NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.
Reference No. 62-21

Telemetering Current Meter
Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

In citing this report in a bibliography, the reference should be followed by the phrase UNPUBLISHED MANUSCRIPT, which is in accordance with bibliographic practice.

Reference No. 62-21

Telemetering Current Meter

-7

Robert M. Snyder
and
Edward H. Chute

Submitted to Office of Naval Research
Under Contract NNR-3351(00) NR 083-501

June 1962

APPROVED FOR DISTRIBUTION [Signature]
Paul M. Fye, Director
TELEMETRYING CURRENT METER

The telemetry of oceanographic data has received much attention of late as techniques and equipment have become available. Most of this attention has been directed toward general principles, however, with little mention of system details. Much of the equipment which has been developed in other fields is applicable here but there are some factors that are unique to oceanography. Among these are - a highly corrosive environment, extremely high pressures at some transducer locations and the necessity for transmitting data along a road which must also serve as a mooring. The latter problem is treated in detail in another report, but it should be noted here that it is generally desirable to place the power required by a transducer at the transducer location for the practical reason that power transmission over two miles of wire is extremely inefficient.

The measurement of ocean currents becomes much more feasible when a semi-permanent station can be set out in the desired area and interrogated from shore when phenomena of interest are expected to occur. One may know immediately whether or not the system is operating correctly and if the phenomenon is present in this way the current meters need not be worked continuously but only when something of interest is taking place. And should the mooring be lost the accumulated data is not lost with it.

The current meter described in this article is a direct descendant of line of current meters developed, tested, and used over the past 2 1/2 years by Dr. W. S. Richardson at Woods Hole Oceanographic Institution. Because the requirements for data telemetry are entirely different from those of data storag
the internal workings of the telemetering instrument are quite different from those of the recording instruments. The transducer systems (compass, vane and rotor assemblies), however, are almost identical. Advantage was taken, wherever possible, of housing and construction techniques and components developed by Dr. Richardson. Therefore the only "debugging" required in the system was related to the electronics in the current meter, the calibration of the transducers having been completely worked out. The Richardson current meter is described in WHOI Reference No. 62-5. Figure 12 shows the Savonius rotor calibration.

The current meter, itself is shown in Figure 1 with components of the various bays indicated. Figure 2 is the circuit diagram. The current meters are placed in a mooring, either on conducting cable or polypropylene rope fitted with conductors. Alternatively the current meter may be used aboard ship by lowering to desired depth on conducting line. In the latter case one would put the electrical output of the current meters directly on a strip chart recorder such as a portable Sanborn. When the current meters are used in a mooring the electrical output is fed to the input circuitry aboard the buoy and transmitted to shore.

As in the Richardson meter the speed is determined by the number of revolutions per unit time of a Savonius rotor. The information is coupled through the aluminum end cap by means of two strong, teflon coated, bar magnets (such as those used for stirring by chemists) which drive a magnetic rotor follower. The rotor follower is shown in Figure 3. The follower magnets are affixed to one end of an aluminum cylinder which rides on carbide and sapphire bearings. A small light bulb is placed inside the cylinder at the...
top end and the photran looks through a hole in the rotor follower case. When this hole lines up with a hole in the rotating aluminum cylinder the photran "sees" the light bulb and puts out a pulse. These pulses are stored in a seven level "flip flop" counter until read out. Figure 4 shows the rotor follower and associated circuitry and Figure 5 shows the flip-flop board.

The current direction is determined from the difference between the positions of a magnetic compass, which registers the orientation of the instrument housing, and a vane which gives the bearing of the current relative to the housing. Both the magnetic compass and magnetically coupled vane follower drive seven level Gray binary discs. The position of these discs is determined in each unit by a radial line of seven "light pipes" which look through the disc at a flash tube mounted inside the units and activate photrans when they see light. The photrans (seven each for compass and vane follower) are PNP light triggered switches which (like all PNP switches) have an inherent binary memory. They are connected to the circuit as shown in Figure 2 so that if their particular channel in the Gray binary disc is clear they see light and trigger giving an output signal of plus 7.5 volts. If the Grey disc channel shows black the particular photran output is minus 7.5 volts. A typical Gray coded disc is shown in Figure 10. The flip-flops are powered in a similar manner giving either plus or minus outputs so that at no time is a zero signal used to convey information - plus signals mean binary zeros and minus signals mean binary tens. Figure 6 shows the compass and Figure 7 the vane follower.

A'16 bits are fed in proper order to the scan switch shown in Figures 8 and 9. This unit also contains the cams and microswitches which control the photran circuit power, the flash tube trigger circuit, drive motor power, and Shockley power. The system operates as follows:
1. Interrogate buoy from shore based transmitter (manual or automatic)
   Buoy automatically programs remainder of cycle.
2. Buoy sends a -24 volt D.C. signal down the line to all current meters in
   the mooring (current meter are electrically in parallel - mechanically in
   series. The number of current meters is limited only by practical con-
   siderations).
3. The -24 VDC signal triggers the Schottky diode Sh_2 in the lockup circuit
   activating By_1 which in turn activates By_2. This relay supplies the
   power (3 voltages) and simultaneously, a reset pulse to the Hamon Karden
   flip flop (FF) board so that the rotor counts may be stored.
4. The -24 VDC signal also triggers the transistor switch TR_1 in the rotor
   lite circuit so that the rotor revolutions are seen by the FF trigger phototran
   Ph_1 as lite pulses through a magnetically coupled lite chopper. As the
   Severnus rotor spins the lite pulses are converted by Ph_1 to electrical pulses
   which store in the FF board via a Schmitt trigger. The FF board contains
   seven flip flops allowing a maximum count of 127 pulses. Separate magnetic
   lite choppers have been made that supply from 6 pulses per rotor revolution
   to 1 pulse per 10 rotor revolutions so that the total counts in the count
   interval may be made to fall in a range consistent with efficient use of the
   counting circuit.
5. The -24 VDC signal is chromometrically controlled to give an accurate count
   interval. This interval would typically fall in a range from 10 to 90
   seconds using appropriate lite chopper coupling.
6. When the -24 VDC is turned off the transistor switch in the rotor lite circuit extinguishes the rotor lite by cutting off power to By 3. The Shockley diode Sh 2, however remains conducting due to its binary memory which causes relay By 1, and hence, relay By 2 to remain closed so that the stored rotor counts will be available for readout. Operations 2 through 6 occur simultaneously in all current meters.

7. Buoy now begins to interrogate each current meter individually. Each current meter is equipped with a resonance reed relay tuned to a specific frequency. A precisely tuned 12 V audio tone is impressed on the line which activates the resonance reed relay By 5 through T2 and TR2 via the home position of the SCAN SWITCH. After a short delay determined by the value of C2 and R13 the transistor TR3 conducts activating By 4. The contacts of By 4, when closed place -7.5 volts on the motor M01 which drives it off its home position. The length of the audio tone is controlled so that as the motor goes off home position the tone is stopped so that the line will be clear for conducting the data bits from the scan switch. Now just as the motor drives the scan switch off its home position it causes the micro-switch S1 via a cam affixed to the motor shaft. This switch puts the -7.5 volts directly on the motor and remains closed until the scanning is complete when it again opens to 6 of the scan switch on its home position.

8. Positions 1 through 4 of the scan switch are alert pulses and are cooked directly to the -7.5 volt supply. Positions 5 through 6 are code positions used to identify the particular current meter. These four bits allow use of up to 16 current meters in one mooring without repetition of code -76s.
The code bits are wired directly to the plus and/or minus 7.5 volt supplies depending upon the code word desired. While the scan switch is scanning positions 1 through 6 the motor shaft cams 1) turn on the photron power and 2) trigger the flash tubes V₁ and V₂ locking the vane and rotor follower orientation in the photron memory circuit.

9. The scan switch continues its one revolution picking off the 7 flip flop outputs which yields a 7 bit straight binary number proportional to current speed and the 7 compass bits and finally the 7 vane follower bits. The 7 vane bits when compared to the 7 compass bits yield the magnetic sec of the current. These last two 7 bit numbers are in Gray binary and may be compared as Gray directly or converted individually to straight binary, decimal binary or magnetic or true bearing and then compared.

10. After reading the 32nd bit the photron power microswitch is turned off and a fourth microswitch momentarily opens the lockup circuit resetting the Shockley diode S₂.

11. The scan switch returns to "home" and the motor microswitch S₁ opens stopping the scan switch on home and returning the current meter to its standby position. This standby position of the current meter requires only 2 μamps of current from the contained supply.

12. The buoy circuitry then repeats steps 7 through 11 for the current meters remaining in the line. The time required for each interrogation is approximately 10 seconds. Hence, the entire interrogation time for a string of 10 current meters would be 15 seconds + 10 x 10 seconds = 115 seconds. The program may then be repeated in its entirety or the buoy and current meters may be left on standby until further information is desired.
The current meters are provided with enough battery power to
operate (to 1.2 volts/cell end point) once per hour for 1 year. The standby
life of the system is equivalent to the shelf life of the batteries.

**Format**

The frequency shift keying (FSK) method was chosen for its ability
to transmit information over longer distances with less chance of noise interference. The coding system chosen was pulse duration modulation (PDM) so that
7 bit binary numbers could be transmitted in such a way to give a quadrupally redundant code, i.e. the information can be derived from the received signal
by four independent decoders and compared with each other. If the four decoded signals agree then the information is taken as real. If agreement is not
complete then an attempt is made to locate the source of disagreement (usually
a noise pip). If an obvious source cannot be found then the data is disregarded.
A further aid to choosing the correct data is a parity bit transmitted at the end of the last code word which tells the absolute number of binary "ones"
that were fed to the transmitter. The overall usefulness of the system is
enhanced if a decoding and monitoring system is operated in parallel with the
receiver. In this case, if the data is found to be untrustworthy the operator
immediately reinterrogates the system in hopes that the disrupting source was
random and will not show up twice in succession.

The output of the current meter is shown in Figure 11A. This output,
when transmitted received and discriminated, is shown in Figure 11B. By looking
at the expanded section of Figure 11B one can see where the quadruple redundancy
arises. If the discriminated signal is centered about zero as indicated, the
four decoders may operate as follows:
1) first decoder (integrator) detects signals between 5 and 7 units long on positive side of zero.
2) second decoder detects signals between 1 and 3 units long on positive side,
3) third decoder detects signals between 2 and 5 units on negative side and
4) fourth decoder detects signals between 7 and 9 units long on negative side. Coincidence circuits are not needed because the program is chronometrically controlled. Printout of the four separate words (i.e., location, rotor counts, compass and vane) is triggered by a detector which operates on the negative side and activated by a signal between 13 and 19 units long. The extra long signal on $f_1$ is due to the spaces between words as shown in Figure 11A. Each code word begins with the least significant bit and the "spaces" are used for printout to prevent crossover of words in case a bit is missed.

One complete current meter has been built and tested on nonconductor cable at sea aboard the R.V. CHAIN. Readings were taken at various depths in the Gulf Stream during March 1962. No difficulties were encountered and 13 more meters are being manufactured for use in a mooring this summer. The readout system described above is now being assembled and we expect to have the entire system operational by late summer. Obviously, in this type of work there are many possible sources of trouble which cannot be foreseen and there will likely be a number of modifications throughout the system before it becomes reliable. We feel the current meter itself, because of previous experience with its primary components will be an increasingly useful tool with only minor changes.
A = VANE Follower, \( V_1 \)

B = VANE FOLLOWER

LITE PIPES

C = CONNECTIONS FOR BAYE'\( ^* \)

\( R_2, C_2, D_4 \) VANE FOLLOWER

PHOTTRANS AND CIRCUITRY

(PRINTED CIRCUIT CARD #1)

D = RY_1, RY_2, RY_4, MO, RY_5

E = 4 CAMS ON MOTOR SHAFT

S_1, S_2, S_3, S_4

F = SCAN SWITCH

G = 2 BATT'S - EVEREADY

\#493, R_3, H_4, C_3, C_4, C_5

R_5, T_1

H = HARMON KA-100N FLIP FLOP

BOARD AND PLUG, PRINTED

CIRCUIT CARD #2

I = COJPASS, LITE PIPES, \( V_2 \)

J = BATTERY DISCONNECT

PLUG AND BATTERY

K = R_6, R_7, R_8, T_9, H_10, H_1

C_6, C_7, D_5, T_A, RY_3, P_H

ROTOR LITE

FIG. 1
START
1 ALERT PULSES
2 LOCATION CODE
3 SPACE
4 ROTOR COUNT — STRAIGHT BINARY
5 COMPASS READING — GREY BINARY
6 VANE READING — GREY BINARY
7 PARITY BIT

FIG. 11
### DISTRIBUTION LIST

**DEPARTMENT OF DEFENSE**

1. **Director of Defense Research and Engineering**
   Attn: Coordinating Committee on Science
   Pentagon
   Washington 25, D. C.

2. **Office of Naval Research**
   Geophysics Branch (Code 416)
   Washington 25, D. C.
   Office of Naval Research
   Washington 25, D. C.
   1. Attn: Biology Branch (Code 446)
   1. Attn: Surface Branch (Code 463)
   1. Attn: Undersea Warfare (Code 466)
   1. Attn: Special Projects (Code 418)

1. **Commanding Officer**
   Office of Naval Research Branch
   207 West 44th Street
   "w York 11, New York

1. **Commanding Officer**
   Office of Naval Research Branch
   The John Crerar Library Building
   86 East Randolph Street
   Chicago 1 Illinois

1. **Commanding Officer**
   Office of Naval Research Branch
   1500 Geary Street
   San Francisco 9 California

1. **Commanding Officer**
   Office of Naval Research Branch
   1030 East Green Street
   Pasadena 1 California

1. **Commanding Officer**
   Office of Naval Research Branch
   Navy N. 100 Fleet Post Office
   New York New York

1. **Contract Administrator Southeast Area**
   Office of Naval Research
   2110 "G" Street, N. W.
   Washington 9, D. C.

1. **Your Resident Representative**
   Office of Naval Research

6. **Director**
   Naval Research Laboratory
   Attn: Technical Services Information Officer
   Washington 25, D. C.

(Note: 3 copies are forwarded by this addressee to the British Joint Services Staff for further distribution in England and Canada)

8. Hydrographer
   U. S. Navy Hydrographic Office
   Washington 25, D. C.
   Attn: Library (Code 1640)

1. **U. S. Navy Branch**
   Hydrographic Office
   Navy 3923, Box 77
   F.P.O.
   San Francisco California

   Chief Bureau of Naval Weapons
   Department of the Navy
   Washington 25, D. C.
   1. Attn: PASS
   1. Attn: BU-227

1. **Office of the U. S. Naval Weather Service**
   U. S. Naval Station
   Washington 25, D. C.

1. **Chief Bureau of Yards and Docks**
   Office of Research
   Department of the Navy
   Washington 25, D. C.
   Attn: Code 70

1. **Commanding Officer and Director**
   U. S. Navy Electronics Laboratory
   San Diego 52 California
   1. Attn: Code 2201
   1. Attn: Code 2420
Navy

1 Commanding Officer and Director
U. S. Naval Civil Engineering Laboratory
Port Hueneme, California
Attn: Code L56

1 Code 3145
Ex: 7
Ft. Mugu Missile Range
Pt. Mugu, California

1 Commander, Naval Ordnance Laboratory
White Oak, Silver Spring, Maryland
Attn: E. Liberman, Librarian

1 Commanding Officer
Naval Ordnance Test Station
China Lake, California
Attn: Code 753
1 Attn: Code 568

1 Commanding Officer
Naval Radiological Defense Laboratory
San Francisco, California
Chief, Bureau of Ships
Department of the Navy
Washington 25, D. C.
1 Attn: Code 312
1 Attn: Code 341C
1 Attn: Code 631
1 Attn: Code 668

1 Officer in Charge
U. S. Navy Weather Research Facility
Naval Air Station Bldg. B-48
Norfolk Virginia

1 Commanding Officer
U. S. Navy Air Development Center
Johnsville, Pennsylvania
Attn: NDC Library

1 Superintendent
U. S. Naval Academy
Annapolis, Maryland

2 Department of Meteorology and Oceanography
U. S. Naval Postgraduate School
Monterey, California

AIR FORCE

1 Hqtrs., Air Weather Service
(AMSS/TIPU)
U. S. Air Force
Scott Air Force Base, Illinois

1 ARCEL (CRZF)
L. G. Hancock Field
Bedford, Massachusetts

ARMY

1 Army Research Office
Office of the Chief of R and D
Department of the Army
Washington 25, D. C.

1 U. S. Army Beach Erosion Board
5201 Little Falls Road, N.W.
Washington 16, D. C.

- Commanding Officer
U. S. Naval Underwater Sound Laboratory
New London, Connecticut

1 Commanding Officer
U. S. Navy Mine Defense Laboratory
Panama City, Florida

OTHER U. S. GOVERNMENT AGENCIES

1 Office of Technical Services
Department of Commerce
Washington 25, D. C.

10 Armed Services Technical Information Agency
Arlington Hall Station
Arlington 12, Virginia

2 National Research Council
2101 Constitution Avenue
Washington 25, D. C.
Attn: Committee on Undersea Warfare
Attn: Committee on Oceanography

1 Commandant (CGF)
U. S. Coast Guard
Washington 25, D. C.
Ottal L. S. Government Agencies

1 Director
    Commanding Officer
    U. S. Coast Guard Oceanographic Unit
    c/o Woods Hole Oceanographic Institution
    Woods Hole, Massachusetts

1 Director
    U. S. Geological Survey
    Washington 25, D. C.
    Attn: J. A. Trumbull

1 Director
    U. S. Weather Bureau
    Washington 25, D. C.

1 Laboratory Director
    Bureau of Commercial Fisheries
    Biological Laboratory
    U. S. Fish and Wildlife Service
    Washington 25, D. C.

1 Director
    National Oceanographic Data Center
    Washington 25, D. C.

RESEARCH LABORATORIES

2 Director
    Woods Hole Oceanographic Institution
    Woods Hole, Massachusetts

3 Project Officer
    Laboratory of Oceanography
    Woods Hole, Massachusetts

1 Director
    Narragansett Marine Laboratory
    University of Rhode Island
    Kingston, Rhode Island

1 Laboratory Director
    Bingham Oceanographic Laboratories
    Yale University
    New Haven, Connecticut

1 Laboratory Director
    Gulf Coast Research Laboratory
    Post Office Box
    Ocean Springs, Mississippi
    Attn: Librarian

2 Library, U. S. Weather Bureau
    Washington 25, D. C.

1 Director, Bureau of Commercial Fisheries
    U. S. Fish and Wildlife Service
    Department of Interior
    Washington 25, D. C.

1 Laboratory Director
    U. S. Bureau of Commercial Fisheries
    Fish and Wildlife Service
    P. O. Box 271
    La Jolla, California

1 Chairman
    Department of Meteorology and Oceanography
    New York University
    New York, New York

1 Director
    Lamont Geological Observatory
    Torrey Cliff
    Palisades, New York
Research Laboratories

1 Director
Hudson Laboratories
145 Palisades Street
Dobbs Ferry, New York

2 Great Lakes Research Division
Institute of Science and Technology
University of Michigan
Ann Arbor, Michigan

3 Head, Department of Oceanography and Meteorology
Texas A and M College
College Station, Texas

4 Director
 Scripps Institution of Oceanography
La Jolla, California

5 Allen Hancock Foundation
University Park
Los Angeles 7, California

6 Department of Engineering
University of California
Berkeley, California

7 Head, Department of Oceanography
Oregon State University
Corvallis, Oregon

8 Director
Arctic Research Laboratory
Barrow, Alaska

9 Dr. C. I. Beard
Sylvania Electric Defense Laboratory
P. O. Box 205
Mt. View, California

10 Head, Department of Oceanography
University of Washington
Seattle, Washington

11 Geophysical Institute of the University of Alaska
College, Alaska

12 Director
Bermuda Biological Station for Research
St. George's, Bermuda

13 Department of Meteorology
and Oceanography
University of Hawaii
Honolulu 14, Hawaii

Attn: Dr. R. M. Johnson
Research Laboratories

1 Technical Information Center, CU-201
Lockheed Missle and Space Division
3251 Hanover Street
Palo Alto California

1 University of Pittsburgh
Environmental Sanitation
Department of Public Health Practice
Graduate School of Public Health
Pittsburgh 13 Pennsylvania

1 Director
Hawaiian Marine Laboratory
University of Hawaii
Honoolu Hawaii

1 Dr. F. B. Berger
General Precision Laboratory
Pleasantville New York

1 Mr. J. A. East
Wildlife Building
Humboldt State College
Arcata California

1 Department of Geodesy and Geophysics
Cambridge University
Cambridge England

1 Applied Physics Laboratory
University of Washington
1013 NE Fortenth Street
Seattle 5 Washington

1 Documents Division - NL
University of Illinois Library
Urbana Illinois

1 Advanced Undersea Warfare Engineering
Advanced Electronics Center
General Electric Company
Ithaca New York

1 CCR Special Representative
c/o Hudson Laboratories
Columbia University
145 Palisade Street
Dobbs Ferry New York

1 Stanford Research Institute
Department of Defense
Menlo Park California

1 Bureau of Sport Fisheries and Wildlife
U. S. Fish and Wildlife Service
Sandy Hook Marine Laboratory
P. O. Box 425
Highlands, New Jersey
Attn: Librarian

2 Defence Research Member
Canadian Joint Staff
2620 Massachusetts Avenue N.W.
Washington 8 D. C.

1 Bureau of Commercial Fisheries
U. S. Fish and Wildlife Service
Biological Laboratory
730 Jackson Fiare, N.W.
Washington 25, D.C.
Attn: Mr. Thomas S. Austin

1 Library
Institute of Oceangraphy
Worley Godalming
Surrey England

1 Geophysical Field Station
Columbia University
APO No. 856
New York, New York

MEMBERS OF UNDERSEA WARFARE RESEARCH AND DEVELOPMENT PLANNING COUNCIL

1 Captain B. H. Andrews, USN
Commanding Officer and Director
U. S. Navy Underwater Sound Laboratory
New London Connecticut

1 Captain C. Blemel, Jr.
U. S. Naval Ordnance Test Station
China Lake, California

1 Captain J. H. Brandt, USN
U. S. Navy Underwater Ordnance Station
Newport, Rhode Island

1 Dr. R. J. Christensen
Acting Technical Director
U. S. Navy Electronics Laboratory
San Diego 52 California

1 Captain W. D. Coxe, USN
U. S. Naval Ordnance Laboratory
White Silver Spring Maryland

1 Dr. Robert A. Frost, Director
Hudson Laboratories
Columbia University
145 Palisade Street
Dobbs Ferry New York
KINDERS OF THE UNDERSEA HARP Research
AND DEVELOPMENT PLANNING COUNCIL

1 M. G. G. Gould
Technical Director
U. S. Naval Underwater Ordnance Station
Newport, Rhode Island

1 Dr. G. K. Hartmann
Technical Director
U. S. Naval Ordnance Laboratory
White Oak
Silver Springs, Maryland

1 Dr. J. E. Henderson, Director
Applied Physics Laboratory
University of Washington
1013 East 40th Street
Seattle 5, Washington

1 Captain F. A. Herold, USN
Commanding Officer and Director
U. S. Navy Electronics Laboratory
San Diego 52, California

1 Dr. J. W. Horton
Technical Director
U. S. Navy Underwater Sound Laboratory
New London, Connecticut

1 Dr. John C. Johnson
Director (and Prof. of Engineering Research)
Ordnance Research Laboratory
Pennsylvania State University
University Park, Pennsylvania

1 Captain A. K. Kees, USN
U. S. Navy Research Laboratory
Washington 25, D. C.

1 Dr. Harry Kratter
Chief Scientist
U. S. Naval Air Development Center
Johnsville, Pennsylvania

1 Captain H. L. Leon, USN
U. S. Naval Air Development Center
Johnsville, Pennsylvania

1 Dr. W. B. McLellan
Technical Director
U. S. Naval Ordnance Test Station
China Lake, California

1 Captain J. A. Obermeyer, USN
Commanding Officer and Director
David Taylor Model Basin
Washington 7, D. C.

1 Dr. Norman Roberts
Applied Physics Laboratory
University of Washington
Seattle, Washington

1 Dr. Karl R. Schoenherr
David Taylor Model Basin
Department of the Navy
Washington 7, D. C.

1 Mr. A. H. Schooley
Associate Director of Research and
Electronics
U. S. Naval Research Laboratory
Washington 25, D. C.

1 Dr. Fred W. Spies
Director, Marine Physical Laboratory
University of California
San Diego 52, California

1 U. S. Navy Mine Defense Laboratory
Panama City, Florida