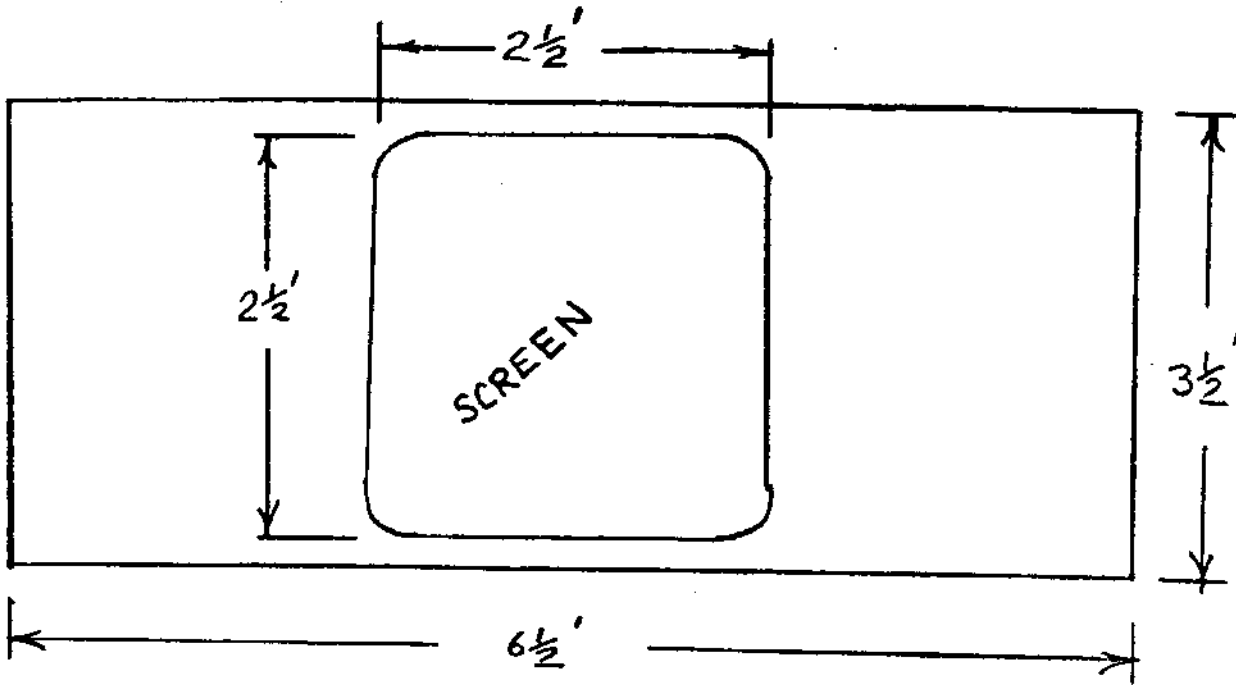


FIGURE 6.1
Catch Basin

2-1/2 square feet of styrofoam, two hinges, two hook-type clasps, four 8" bolts, washers and nuts, nails, and 2"x1/2" wood planks, and staples.

The first thing constructed was the top. This was made out of 1/2" plywood. It was made 3-1/2' wide and 6-1/2' long. The middle of this was cut out into a 2-1/2' square with the corners rounded to give the plywood added strength.

The styrofoam was attached in two pieces at the two ends of the top piece of plywood. This was accomplished by cutting out two pieces of plywood approximately one foot by two feet. Then bolts were put through the top layer of plywood, then through the styrofoam, and then through the two pieces of plywood, one piece of which was put under each piece of styrofoam. Two bolts were used for each piece of styrofoam and washers and nuts were tightened on each, thus holding the styrofoam firmly in place.

Next sills were added on three sides of the central cut-out section. These were nailed into place and small pieces of bracing were added to each corner to give them added support.

For the front piece of sill two hinges were used to fasten it in place. Two hook-and-eye fasteners were used to secure it to the rest of the sills.

The sills were designed to keep the large quantities of mud and silt from spilling over the side. The hinged section permits easy emptying of this debris.

The last piece added to the catch basin was a three-foot square piece of 1/4" wire screen. This was nailed to the plywood over the middle cut-out section by staples.

When completed and put in the water, the catch basin floated well. It set nearly level in the water with the screen approximately three inches above the surface.

When it was later tested with the dredge, it worked perfectly. It allowed all small stones, sand and mud to fall back into the water; yet it retained the sea urchins which were dredged up.

Under actual working conditions in the bay where it was supposed to be used, it might be harder to handle, but would probably work out quite well.

6.6.2 Lift Pump

The dredge was to be used on the Revolutionary War wreck, the DEFENCE, to help clear away some of the mud and silt and also find small objects such as buttons. It was to be used in twenty to thirty feet of water.

The material that was used on the dredge was 30' of 4"-PVC piping, 50' of garden hose, one quick shutoff valve, about 6" of 1/2" copper tubing and fittings, and one section of PVC piping in a 90° bend.

To put the lift together a hole was drilled about 1-1/2' up one length of piping. A 3" piece of copper tubing was placed in this.

The quick-throw valve was then fitted to the copper tubing and another small piece of copper tubing approximately 3" long was fitted to the other end of the valve. The rubber hose was then placed over the copper tubing and a clamp used to make a firm connection.

The PVC piping was then fitted together. This was the dredge that was successfully tested on July 26, 1973.

For that test a 3/4 hp air compressor was used. The pressure for most of the test was about 20 psi, although a pressure of 60 psi was reached. The 20 psi was quite adequate to run the dredge and the planned working pressure of 30 psi should be excellent.

Although a diver was used he did not have a wetsuit on and was unable to stay down long enough to actually work the dredge. However, by just random dredging five starfish were retrieved and the diver observed a large crater where the dredge was placed. The dredge was deemed a success; however, a problem did arise.

Where the copper tubing entered the PVC piping a crack was observed which forced determination of the trial run. The copper piping put too much strain on the PVC.

To prevent this occurrence, the PVC must be reinforced. Either bands of fiberglass around the PVC or a very tight-fitting steel collar at the point that the copper piping enters the PVC would probably alleviate the problem.

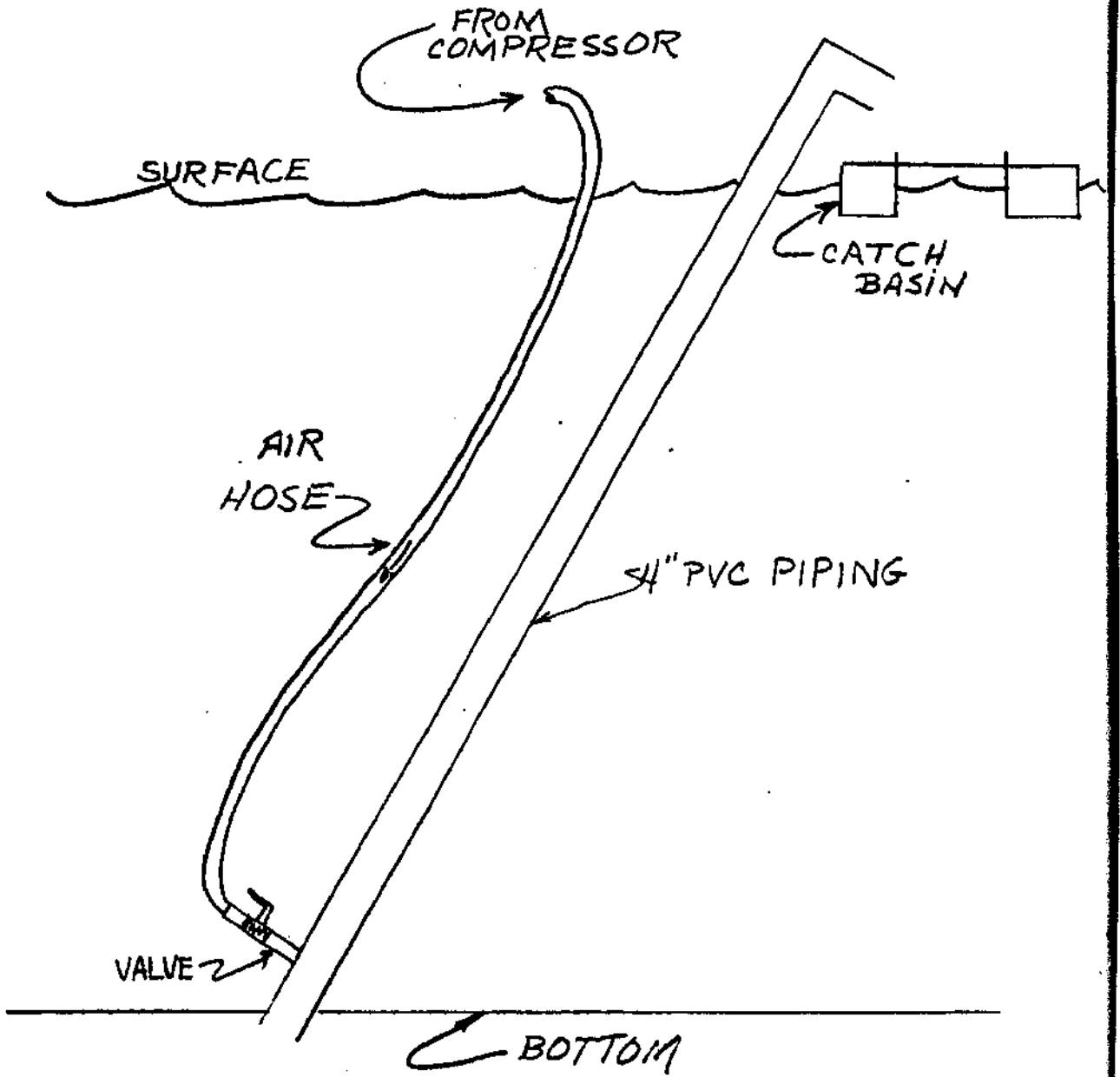


FIGURE 6.2

Lift Pump

An air compressor formerly used for the air brakes on a truck had been obtained and was supposed to have been mounted in one of the work boats. This would then have supplied a sufficient amount of air to power the dredge. If this had been put into operation, a manifold made out of 2" steel reinforced pipe about 2' long would have been used. This manifold had placed in it two pressure release safety valves to prevent overpressurization. One was set to release at 60 psi and the other at 65 psi.

Also placed in the manifold was a pressure gauge. Caps were drilled for the fitting of the 1/2" copper tubing used for the air line, one leading from the compressor to the manifold and the other from the manifold to the rubber air hose.

7.0 UNDERWATER POWER GENERATOR

7.1 Objective

The objective of this project is to build a nonpolluting underwater power generating system on a small scale and use it to study the feasibility of much larger units that could perhaps be tethered in the Gulf Stream or in other tidal rivers.

7.2 Background

It was decided to probe a natural form of power generation after exposure to the research proposal submitted to the National Science Foundation by the University of Massachusetts, Amherst, concerning an investigation into a national network of pollution-free energy sources. It is felt by many that alternative energy sources will be necessary in the future as our fossil fuels and U235 supplies become rapidly depleted. Also it is expected that environmental pollution will worsen in the near future, thus creating a vital need for some form of pollution-free energy.

7.3 Results

No operational results have been obtained at this time, pending final assembly of the machine. However, the design is finalized and most of the necessary components have been gathered. Work continued during the Fall of 1972 under a Special Studies Program for assembly and testing purposes.

7.4 Conclusions

The prime design criterion in these northern latitudes is adequate protection from ice. Also, the completed unit should not hamper the boating traffic of the river, and it should not inflict scenic damage to the surrounding area, along with a zero contribution to pollution of air and water.

It can be concluded that this small machine, when fixed on the bottom at a depth of thirty to forty feet, will have sufficient clearance between it and the surface to permit navigation of the river, and also be deep enough to avoid the danger of floating debris and ice. However, with larger units in the same depth, there may be clearance problems and/or ice damage. In addition, site location would be an important consideration. The unit, when in place, would be completely submerged and invisible, and by nature of design, cause no air or water pollution.

Pollution-free Energy Source
Underwater Power Generator
Basic Plan:
Side View

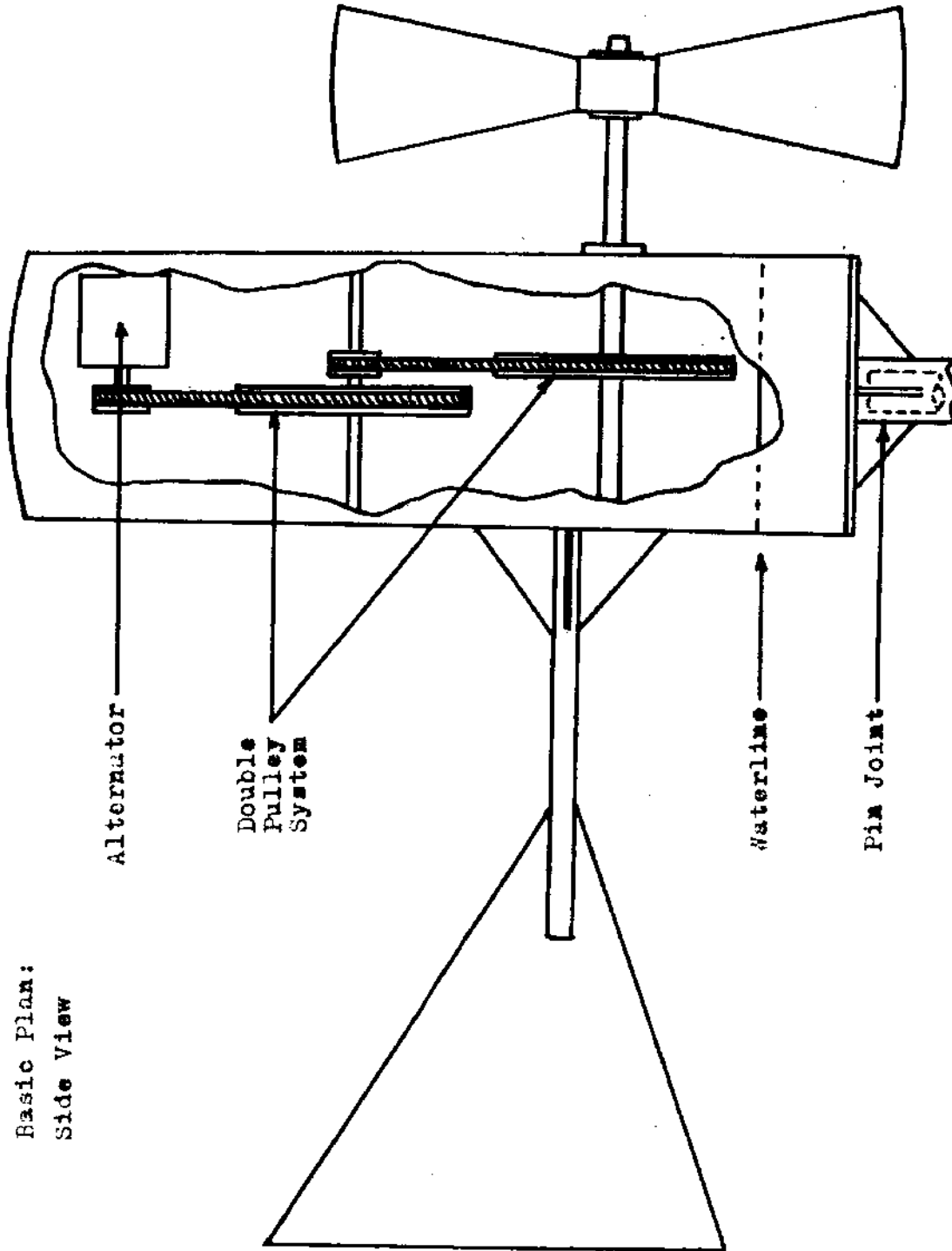


FIGURE 7.1

Underwater Power Generator

7.5 Recommendations

To reduce costs, several changes were made to the original concept. Instead of fabricating the underwater housing out of plate steel, a hot water heater tank was substituted--necessitating building a framework to support components. It is believed that it would be easier to mount bearings in the flat surfaces of a sheet steel box than in the curved surface of the cylinder.

Another recommendation concerns raising the efficiency of the machine; a step in the right direction would be to use one pulley system versus the two smaller systems presently required due to cylinder dimensions. Also, a more efficient propeller could be designed and built (in this case a flat plexiglass sheet was cut into blades, simplifying design and construction).

7.6 Detailed Procedures

7.6.1 Location and Conditions

The Narrows of the Bagaduce River above Castine was chosen as an ideal site for this project. The current velocities are high and it is in close proximity to the Summer Lab project site.

Work began in April 1972 with a study of tidal velocities. By timing current drogues, the velocity approximately two hours after low tide was determined to be between 3.0 and 3.5 knots, with a 4-knot maximum to be expected (confirmed in Tide Tables for the Narrows).

7.6.2 Design

A configuration similar to a windmill was chosen: a bladed axial flow machine capable of pivoting on its vertical axis to enable the propeller to face squarely into the oncoming current.

The machine would consist of three major sections: the propeller and rudder vane, cylindrical case housing the generating apparatus, and the supporting tripod structure.

The plexiglass hub of the propeller with a nylon bushing insert will be mounted on a 3/4-inch stainless steel shaft, and a sealed bearing set will be pressed to the shaft and then welded to the cylinder to prevent leakage. The pressure inside the open-bottomed cylinder will be ambient, reducing the possibility of

any leakage through the sealed bearing set. If any leakage occurs, it can be checked with an occasional blast of SCUBA air from a diver's mouthpiece. Behind the propeller and casing will be a rudder or sheet metal vane, larger in area than the propeller, to cause the propeller to swing normal to the stream.

An automobile alternator driven by a system of pulleys and V-belts was selected for the generating unit. These components will be mounted on a framework, then inserted into the housing. The upper sections will join the tripod structure at a pin-in-pipe joint located at the base of the cylindrical housing.

8.0 CAN BUOY

8.1 Objective

The objective of this project is to design and build a workable buoy that could serve as an instrument platform or as a mooring buoy for the stable Spar Buoy (Section 9.0).

8.2 Background

In the first Summer Ocean Engineering Laboratory (1971) two buoys were quickly fabricated to hold the data storage equipment for current meters. The buoys performed their function, but it was obvious they could be improved. The can buoy and the stable spar buoy were built to provide good instrument platforms for the 1973 Summer Laboratory.

8.3 Results

A can buoy was designed and built to act as an instrument platform or as a mooring buoy. When tested, the can buoy floated properly, but its natural period of oscillation was very close to the anticipated period of waves in Penobscot Bay.

8.4 Conclusions

The buoy was not tested on station, but from the pierside tests it can be concluded that it will work satisfactorily at sea. The coincidence of the buoy's natural period of oscillation with that of the waves will cause the buoy to have considerable motion. As a result it will be a suitable platform for such instruments as data-recording devices, temperature indicators, etc.; but it will not be a satisfactory foundation for direct attachment of current meters, wind velocity meters, wave height indicators, and other types of instruments that are sensitive to motion.

8.5 Recommendations

The buoy was built of wooden slats over plywood circles and then fibreglassed on the outside. The wooden slats could be improved by beveling the edges so that no space at the outside joints would have to be bridged by the fiberglass. This project would also have benefited from having the design work completed prior to the actual Summer Laboratory, thus allowing more time for construction and testing.

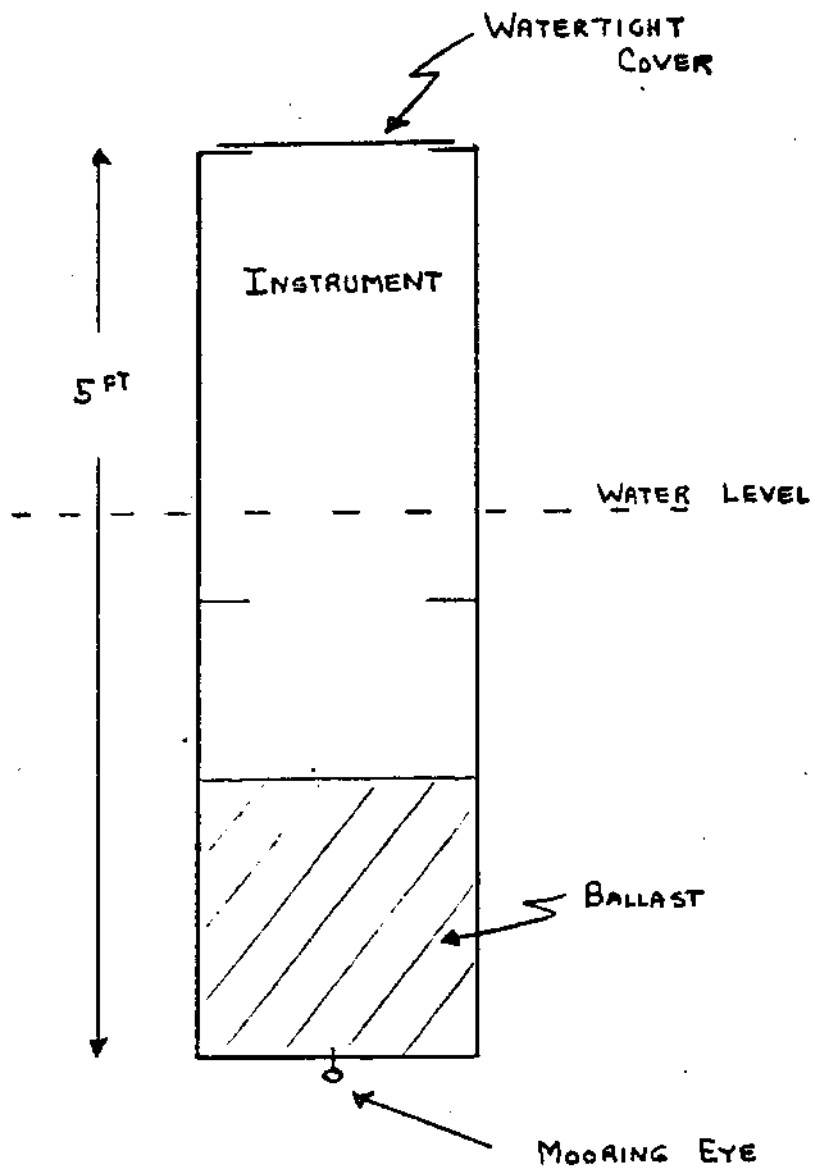


FIGURE 8.1

Can Buoy

8.6 Detailed Procedure

In the planning stages, the size and shape of the buoy were altered to produce the best design to do the job at hand. The original structure was to be constructed in a doughnut shape with a tower attached to its top. This idea was abandoned to make way for a new idea which proved to be our final product. A buoy five feet by 18 inches in diameter which would be ballasted to float two feet above the water and three feet below was decided upon. This structure was to be a can buoy which would theoretically float 25 pounds of equipment.

It was built of 24 2-1/2-inch wooden slats, five feet long. These slats were attached to three 18-inch diameter, 3/4-inch plywood circles by way of wood screws. The top two circles have 12-inch diameter circles cut in them to provide space for ballast. Two hundred and thirty-five pounds of sand ballast was needed to achieve the desired stability and water level. Fiberglass was used to enclose the structure and to make it watertight. At the bottom, a steel eye was placed through which a mooring line can be secured.

A three-point mooring system was thought best to moor the buoy using three Danforth anchors at angles of 120 degrees from the center. Calculations for the mooring system were not made this year because the buoy was not ready for the water until the day before the project was to end.

After completion of the buoy, the next and last step was the "sea trials." The number of pounds of ballast needed and the amount of sand needed to meet this weight were calculated. The weight of one cubic foot of sand is 100 pounds and the amount of ballast needed to submerge the buoy three feet was found to be 235 pounds. After ballasting the buoy to the calculated level, we found more weight was needed to reach the desired flotation height. This error was due to the poor selection of sand which contained pieces of wood, trash, and other miscellaneous items. The oscillation period of the buoy was calculated to be two seconds, but testing revealed a three-second period. The nearness of the three-second oscillation period of the buoy and the four-second period of the waves would cause the buoy to bob like a cork in heavy seas. To remedy this, a damper plate, or some other method of restraining the buoy could be used.

9.0 STABLE SPAR BUOY

9.1 Objective

A stable spar buoy was to be designed and built to provide a floating, relatively motionless platform for a 20-pound instrument package. It is planned that the spar buoy will be used as an instrument platform for instruments to be built for the 1973 Summer Ocean Engineering Laboratory.

9.2 Background

A number of large stable spar buoys have been built in the past few years to provide relatively stable instrument platforms. In the first Summer Ocean Engineering Laboratory, two buoys were quickly fabricated to hold current meter-recording equipment. The buoys performed their function, but it was obvious they could be improved upon. The stable spar buoy and can buoy (Section 8.0) were built to provide instrument platforms for the 1973 Summer Laboratory, and the stable spar buoy is patterned after the larger stable spar buoys.

9.3 Results

A stable spar buoy was designed and built with a natural period of oscillation well above the usual summer waves in Penobscot Bay. Time did not permit the installation of the buoy on site with its mooring system.

9.4 Detailed Procedure

The buoy was designed to hold 20 pounds of equipment above the surface in a relatively stable position. The proposed mooring site is in 260 feet of water with waves having periods of three to four seconds. This means that the natural oscillation period of the buoy must be significantly greater than the period of the waves. If the buoy's natural period of oscillation is the same as the waves', it will heave up and down wildly, damaging both itself and the installed instruments.

The buoy was constructed of four-inch plastic PVC pipe with a steel ballast and damping plate attached at the bottom. The center tube is 15 feet long. Three four-inch flotation tubes five feet long are attached to the outside of the center tube with their tops two feet below the waterline. The center tube extends three feet above the waterline.

STABLE SPAR BUOY

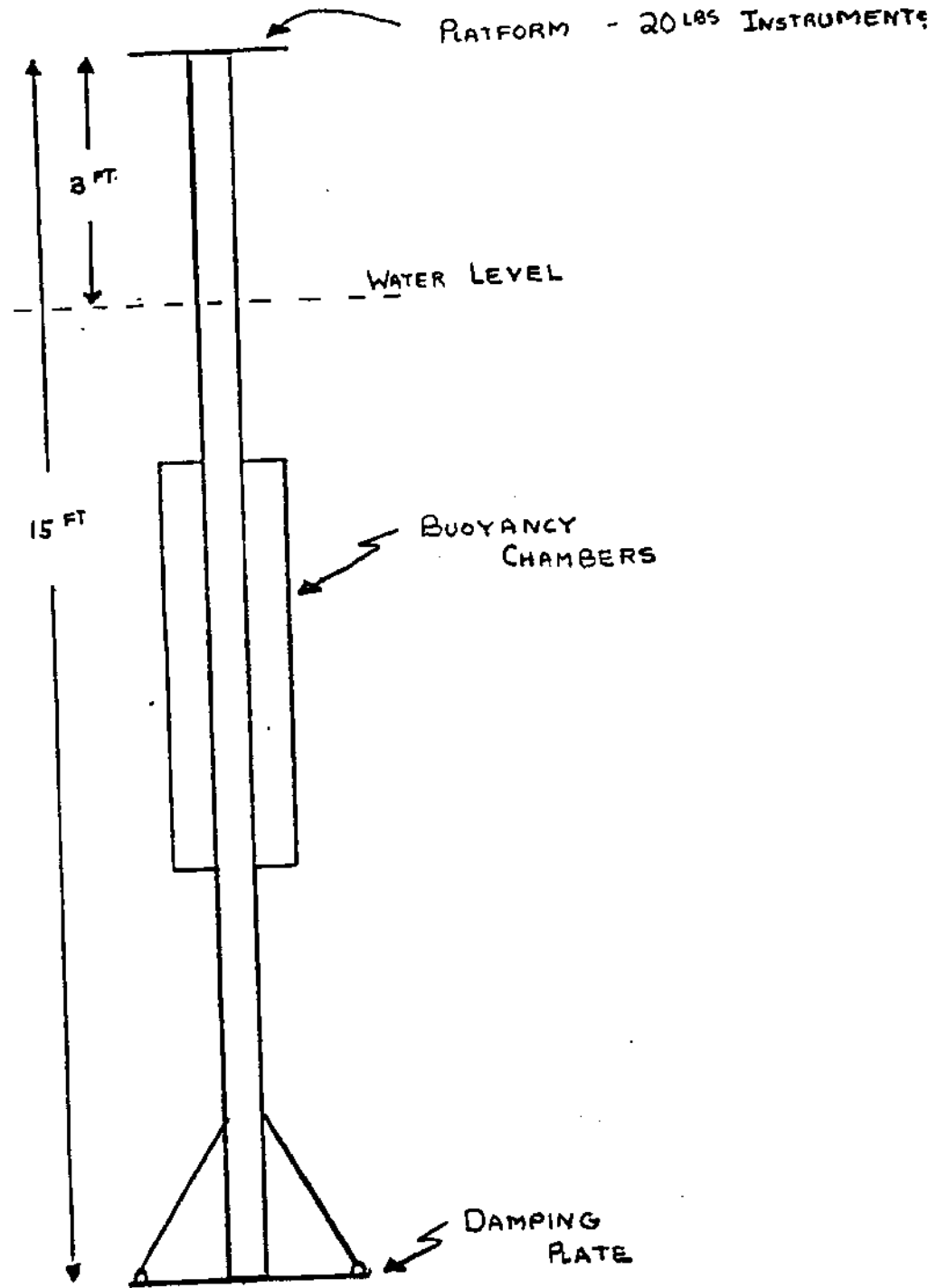


FIGURE 9.1

The buoyancy of the tubes was found by subtracting the weight of the tube from the weight of the water displaced. It was calculated to be 6.6 pounds per foot. The buoy was a very stable platform because the center of gravity is 3.6 feet below the center of buoyancy giving it a very good righting moment. The weight of required ballast was found by calculating the amount of buoyancy that was below the design water level and subtracting it from the weight of the buoy.

The period of heave was determined by the formula $T = 2\pi\sqrt{\frac{m}{k}}$, where T is the time in seconds, m the mass, and k is the buoyancy in lbs/ft at the waterline. The purpose of a spar buoy is to get a long oscillation period; therefore, k should have a small value and m should have a large value. As a result the buoy is quite long to get a large mass but has a very small area which pierces the surface. The m value is not just the mass of the buoy, but the virtual mass, which is increased by adding a damping plate. The mass is increased by adding the weight of a sphere of water with the same radius as that of the damping plate. The damping plate is 15 inches in radius. The natural period of heave was calculated to be 10.9 seconds.

When the buoy was tested, the only correction needed was to add more ballast to the damping plate because it floated too high out of the water. After the extra ballast was added and the buoy was lowered to the proper level, the actual oscillation period was timed at approximately 9-10 seconds. A mooring system was designed, but not tested. The buoy was floated at the dock for three days without any apparent leakage. The pipes had been filled with styrofoam for added security.

10.0 NAUTILUS ROCK TOWER

10.1 Objective

The objective of this project is to design, build and test an open framework tower that can be used in the 1973 Summer Ocean Engineering Laboratory. The tower is to be temporarily installed on Nautilus Rock, Lat. 44°-22'-15" North, Long. 68°-48'-40" West and during the 1973 Summer Laboratory it will be installed to be used as a fixed platform for instruments or surveys.

10.2 Background

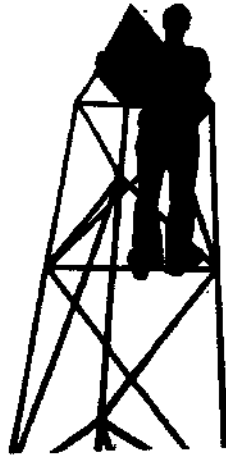
The tower project was selected to provide a stationary instrument platform and also to allow the students to make practical use of the knowledge they gained in their basic engineering courses of Statics, Strength of Materials, and Fluid Mechanics. A stationary instrument platform is necessary for instruments such as tide height recorders, wave height recorders, and can be useful for mounting current meters. It is hoped that this tower will be used for that purpose next summer.

10.3 Results

The tower was designed to resist wind, wave and current forces that could normally be expected during the summer months in Penobscot Bay. When the design was completed, construction was begun with one-inch inside diameter steel pipe. The tower was completed and was set up at the waters' edge, but due to lack of time was not installed on Nautilus Rock. It is anticipated that it will be installed on Nautilus Rock next summer. The tower when tested did stand upright and it easily held the live load it was designed to hold. The testing on site was not accomplished and how it will withstand the wind, wave and current forces is unknown at this time.

10.4 Detailed Procedures

In order to obtain permission from the U.S. Coast Guard to erect this tower, a permit had to be granted by the U.S. Army Corps of Engineers, who required a clearance from the State of Maine Environmental Improvement Commission and the Town of Castine. Permission was granted by the various regulatory agencies.



PLATFORM

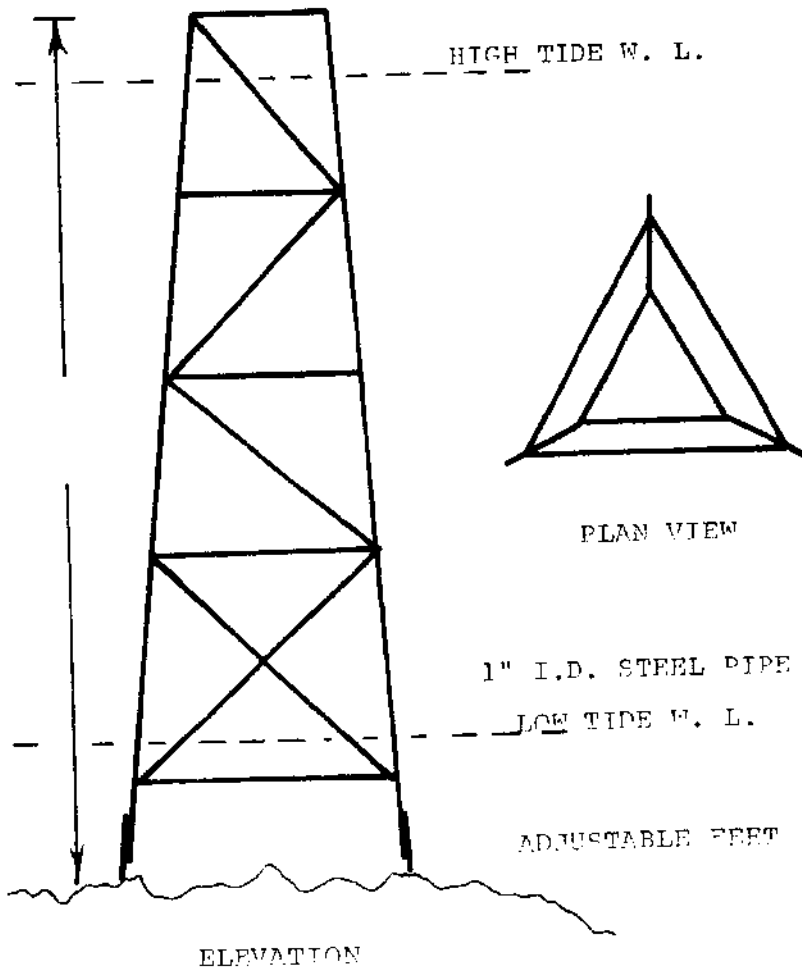


FIGURE 10.1 NAUTILUS ROCK TOWER

The project was begun by surveying the site to determine the depth of water above the Rock and the contour of the Rock itself. The depth of water was found to be 18.7 feet at highest high water. Next the forces that would be exerted upon the tower were calculated. These forces were due to wind, current and wave action. Maximum values of these forces were used to design this tower. Forces were estimated to be as follows:

current force	0.36 lbs/ft of steel tubing
wind force	0.4 lbs/ft of steel tubing
wave force	0.9 lbs/ft of steel tubing

The total weight of the structure was then determined; this included weight due to materials used and live weight. This was estimated to be a maximum of 1,000 pounds. With the previous calculations having been made, a structural analysis of the tower was completed.

Construction was begun by cutting and grinding the one-inch steel tubing lengths to provide the necessary fit required for a strong, permanent weld. The first side was constructed separately and then tubing forming the other two sides was fabricated to it to form the three-sided structure. Upon completion of all welding, adjustable legs were installed to insure a level platform when installed on a very irregular surface. A plywood platform, three feet square, was then secured by bolts to the top of the tower.

11.0 SCALLOP DREDGE

11.1 Objective

The objective of this project is to build a scallop dredge for verification of a new design prepared by the Maine Department of Sea and Shore Fisheries. During the scallop season of 1972-1973 the dredge's fishing characteristics will be tested and, if successful, the design will hopefully be adopted by Maine's scallop fishermen.

11.2 Background

The construction of the dredge is a cooperative project between Maine Maritime Academy, the Extension Division of the Maine Department of Sea and Shore Fisheries, and fisherman Earl Clifford. In May 1972 a conference on "Renewable Marine Resources" was held at Maine Maritime Academy. At that conference the Academy offered to help fishermen work on gear development. This project is a result of that offer. The scallop dredge is a modification of the typical New Bedford scallop dredge, which is much larger than the typical Maine scallop dredge and works better on hard bottoms in deep water. Conventional Maine scallop dredges turn upside down in deep water on hard bottoms; this should not be a problem with the new dredge.

11.3 Results

The scallop dredge has been built to plans prepared by the Department of Sea and Shore Fisheries. The dredge will be tested this winter when the scallop season opens in Maine waters.

11.4 Conclusions

The scallop dredge appears as though it will be successful, but verification of the design must await the operational testing this winter.

11.5 Recommendations

When another dredge of this design is built, some of the steel pieces can be purchased in the thickness required, rather than making the required thickness by welding two pieces together.

Bar steels 1"x2"x73" and 1/2"x2"x73" are welded together to constitute a stock material of 1-1/2"x2"x73". This entailed several extra hours of labor.

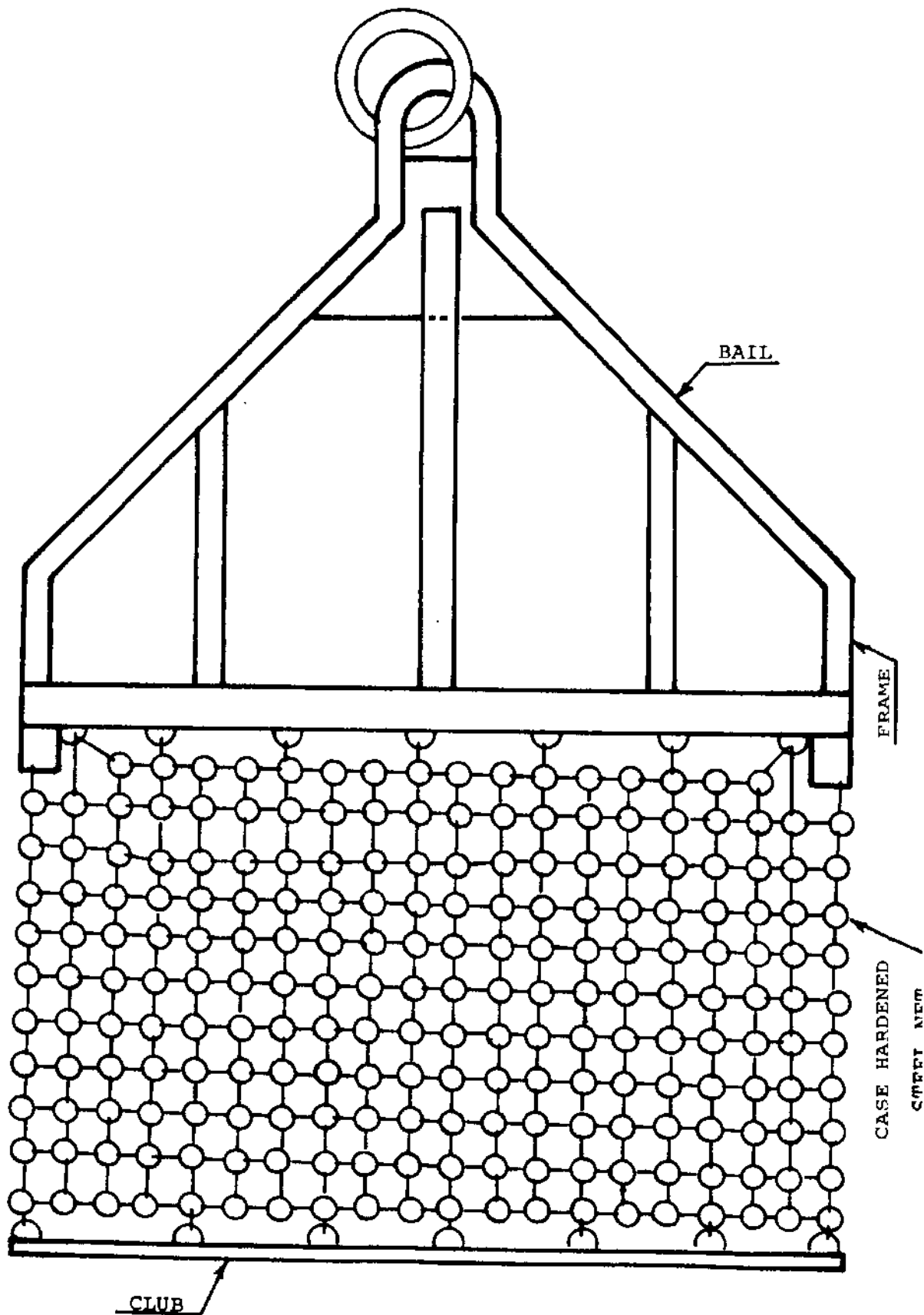


FIGURE 11.1 SCALLOP DREDGE

Solid bar steel of 1-1/2"x2"x73" should be used. This would result in a savings of labor costs; the actual purchase price of the steel stock would remain the same, for steel is purchased by the pound.

The entire New Bedford-type club was replaced by the typical club found on Maine scallop drags and should be changed on the design.

11.6 Detailed Procedure

The forming of the drag's bail was accomplished by heating 1-1/2-inch mild round stock steel to glowing red and then bending to a specific shape to form the bail. The frame was welded together and attached to the bail.

A chain link net was fabricated of three-inch case-hardened steel links, joined together with one-inch case-hardened connector links. Case-hardened steel was used for this particular chain net because of its abrasive resistance quality.

APPENDIX A

DIVING LOG

<u>Time</u>	<u>Dive No.</u>	<u>Divers</u>	<u>Location</u>	<u>Depth</u>	<u>Dura- tion</u>	<u>Comment</u>
12 July	1	Lukens Chertow	Isleboro Ledge	40'	20 min	Training dive on wreck "ALICE 1 CLARK"
12 July	2	Lincoln Wells Murphy	Isleboro Ledge	40'	20 min	Training
12 July	3	Lincoln Murphy	Stockton Harbor	20'	40 min	Search for "DEFENCE"
13 July	4	Sawyer Siapkaras	Isleboro Ledge	50'	29 min	Training
13 July	5	Lincoln Parker Dwyer	Isleboro Ledge	50'	26 min	Training
13 July	6	Wells Labrecque	Isleboro Ledge	50'	23 min	Training, sawed on ship's wheel
13 July	7	Lincoln Sawyer	Stockton Harbor	22'	20 min	Search for "DEFENCE"
14 July	8	Kunz Schenck Siapkaras Chertow Keller Murphy Sawyer	Holbrook Cove	45'	32 min	Search for lost boat rudder, no success
15 July	9	Kunz Keller Murphy	Isleboro Ledge	50'	31 min	Training
15 July	10	Lincoln Cebelius Dwyer Lukens	Isleboro Ledge	50'	16 min	Training, sawed on ship's wheel
15 July	11	Kunz Murphy	Isleboro Ledge	50'	24 min	Training, sawed on ship's wheel
17 July	12	Kunz Murphy Sawyer	SSears Island Ledge	25'	44 min	Search for "ACTIVE"

DIVING LOG (continued)

<u>Time</u>	<u>Dive No.</u>	<u>Divers</u>	<u>Location</u>	<u>Depth</u>	<u>Dura- tion</u>	<u>Comment</u>
19 July	13	Chertow Murphy	Stockton Harbor	20'	65 min	Found wreck sus- pected to be "DEFENCE." Recovered knee, bricks, buoyed off objects sus- pected to be cannon
19 July	14	Lincoln Schenck Miller	Stockton Harbor	40'	50 min	Recovered piece of gun carriage with 3 cannon balls
20 July	15	Wells Schenck	Stockton Harbor	20'	50 min	Photograph wreck
20 July	16	Lukens Siapkaras	Stockton Harbor	20'	38 min	Survey
20 July	17	Parker Sawyer	Stockton Harbor	20'	30 min	Survey
20 July	18	Murphy Dwyer Sawyer	Stockton Harbor	20'	38 min	Survey, found mast south of wreck
20 July	19	Lincoln Lukens	Stockton Harbor	20'	40 min	Rigged cannon for lift. Recov- ered remainder of gun carriage with cannon balls
21 July	20	Wells Schenck	Stockton Harbor	20'	48 min	Wreck photography
21 July	21	Chertow Labrecque Siapkaras	Stockton Harbor	20'	25 min	Wreck survey
21 July	22	Chertow Labrecque	Stockton Harbor	20'	20 min	Cannon salvage preparation
21 July	23	Lincoln Lukens	Stockton Harbor	20'	28 min	Cannon salvage
24 July	24	Lincoln Wells	Stockton Harbor	20'	33 min	Wreck photography and survey

DIVING LOG (continued)

<u>Time</u>	<u>Dive No.</u>	<u>Divers</u>	<u>Location</u>	<u>Depth</u>	<u>Duration</u>	<u>Comment</u>
24 July	25	Murphy Wells Chertow	Stockton Harbor	20'	15 min	Recovered lead scupper
25 July	26	Schenck Siapkaras	Henry Point	50'	13 min	Light attenuation study
25 July	27	Lincoln Cameron Cianchette	Henry Point	50'	15 min	Checkout
26 July	28	Lincoln Wells Bradford Bartlett Blackwood Benson Sauter	S. Entrance Holbrook Cove	45'	16 min	Checkout
26 July	29	Schenck Siapkaras	S. Entrance Holbrook Cove	45'	27 min	Light attenuation study
28 July	30	Lincoln Devlin Campbell	Holbrook Cove	30'	23 min	Checkout
28 July	31	Chertow Murphy	Holbrook Cove	40'	43 min	Search for whaleboat rudder

APPENDIX B

SMITHSONIAN INSTITUTION
U.S. National Museum
Washington, D.C. 20560

PRESERVATION OF LARGE IRON OBJECTS RECOVERED FROM SEA WATER

The first step in preserving large iron objects such as gun tubes, solid shot, and wrought-iron fittings recovered from sea water is to prepare a bath of 10 to 15 percent sodium peroxide. The object should then be cleaned of the calcareous coating of coral sand and other deposits by gently tapping it with a hammer. After the crust is removed the object should be immediately placed in the bath and allowed to soak for a period lasting from 4 to 6 weeks. At the end of this period, the bath should be renewed and "mossy" zinc metal should be placed around and on top of the object so that its entire surface is in contact with the zinc. After a day or two the solution will begin to bubble. This indicates that the reaction is going forward. In a few weeks a white deposit will form on the object and the bubbling will stop. This means that the oxygen which was in the surface of the corroded object has left it and has combined with the zinc metal forming the white zinc oxide. The object should be left in the bath for 3 or 4 weeks after the above conditions are observed. At the end of this time it should be removed and the white coating dissolved with a mild solution of sulfuric acid. After the object is dried, it should be coated with a clear synthetic lacquer or plastic solution to prevent further corrosion. Smaller objects may be coated satisfactorily by dipping them in a solution of hot paraffin. The reaction should be carried out in a heavy iron trough. Any attempt to shorten this routine will probably result in the loss of the object through disintegration.

Objects waiting for the preservative process should be kept under water until they can be put into the chemical bath. An object should never be allowed to dry out even before the crust is removed.

SMITHSONIAN INSTITUTION
United States National Museum
Museum of History and Technology

PRESERVATION OF WOOD

Wood that has been submerged in water for long periods of time must be thoroughly dehydrated before it can be preserved. This is accomplished by putting it in three successive baths of pure alcohol, each of the baths to last one week. The alcohol, being very hygroscopic, will remove the water. When this has been completed, the wood should be placed in two successive baths of xylene, the first bath requiring one week.

When the wood is in the second bath of xylene, paraffin chips should be added until a saturated solution of paraffin is obtained. This will be evident when paraffin becomes recrystallized around the edges of the solution. The wood should remain in the saturated solution of paraffin for approximately two weeks. At the end of this period the wood may be removed from the solution and the xylene in the wood allowed to evaporate.

A coat of small crystals of paraffin will be seen on the wood as a result of the process. This excess paraffin on the surface may be removed with a gentle brushing. The specimen then should be perfectly preserved. In effect, this treatment replaces the moisture in the wood with paraffin and permits the wood to retain its original shape.

METHOD OF PROCEDURE
(for electrolytic reduction)

Prepared by:
Joseph M. Young

Sodium Carbonate Na_2CO_3 (soda ash)

- it is soluble in water/insoluble in alcohol.
- it replaces sodium hydroxide NaOH for our use.
- it has a high electrical conductivity rate, result
low voltage as low as 6V.
- used in the ratio of 1 lb. per gal. or a 5% solution
water H_2O it will go into solution quite well.
- voltage of power supply can range from 4V to 300V
depending on need.
- highest current density recommended, however, is
10 amps per square decimeter calculated from the
total surface area of the object.
- a source yielding 12A at 12V can suffice.

PROCESS FOR METAL

Prepared by:
Joseph M. Young

- 1st STEP: Go through¹ electrolytic process in usual manner (test for chlorides to indicate completion of process).
- 2nd STEP: Wash in distilled or fresh water (distilled preferred).
- 3rd STEP: Buff with wire brush and rinse.
- 4th STEP: Put specimen on a hanging wire and hang in a tank of a two percent solution of versene for about twenty-four hours or overnight.
- 5th STEP: Remove the specimen from the versene solution and let it air dry for about ten minutes. Then put it in the oven pre-set at between 65 or 70°C for three hours.
- 6th STEP: Remove from oven and let cool.
- 7th STEP: Upon drying, the specimen is then placed into a solution of molten wax, dried and placed into the collections.

¹See: Method of procedure

APPENDIX C

SCUBA Diving Standard Operating Procedures

The purpose of this instruction is to establish responsibilities and standard operating procedures for SCUBA diving operations conducted in conjunction with the 1972 MIT-MMA Summer Laboratory at Castine, Maine.

Diver Quals:

Only divers certified by formal SCUBA courses such as NAUI, YMCA, or U.S. Navy Diving School will dive in this program.

Diver Instructions

1. No recompression diving will be conducted.
2. A safety diver will be fully rigged and standing by whenever divers are in the water.
3. All divers will wear the inflatable flotation vest.
4. Divers will maintain visual contact with their assigned buddy. As soon as visual contact is lost, a diver will surface.
5. Depth limit is 45 feet for newly qualified divers until further open water checkout by the diving officer.
6. All divers shall report to the Diving Officer before entering the water and notify him of any dives conducted within the last 12 hours.

Operating Procedures

1. The Diving Officer shall:
 - a. give the dive briefing
 - b. maintain station in the dive launch
 - c. assign buddy teams
 - d. designate safety diver
 - e. make equipment check of divers prior to their entering the water
 - f. maintain the diving log and repetitive dive sheets
 - g. direct chase boat activities
 - h. ensure diving flag is visible
 - i. the diving officer may delegate temporary responsibility to the assistant diving officer when he is actually diving

The Diving Officer shall have the final determination with regard to diving conditions and diver capabilities for a given dive.

2. The Safety Diver shall be prepared to render aid at the discretion of the diving officer to any disabled diver. He shall be rigged prior to any diver entering the water.
3. Diving ops. will normally be conducted from the CHALLENGER and the MIT Research Vessel. They may maintain contact with each other on VHF radio channel 9. A chase boat shall accompany the dive boat and shall be manned at all times.
4. Conduct a radio check with the nearest Coast Guard facility on VHF channel 16 before beginning diving ops.
5. The MMA Medical Officer (Dr. Russell) shall be informed when open water dives are planned, and suitable communication procedures established in the event of emergency.
6. All dive gear shall be off-loaded as soon as the boat returns to port. Gear shall be washed in fresh water and stored in a designated place. Tanks shall be filled as soon as possible by personnel qualified on the air compressor.

Emergency Procedures

In any emergency the Camden Marine Operator may be utilized to conduct telephone calls from the boats. In case of air embolism or decompression sickness the nearest recompression facility is at Portsmouth Naval Shipyard. Emergency medical evacuation is made by helicopter; the following steps are to be followed:

1. Call Coast Guard on VHF channel 16 and request emergency medical evacuation. Identify yourself as MIT-Maine Maritime Diving Group. Give victim status and location.
2. If the return trip by boat to Castine will involve some time call MMA via Camden Marine Operator.
3. Personnel at MMA will call the Duty Officer at Portsmouth, 207-439-1000, ext. 1900. Tell him that victim is on the way for recompression.
4. Administer first aid in accordance with App. A of the U.S. Navy Diving Manual until arrival of a medical doctor qualified in diving medicine. Air embolism and decompression sickness treatment is in section 1.6.2-1.6.3 of USNDM.

APPENDIX D

1.0 REPORT ON TRIP TO BOOTHBAY JULY 17, 1972, TO VISIT DR. COOPER

We left Castine at 9:30 A.M. and arrived at the National Marine Fisheries Service station at about 12:15 P.M. Everyone was out to lunch. We looked at some of the lab setup. There were several big vats, several large shallow boxes in shelf-like arrangement, and lots of small compartments, all with lobsters of corresponding size. The little ones (probably of one to four molts) all had names and were in individual boxes. The larger containers had many lobsters plus an abundance of other sea life, like starfish, anemones and clams.

At about 1:00 P.M. Dr. Cooper returned. He arranged to have us go out on a boat for specimen-gathering and filming trip. There were three divers and someone to handle the boat.

While they were getting ready, Ken (an assistant) took us to see the aquarium, which consisted of several large tanks and a seal pool. There were several lobsters. They tag them in one of their studies by placing a tubing with a monofilament leader and a steel anchor in the dorsal extensor muscle below the carapace. Since the membrane at this point breaks down at molting to allow the animal to get out, the tag is retained through several molts. The biggest lobster ever caught was over 40 pounds. The biggest they had was around 20 pounds and he was enormous! Too big to eat, the limit on lobsters is a little over 5" maximum and 3-3/16" minimum (carapace length).

We went to the dock and left for a cove a short distance away. The divers went down for about half an hour to a depth of 40 or 50 feet and perhaps 50 to 100 yards offshore. One diver carried a 35 mm NIKONOS that had a strobe attachment and several close-up lenses. The other two gathered half a dozen lobsters. On the way back Ken showed us how to differentiate between male and female by examining the first pair of swimmerets. If soft, it's a female; if hard, it's a male. Dr. Cooper met us at the dock and examined one of the lobsters. He explained how you can tell when a lobster is about to molt. The shell softens at claw joints; it also becomes bloated and puffy at the forward carapace joint and softens at the edges of the carapace. We dumped

them into one of the tanks. Dr. Cooper pulled out a discarded shell and unsuccessfully tried to locate the newly-shed animal. After molting, a lobster is darker and soft and therefore completely vulnerable. This one had probably been eaten. There are left-handed and right-handed lobsters according to which claw is crusher and which ripper. The crusher claw, usually broader, has blunt teeth; the ripper has sharp serrated edges.

Dr. Cooper made a suggestion for an observation of molting. Perhaps it would include or be part of an experiment to see just how small a female can be mated and to how large a male. Females are receptive only just after shedding and the knowledge of minimum breeding size and maximal ratio between female and male would be very useful commercially.

We then went to his office for an hour-long discussion. His group had been working on lobster migration. There are apparently two sorts of populations--an inshore stationary one and an offshore migratory one. The offshore group comes inward during the summer probably to encourage maturation cycle because of the warmer water. Then when the water grows colder, they move outward to deeper and warmer temperatures. As a result they maintain themselves under the best available conditions. They grow faster than inshore lobsters, which become sluggish and practically dormant in the winter, by having year-round growing conditions.

When I mentioned my interest in using time-lapse photography, he elaborated on the problems involved. First of all, lobsters are mainly nocturnal so that if I wished to photograph activity around a trap (i.e., feeding behavior was necessary), I'd need a strobe. Aside from the engineering problems of energy supply, etc., I'd need a study of the effects of light variance (strobe) on lobsters. He suggested that I put the camera system above to watch the trap and surroundings.

I asked about conditioning and intelligence experiments along with physiological ones like light sensitivity. He mentioned that some people at Woods Hole Oceanographic Institution were working on chematography. He also suggested that I use electric shock as stimulus instead of hunger or light--once

again problems of measurement. (There is an experimental shock trawl in use somewhere.)

Dr. Cooper mentioned that a basic sound study had been conducted at the University of Rhode Island. Apparently lobsters hum; they sort of vibrate. You can feel it when you hold them around the abdomen. I asked if you could use hydrophones and make recordings. He said that recordings of predator fish were available at U.R.I. and that perhaps filming lobster reactions (in coordination with sound recording) under different conditions (e.g., predators) and using lobsters of different classifications (e.g., male, female, young, old, etc.) would be interesting. The lobster has six major enemies--goosefish, cunner, wolffish, sculpin, sea raven, and codfish.

Concerning behavior about a trap, he said they first feel around it and into it with claws and antennae and then back in afterwards. I told him I still wanted to do some behavioral psychology research and asked if lobsters were afraid of fire. Naturally he said no. In the ocean there is no fear of falling, no fear of fire or disease. The main fear of an undersea creature is the predator. His entire life is spent feeding, mating, and hiding. The idea of observing behavior and sound production sounds pretty good. Dr. Cooper then gave us two specimens after viewing some slides on local flora and fauna and from Techtite and Sea Lab.

2.0 HOLDING LIVE LOBSTERS IN AERATED SEA WATER BY D. G. WILDER. 1953. Condensed from Fisheries Research Board of Canada

Natural sea water contains about 3-1/2 percent sodium chloride by weight, but along the coast where lobsters are caught the freshwater runoff reduces the salt content to about three percent. (This article contains instructions for building a holding unit.) Oxygen requirements are amply met by bubbling compressed air through air stones into the water. A filter using cotton gauze should be used to keep the water clean. Toxic materials such as copper, zinc, and lead must be avoided, and care taken to prevent nitrogen poisoning; stainless steel or aluminum alloy should be used. A variety of fish and shellfish provide a good food supply; usually herring or other

inexpensive fish are used. Optimal temperature would be in the 60-70 degree range.

NOTE: A large holding tank would probably be most economical, but, if handling were to be minimized, it might be preferable to keep one or two lobsters per tank. Also, if smaller (i.e., not huge wooden) glass tanks are used, filming would be possible. This filming would remove the possibly disturbing influence of an observer. Also, inactivation of claws would be unnecessary (if needed, rubber bands are best).

APPENDIX E

CALCULATIONS FOR THE UNDERWATER POWER GENERATOR

The available kinetic energy flowing per square foot normal to the stream was calculated for a velocity of six feet per second:

$$KE = \frac{1}{2} \dot{m} V^2$$

where

$$\dot{m} = \rho A V$$

$$\dot{m} = \frac{2 \text{ slugs}}{\text{ft}^3} \cdot \frac{1 \text{ ft}^2}{1} \cdot 6 \text{ ft/sec}$$

$$\dot{m} = 12 \text{ slugs/sec}$$

$$\text{So } KE = \frac{1}{2} (12 \text{ slugs/sec}) (6 \text{ ft}^2/\text{sec}^2)$$

$$KE = 216 \text{ ft-lb/sec}$$

or, say, 200 ft-lb/sec per foot available kinetic energy.

The alternator is rated at: 50 amps at 5000 rpm, and is 12 volt.

$$\text{Power} = V I$$

$$P = (12) (50)$$

$$P = (600 \text{ watts}) \left(\frac{1 \text{ hp}}{746 \text{ W}} \right)$$

$$P = 0.8 \text{ hp}$$

Estimating that this primitive propeller-driven, double-pulley system will be only 45% efficient, 90 ft-lb/sec is calculated for final available KE. Since

$$(0.8 \text{ hp}) \left(\frac{550 \text{ ft-lb/sec}}{1 \text{ hp}} \right)$$

$$= 440 \text{ ft-lb/sec}$$

Dividing by 90 ft-lb/sec:

$$\frac{440}{90} = 5 \text{ ft}^2 \text{ area of propeller}$$

Therefore, $r = 15.5$ inches or diameter of 31 inches.

It was decided to use a 30-degree blade angle, as this has worked favorably on previous current meters employing similar blade construction. Working backwards for the 30-degree blade angle:

$$\text{Pitch} = \sin \theta = \frac{x}{(\pi) (2/3 r)}$$

$$\sin 30 = \frac{x}{31.4}$$

$$\text{Pitch} = 15.7 \text{ inches}$$

$$\frac{1 \text{ rev}}{15.7 \text{ in}} \cdot \frac{4 \text{ ft}}{\text{sec}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{60 \text{ sec}}{1 \text{ min}} = 200 \text{ rpm}$$

@ prop.

Optimum alternator speed: 5000 rpm. Total gear ratio equals 25 : 1, or two 5 : 1 pulley ratios. The large wheel diameters should equal 12.5 inches, with 2.5 inches for the smaller pulleys--easily fitting inside the 14-inch diameter cylinder.

The tubular steel support structure will be of sufficient size to prevent any moving or tipping of the machine, once in place. The moments will be worked out when the weights of the upper sections have been confirmed.

George R. Benson

Robert McCarty