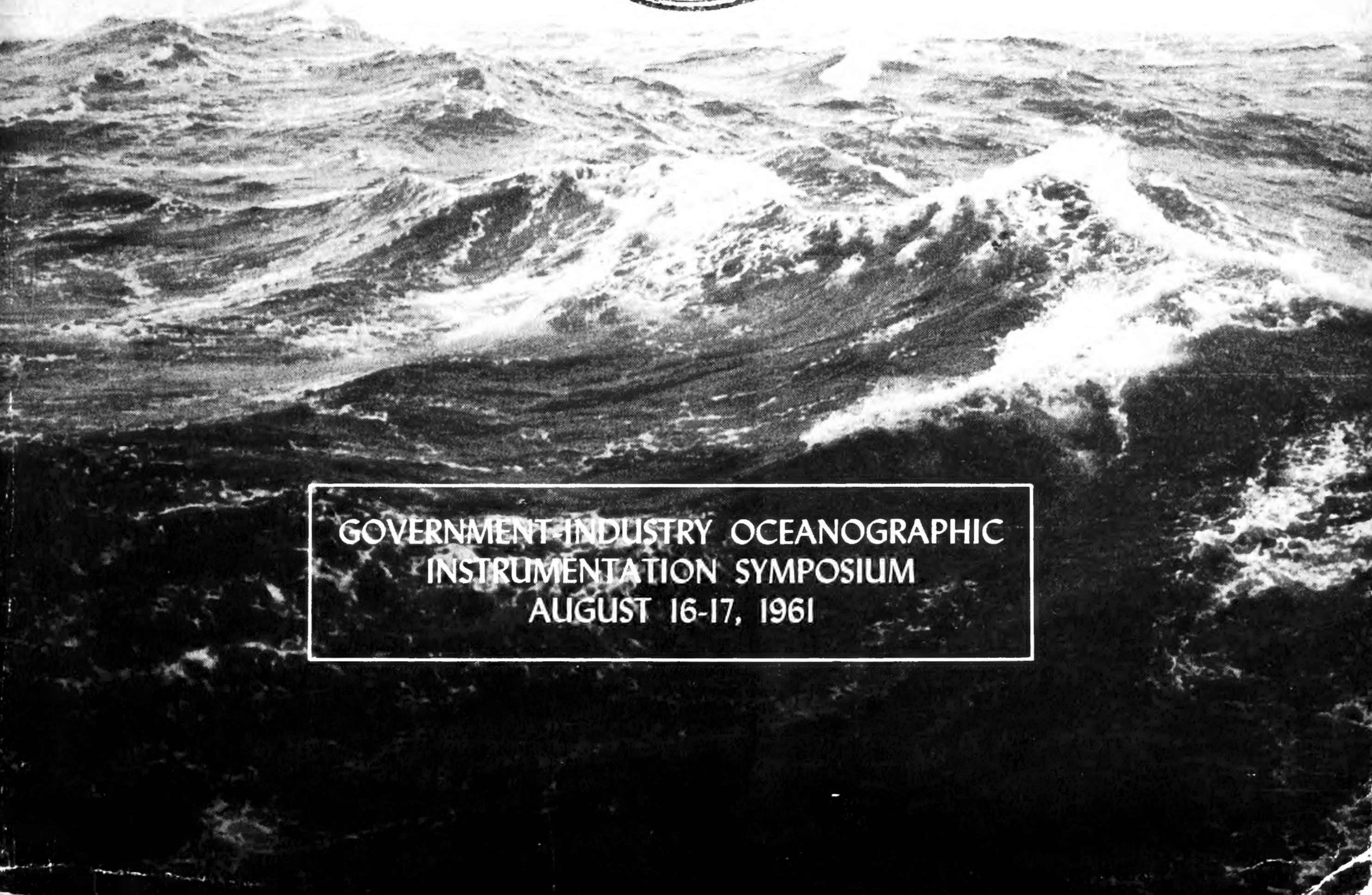
Interagency Committee on Oceanography
of the
Federal Council for Science and Technology
United States of America



GOVERNMENT-INDUSTRY OCEANOGRAPHIC INSTRUMENTATION SYMPOSIUM
AUGUST 16-17, 1961

Photograph by R. Wright
Woods Hole, Massachusetts

PROCEEDINGS

GOVERNMENT-INDUSTRY OCEANOGRAPHIC INSTRUMENTATION SYMPOSIUM

JAMES M. SNODGRASS, Head, Special Developments, Scripps Institution of Oceanography

HON. JAMES H. WAKELIN, Jr., Assistant Secretary of the Navy for Research and Development and Chairman, Interagency Committee on Oceanography.

FRONTISPIECE

REAR ADMIRAL EDWARD C. STEPHAN, Oceanographer, The Navy

DONALD L. McKERNAN, Director, Bureau of Commercial Fisheries, Chairman, Panel on Facilities, Equipment, and Instrumentation, ICO, and Chairman of Symposium

PROCEEDINGS

GOVERNMENT-INDUSTRY OCEANOGRAPHIC INSTRUMENTATION SYMPOSIUM

Washington, D. C.
August 16 and 17, 1961

Sponsored by

INTERAGENCY COMMITTEE ON OCEANOGRAPHY

of the

FEDERAL COUNCIL FOR SCIENCE AND TECHNOLOGY

Julius Rockwell, Jr. - Editor

Miller-Columbian Reporting Service
931 G Street NW
Washington 1, D. C.

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ABSTRACT

The proceedings include the 25 papers presented at the Government-Industry Oceanographic Instrumentation Symposium by top administrators and scientists, answers by panel members to questions received from the floor, lists of the scientific and industrial laboratories concerned with oceanographic research and development, lists of instrumentation developments now required for oceanographic survey and research, and other miscellaneous information.

It was pointed out in these papers that: Our Nation's lines of defense, weather control, new sources of protein, and untold mineral wealth lie in the sea, and it is essential that we increase our understanding of this important portion of man's realm.

A major requirement for the necessary growth in oceanography is the availability of reliable, precise, and easily-used instruments to record the parameters of the oceans. Most of our present-day instruments are of primitive design and largely of the "homemade" variety. A great movement is now underway to introduce new devices and modern techniques into this field. The entire ocean floor, three quarters of the earth's surface, must be mapped in topographic and geological detail. The conditions affecting the transfer of sound must be known in general principle and in specific local detail. The earth's heat budget and energy transfers from the atmosphere to the water must also be defined. The range of the animals and plants in the sea and the extent and nature of the environment affecting the individual species must be understood if they are to be harvested efficiently, and if the farming of the sea is to become an accomplished fact. Rock specimens, cores, deep drilling, and the strata of the ocean bottom must be plotted if we are to use the sea's mineral resources. Many of the instruments to do these tasks have been invented; many have not yet been conceived; some are still in the predevelopment stage and much refinement needs to be done to make them generally applicable. The instrument needs for the rapidly expanding National Oceanographic Program were comprehensively outlined in the two-day Symposium. Industry was invited to assume an ever-increasing responsibility in this field.

"Two-thirds of the earth's surface is covered by the waters of the seas. The waters themselves greatly affect our lives -- they play a major role in governing our climate; they provide inexpensive transportation; from them we derive important quantities of nourishment; they have traditionally provided protection against military attack. Beneath the surface a myriad of wonders is concealed. There are trenches, the floors of which are as much as 7 miles below sea-level. Mountains which approach Mt. Everest in height rise up from the ocean floor. Sediments in the ocean deeps contain detailed records of earth history -- and, associated with it, life history. The more than 300 million cubic miles of water contain huge assemblages of living matter of fantastic variety.

"As our technological civilization increases in complexity, as human populations grow more and more rapidly, as problems of military defense become increasingly difficult, as man pushes forward with his relentless quest for greater understanding of himself, his origins and the universe in which he lives -- as all of these changes take place, detailed knowledge and understanding of the oceans and their contents will assume ever greater importance.

"Man's knowledge of the oceans is meager indeed when compared with their importance to him."

From "Oceanography 1960-1970"
National Academy of Sciences --
National Research Council

PREFACE

The Government-Industry Oceanographic Instrumentation Symposium, held August 16-17, 1961, in the Interior Auditorium in Washington, D. C., was sponsored by the Interagency Committee on Oceanography (ICO), a permanent committee of the Federal Council for Science and Technology. The purpose of this meeting was to facilitate communication between Government and Industry in the area of instrumentation requirements and development programs. The National Oceanographic Program was not only new to much of Industry, who desired to contribute to its progress, but the agencies engaged in oceanography recognized the need for industrial technological assistance in these developments.

However, this diverse program includes activities and programs in twenty-three agencies:

Department of Defense

Navy

- Bureau of Naval Weapons
- Bureau of Ships
- Navy Hydrographic Office
- Navy Weather Service
- Office of Naval Research

Army

- Beach Erosion Board
- Corps of Engineers

Department of Interior

- Bureau of Commercial Fisheries
- Bureau of Mines
- Bureau of Sports Fisheries and Wildlife
- Geological Survey

Department of Commerce

- Coast and Geodetic Survey
- Maritime Administration
- Weather Bureau

Department of Health, Education, and Welfare

- Office of Education
- Public Health Service

Department of State

- Special Assistant to Secretary of State for Fisheries and Wildlife

Department of the Treasury

- Coast Guard

Independent Agencies

Atomic Energy Commission
National Academy of Sciences
National Oceanographic Data Center
National Science Foundation
Smithsonian Institution

Groups from various industrial firms have visited many of these agencies to present their capabilities and to learn how they might serve. Key agency personnel, on the other hand, have been meeting with their groups and have been giving guidance independently of each other.

The Symposium was conducted for ICO by its Panel on Facilities, Equipment, and Instrumentation to develop a common communication channel between Government and Industry and to provide Industry with a coherent statement of instrument needs. Top government administrators, operating engineers, and scientific experts from the Federal agencies and their contractors led the discussions. At the meeting were 540 representatives from Industry, 139 representatives from Government, 32 from nonprofit institutions, 22 from the press, and 4 individuals representing foreign nations -- a total of 737 attendees.

Because of the interest exhibited during the meetings, the ICO decided to publish the Proceedings of the Symposium. Wherever possible the material reproduced in the Proceedings has been reviewed by the contributor. During the Symposium several questions were submitted on cards to panels which, for several reasons, could not then be answered. These have been reviewed and answers have been provided where possible in appendix A. The lists of non-industrial scientific groups (appendix B) and industries (appendix C) are as complete as the data made available to the Panel. If a laboratory or firm has not been included, the Panel expresses its regrets. It is requested, for future listings, that groups concerned submit their names to the chairman of the Panel.

The full lists of requirements for instruments and instrument systems have been included (appendices E, F, G, and H). The sample "Oceanographic Bibliography" (appendix I) has been compiled from many sources. Comments on the books were provided principally by Jan Hahn, Woods Hole Oceanographic Institution and

Paul T. Macy, Bureau of Commercial Fisheries, Seattle, whose works are also listed in appendix I. The "Information on contacting government contracting agencies" (appendix J) was an interagency effort headed by Captain C. N. G. Hendrix. The basic information in the personnel biographies was derived from "American Men Of Science." i/

The Panel takes pleasure in thanking the editor and his staff, Mr. Donald Ingalls who laid out the illustrations, and the many members of the ICO, its Panels and all those who made this work possible.

Donald L. McKernan

Donald M. McKernan
Director, Bureau of Commercial Fisheries and Chairman of the Symposium.

i/ The Jaques Cattelle Press, Inc., Annex 15, Arizona State University, Tempe, Arizona.

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1. OPENING REMARKS

Donald L. McKernan

Bureau of Commercial Fisheries
Washington, D. C.

Welcome to this Government-Industry Symposium on Oceanographic Instrumentation. Many of you have traveled great distances to attend, and your interest and efforts are impressive. It is regretted that all of those who wished to attend could not do so for limitation of space.

The President of the United States in his letter of March 29, 1961, to the President of the Senate called for increased efforts in the broad field of oceanography to chart and map the bottom topography accurately, and to increase our knowledge of the physical, chemical, and biological phenomena of the sea. He wrote: "Knowledge of the oceans is more than a matter of curiosity. Our very survival may hang on it. Although an understanding of our marine environment and maps of the ocean floor would afford our military forces a demonstrable advantage, we have thus far neglected oceanography. We do not have adequate charts of more than one or two percent of the oceans. ...... The seas also offer a wealth of nutritional resources. They already are a principal source of protein. They can provide many times the current food supply if we but learn how to garner and husband this self-renewing larder. To meet the vast needs of an expanding population, the body of the sea must be made more available. Within two decades, our own nation will require over a million more tons of seafood than we now harvest."

Past oceanographic surveys and research have been studied by Government and non-Government research agencies, important Congressional Committees, and private groups to assess the Nation's needs in the whole broad field of oceanography during the coming years. A ten-year program is being executed which implements the President's desire to broaden the scope of research and to increase our knowledge of the oceans. This program includes new ships, new shore facilities, many new instruments, and novel structures with which to probe the depths of the ocean.

Data must be obtained from the oceans and then be reduced and analyzed by new types of cumputers on ship and shore. It must be gathered in a standard form, compatible with automatic handling and processing, so that scientists and engineers in the various fields of oceanography can readily utilize these data to their fullest extent. To gather this data, new instruments must be developed which are precise, reliable, and easy to operate under the ambient working conditions. The cost of developing and procuring the most efficient and reliable equipment is small when compared to the cost of ship construction and operation.

The administrators of the Navy, Coast and Geodetic Survey, Bureau of Commercial Fisheries, and other Government agencies which operate large oceanographic progams realized that the need for better oceanographic instruments was the most serious obstacle and that some way was needed to coordinate the Government's effort to develop and procure them. The Symposium was brought about to effect a meeting between industry members interested in working with Government and non-Government oceanographic agencies and institutions and the field oceanographers to discuss problems associated with instrument development and manufacture. By such wholesale contact much time and money could be saved, because many companies are inquiring of Government and non-Government oceanographic departments and institutions how they might contribute their unique talents to develop new oceanographic instruments. If the objectives of the oceanographic programs were made known, the special knowledge of industrial engineers and scientists might provide radically new ideas of instruments and exotic methods to observe and measure natural phenomena in the sea. Out of a discussion of these ideas the Government-Industry Symposium was conceived. It is a somewhat new technique in the field of science and may be quite imperfect. We believe, however, that such a forum will improve communication between oceanographers and American industry so that the broad experience of the first and the great talent and ability of the second can combine to meet one of the greatest challenges of our time, the exploration of the sea.

For the purposes of this Symposium we are considering an oceanographic instrument as (1) a device used to measure a quantity or quality of the sea, be it physical, chemical, or biological, such as temperature, salinity, density, depth, current, wave motion and direction, radiation, water transparency, light absorption, ambient light, tides, gravity, geomagnetism, or bottom structure or form; (2) an advanced positioning device or a device to collect samples of water, marine plankton, marine fishes, and the bottom including core samples for scientific purposes; or (3) a device for observation and manipulation. Not included are operational devices such as commercial fishing devices, mining devices such as oil well drilling, and strictly military equipment for detection, identification, classification, or destruction of military objectives. On the other hand, it is recognized that there is a number of kinds of instruments which have an indirect bearing at least on the collection of accurate, precise oceanographic data. We will be pleased to consider these instruments also.

The primary objectives of this Symposium are to focus attention on oceanographic instrumentation and to inform representatives of the industry of the United States about the known oceanographic instrumentation requirements of the operational and research agencies. To fulfill the national objectives in this accelerated oceanographic program, we need vast improvement in instrumentation, at sea and in the laboratory.

The presentations and discussions of the next two days are unclassified. They reflect the requirements of Federal and non-Federal activities in military and non-military applications. They cover the needs for basic and applied research and for surveys on research and ocean survey vessels. Discussions will involve instruments to be used with ships underway and ships stopped on station. The subject matter will cover a number of disciplines including physical, chemical, and biological oceanography, marine geology, geomagnetics, gravity, bathymetry, radiobiology, special fisheries investigations, and others. You have been invited because your companies have indicated an interest and capability to develop and produce instruments of the kind needed in the Nation's accelerated oceanographic program.

During the Symposium, we will indicate those areas where the development and production of oceanographic instruments are most needed and the extent to which the Government is prepared to enter into cooperative agreements in developing and producing them. Also, our purpose is to indicate the limitations imposed on the development in this field in order that a proper balance between all aspects of our oceanographic program are achieved in view of available funds, manpower, and facilities.

In addition to Government administrators of oceanographic programs, specialists are present to participate formally or informally in the discussions. Opportunities will be afforded during and between the discussions to permit informal meetings of members of industry and other members of the oceanographic community. In this way we feel that maximum interest will be developed so that both industry and the operating oceanographers will be stimulated to think and develop new ideas for measuring and observing natural phenomena above, on, and in the sea.

This morning we will hear from a number of Government administrators in the oceanographic field headed by the Chairman of the Interagency Committee on Oceanography, the Honorable Dr. James H. Wakelin, Jr., and other Government and non-Government officials. This afternoon and tomorrow we will discuss in more detail certain phases of the oceanographic program and the needs for various systems of oceanographic instruments.

As a result of this meeting, we hope that your companies will learn of the need for the development of more precise, efficient, and reliable oceanographic instruments with which to equip our oceanographic vessels for work on and in the oceans of the world.

2. A WELCOME TO THE GOVERNMENT-INDUSTRY OCEANOGRAPHIC INSTRUMENTATION SYMPOSIUM

Hon. James H. Wakelin, Jr.

Department of the Navy
Washington, D. C.

I am delighted to see the results of the long efforts in planning and programming for this particular meeting, which is a milestone in the relationships between our industrial laboratory scientists and development people and those in the scientific fraternity and institutions and in the Government doing oceanographic research and surveys.

Let me say this is by no means a casual gathering that you are attending and casually planned or appreciated. Dr. Jerome B. Wiesner, the President's science advisor, and his staff -- Dr. Edward Wenk, Jr. and Dr. Robert N. Kreidler -- Dr. Harold Brown, the Director of the Defense Research and Engineering for Mr. McNamara and ourselves in the Navy, and I might add also the President's personal interest -- has on the executive side, together with many committees in the House and the Senate, created a national interest in the whole subject of oceanography, both for our own welfare and for our security.

So let me say personally, and in part as the Chairman of the Interagency Committee on Oceanography, I hope you will seriously consider the problems that are laid in front of you today and suggest to us solutions that are real and practical and which we can use to get on with our oceanographic work in the national effort.

The reason we have turned our attention more seriously than previously to the sea is not a result of recent publicity campaigns, but because of a coordinated look at our program from a number of vantage points, which indicated that during the last thirty years we were not in effect giving the proper attention to those areas of oceanography which are both economically and militarily important.

As you know, the oceans hold both a threat and a safeguard to our security. There is a large, and for the most part, untapped source of protein food in the sea that could be used to feed the hungry peoples around the world. Vast mineral treasures may lie in the mysterious mountains of the depths -- close and available. Also, the earth's weather is determined in large part by the currents and movements of the sea. It is in our best interest to hold and maintain a position of world leadership in the development of the oceans for the benefit of all mankind. And, lastly, is the factor which can never be completely denied: Man's quest for knowledge -- the inexorable pull of the unknown.

All great periods of history have been ushered in by men who moved into new areas and opened new territories. They were led by this same desire, a thirst for knowledge. Now, as a bit of background, in 1959 the country's attention was drawn very sharply to the importance of oceanography when the Committee on Oceanography of the National Academy of Sciences published their report, "Oceanography 1960 - 1970," which stated that, relative to other sciences, progress in the marine sciences in the United States was indeed slow. There was agreement that our marine environment was not understood to a degree that was considered adequate to our security, economy, and welfare.

In its review of the Nation's progress in oceanography, the Federal Council for Science and Technology determined that oceanography was, indeed, an area of science which required emphasis and support at the highest level. In January of 1960, therefore, the Federal Council established as a permanent Committee within the Council, the Interagency Committee on Oceanography. The primary purpose of this Committee -- or, as it is called, the ICO -- is to provide a coordinating mechanism among all Government agencies engaged in oceanographic activities for the development of a meaningful national program. This Committee, as it is now constituted, has representation from the following departments and agencies: Defense, Commerce, Interior, Health, Education and Welfare, State, Treasury, the Atomic Energy Commission, and the National Science Foundation.

You can well imagine the scope of our considerations and some of the problems we face in our deliberations to integrate the many diverse aspects of oceanography represented in the vital missions of each of these agencies. However, through the ICO, we are attempting to achieve balance between the need for basic and applied research, the need for new ships and shore facilities, and new instrumentation. We have established a number of panels to study these special subjects. This meeting on instrumentation which has brought us all together this morning was arranged by the Panel on Facilities, Equipment, and Instrumentation of the ICO. And I must say that I congratulate the Chairman of this meeting, together with his conferees in Interior and those in the Hydrographic Office of the Navy and the other members of the Panel, for such an effective program as has been laid out for these two days.

During its brief history, the ICO has taken several major steps toward a coordinated National Oceanographic Program. The first of these was the establishment of the National Oceanographic Data Center here in Washington. The Data Center, which is financed cooperatively by several member agencies of the ICO, receives, processes, stores, and distributes many kinds of data on the oceans. Its purpose is to make the data available rapidly and in proper form for scientific research and operations in oceanography. The Data Center currently is under the management of the Hydrographic Office. It serves the needs of civilian, military, and private institutions as they arise. We are proud to state that the National Oceanographic Data Center became a reality through the efforts of many scientists and members of government working and planning together -- and I might say also through our many friends who help us in the Congress of the United States. It is an example of what can be accomplished through a coordinated pooling of effort backed by a strong common interest that we all have in these agencies in the field of oceanography.

The ICO is now intent upon developing greatly improved instruments and tools with which to conduct oceanographic research and surveys. This will require the cooperation of scientists in and outside of Government, and the special knowledge and engineering talents of industry which can be brought to bear on these problems. Our success in this phase of our National Oceanographic Program will, in a large measure, determine the success and cost of the many phases of research, surveying, data processing, and analysis which lie ahead. Many of the requirements for measurement of ocean variables are well known; others are yet to be defined or discovered. However, problems in connection with the submarine threat, radioactivity disposal and fallout, resource development, weather prediction, applied and basic research and survey operations have a common denominator: They all require accurate measurement of some kind of parameter in the ocean environment.

As I have stated, a large number of Government agencies have vital interests in the oceans. Brief summaries cannot adequately describe their work, but I believe that some mention should be made in terms of their particular interests in the marine environment.

The Department of Defense, with its complex military operations above the sea, on the sea, and under the sea, urgently needs much more detailed knowledge about the ocean than is presently available. Submarine developments during the last few years have made this dramatically clear.

The responsibilities of the Department of the Interior require an understanding of physical and biological effects of the marine environment on the living resources of the sea. The improvement and extension of fishery prediction techniques will help to extend and improve domestic and distant sea fisheries, and the knowledge so gained will lead to a more controlled and productive harvest. Fisheries are assuming increasing importance in international relations, and particularly through the avenue and the vehicle of oceanography.

Within the Department of Commerce, the Coast and Geodetic Survey is making a major contribution to the national effort through its participation in oceanwide survey programs. Of equal significance are the comprehensive coastal survey operations undertaken to acquire knowledge on the characteristics of our near-shore environment. At the surface of the seas, the ocean of air and the ocean of water exert profound influences upon one another. The Weather Bureau is engaged in research to improve our knowledge of these conditions, and now has operational automatic monitoring stations. I might add also, the whole problem of interchange of energy between the atmosphere and the sea is a most important area with which we should be seriously concerned in the region of instrumentation.

The Atomic Energy Commission, of course, is interested in the effects of radioactive materials on the marine environment. The ocean is the ultimate destination of a major portion of radioactive fallout. The ocean itself may be a potential disposal area for atomic wastes. We should make every effort to increase our knowledge of the ultimate effect of radioactivity on all marine life.

The National Science Foundation is a major supporter of oceanographic research at civilian institutions and oceanographic laboratories. Further, the President has designated the National Science Foundation as the coordinator of the United States activity for the International Indian Ocean Expedition, which is now in progress and which will go on for the next several years. Data from this expedition will add appreciably to our knowledge of this inadequately known area.

Each problem in oceanography, whether in connection with military, scientific, or economic problems, requires information that is not now available. During recent months much has been said, implied, or surmised about instrumentation and its needs in oceanography. One of the purposes of this Symposium is to present from a coordinated point of view of the agencies represented in the National Oceanographic Program the data requirements for a wide variety of applications. These must be translated into instrumentation requirements which must be satisfied if the National Oceanographic Program is going to proceed efficiently. We feel that through this coordinated expression of requirements you will be able to gauge those areas of the future oceanographic instrumentation program in which your segment of industry may give us the assistance that we need. A large share of the work necessary to conduct a vigorous instrumentation program -- and by that I mean new ideas, research, development, production, engineering, and manufacture of instruments -- must come from private industry. We feel that you will be in a much better position to help us in meeting this challenge in oceanography if you are informed of our goals and the problems we face. We are in a large part dependent upon you for the creative imagination necessary to develop new devices to increase the effectiveness of our program.

And now, on behalf of the Interagency Committee on Oceanography, I wish to express our sincere appreciation for your attendance at these meetings today and tomorrow. We welcome your participation in the National Oceanographic Program.

3. RESEARCH ASPECTS OF THE OCEANOGRAPHIC PROGRAM

Rear Admiral L. D. Coates

Office of Naval Research
Washington, D. C.

It is a genuine pleasure for me to be here this morning to discuss with you the research aspects of the oceanographic program.

As you may have noted from the agenda, we are making a distinction between research and surveys in connection with the problem of improving oceanographic instrumentation. I would like first to explain why we are making this distinction, and also where the two aspects of oceanography overlap and in what ways they differ, because these factors have a bearing on Industry's approach to assisting us in this instrumentation problem.

One reason for discussing research separately from surveys comes about because each function is pursued, to a large extent, as the primary mission of different Federal agencies. For example, the majority of the survey work is performed by the Coast and Geodetic Survey and the Navy Hydrographic Office. You will hear more about the Survey program from the next speakers, Rear Admiral Pierce, United States Coast and Geodetic Survey, and Rear Admiral Stephan, the Hydrographer. Similarly, we find the research program conducted throughout a number of agencies such as the National Science Foundation, Atomic Energy Commission, Bureau of Commercial Fisheries, and the Office of Naval Research, as well as the Coast and Geodetic Survey and Hydrographic Office. In general, much of the research is supported at private institutions and laboratories in contrast to the nearly complete governmental operation of the survey program. This diffusion of research effort adds to the difficulty in providing an integrated and coordinated instrumentation development program.

Secondly, the nature of basic research itself is such that new ideas, new techniques, and new materials often provide the direction in which a continually changing research program will proceed. To be efficient in this type of operation, the research scientist must be very closely allied with the development of his instruments. Again, this is in contrast to the survey situation where most of the measurements are of a routine nature, therefore, the instrument requirements can be made known in advance.

The contrasting situations between research and surveys I have just described illustrate why a different approach to their respective instrumentation problems is desirable. As I have mentioned earlier, however, there are many instances where the two aspects overlap, the difference between research and surveys being primarily the purpose for which each is being performed. For example, a bathymetric survey may entail a description of the bottom topography needed for navigational purposes. In such a survey, the description or resulting chart is the end product. The same information may be desired by the research scientist who is interested in learning about the origin of the features of the ocean bottom or to prove his hypothesis on the structure of the sea floor. In either case, I am sure you recognize the same instrument could be used to do both jobs. In fact, for the majority of the cases of routine measurements, survey and research instruments will not differ. Consequently, the list of survey instruments you have received will also provide a guide for some of the routine instrumentation needed aboard the new research ships (fig. 3.1). Here the instrumentation for research and surveys will be handled as a single program.

In addition to instruments required for research ships, we are faced with an increasing need of special platforms from which to carry out our research programs. These special platforms each have peculiar and often difficult problems, of which you will hear in more detail tomorrow. Among the platforms required are specially adapted and instrumented buoys, both anchored and drifting, which must be capable of measuring, recording, and in many cases, telemetering information over large distances. Of a similar, but perhaps simpler nature, are the requirements for instrumentation aboard fixed towers (fig. 3.2) such as the Texas Towers, oil platforms, and other platforms now being installed by the Coast Guard to replace lightships. Deep sea research vehicles are already a reality and the part

FIGURE 3.1
U.S.S. ARGO (ARS-27)

This auxiliary rescue and salvage ship, has been extensively altered by the Puget Sound Bridge and Drydock Company, under contract with the Office of Naval Research. Operated by the University of California's Scripps Institution of Oceanography, the 2,000 ton ARGO is 213 feet long and their largest. She carries a six-ton crane, a 45,000-foot step-down cable, and 25,000 feet of half-inch cable, and was the first research ship equipped with scanning type search sonar, precision depth recorder, and a deepwater echo sounder.

FIGURE **3.2**
ARGUS ISLAND

Installed 30 miles southwest of Bermuda on top of an extinct underwater volcano, this tower is used as a relay point for hydrophones placed on the ocean floor and for other oceanographic observations.

they will play in research depends heavily upon the imagination that is used in their instrumentation programs (figs. 3.3 and 3.4). At the other end of the spectrum we find that aircraft are being put to increased use in oceanographic research. The rapid search rate of the airplane, if properly instrumented, makes it more satisfactory for some purposes than the research ship. It can be anticipated that the development of these platforms and their associated sensor, recording, and telemetering systems will represent a major interest of our research programs.

Now that I have outlined some of the areas in which Industry might participate in oceanographic research, I would like to mention how I feel Industry can be of assistance. First, the problem of what instrumentation needs to be developed is known best by the scientist, not by an administrator sitting in Washington. I do not mean by this remark that you should invade the private laboratories, for this would hinder rather than help the situation. What needs to be done is to develop some mechanism whereby the scientist can be made aware of your capabilities and interests and also a mechanism whereby the same scientist can get funds to pursue his requirements. In my opinion, neither mechanism now exists in an adequately coordinated form. I hope the establishment of such a mechanism will be one of the results of this Symposium.

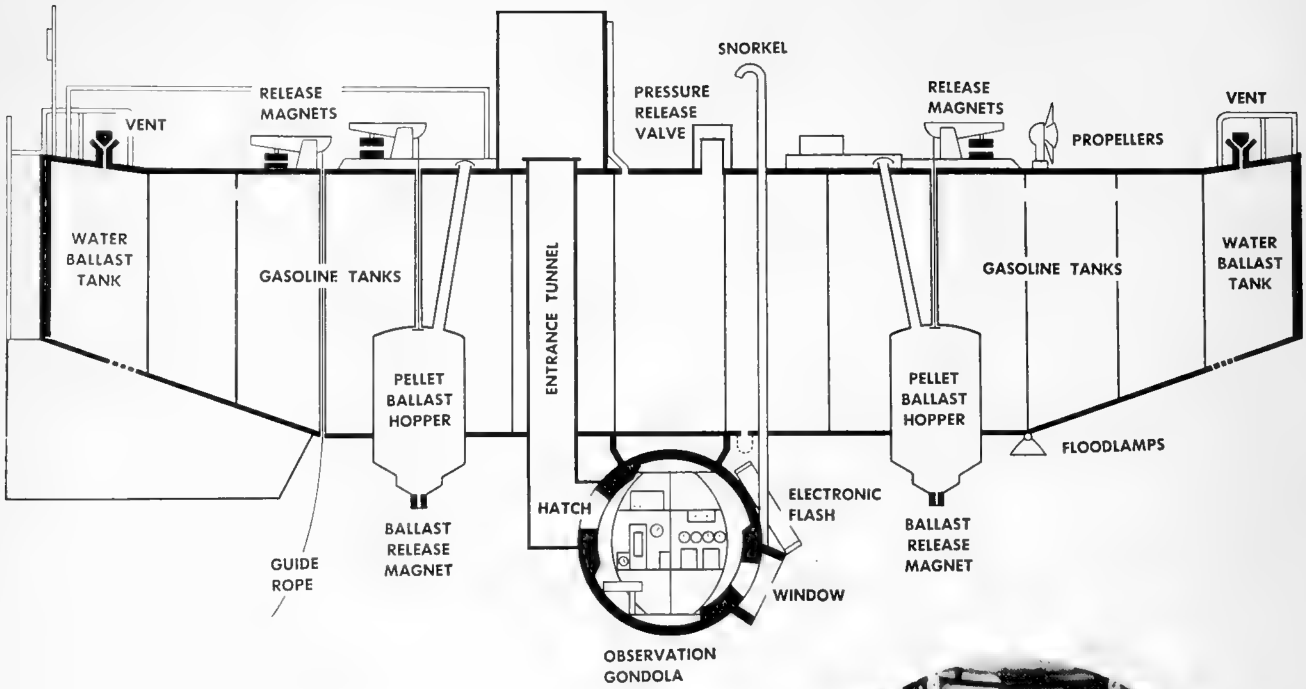


FIGURE 3.3
BATHYSCAPHE

The Navy's Bathyscaphe Trieste set an alltime depth record off the Island of Guam in the Pacific on January 23, 1960, when it plunged 35,800 feet to the bottom of the Marianas Trench. This dive, one of a series in the oceanographic programs of the Office of Naval Research and the Navy Electronics Laboratory (San Diego), was the result of two years of planning. The objectives of Project Nekton were to gather basic information about the penetration of sunlight, underwater visibility, and transmission of manmade sounds, and to conduct marine geological studies of the trench.

INSIDE THE OBSERVATION GONDOLA, DR. ANDREAS B. RECHNITZER AND LT. DON WALSH CHECK INSTRUMENTS.

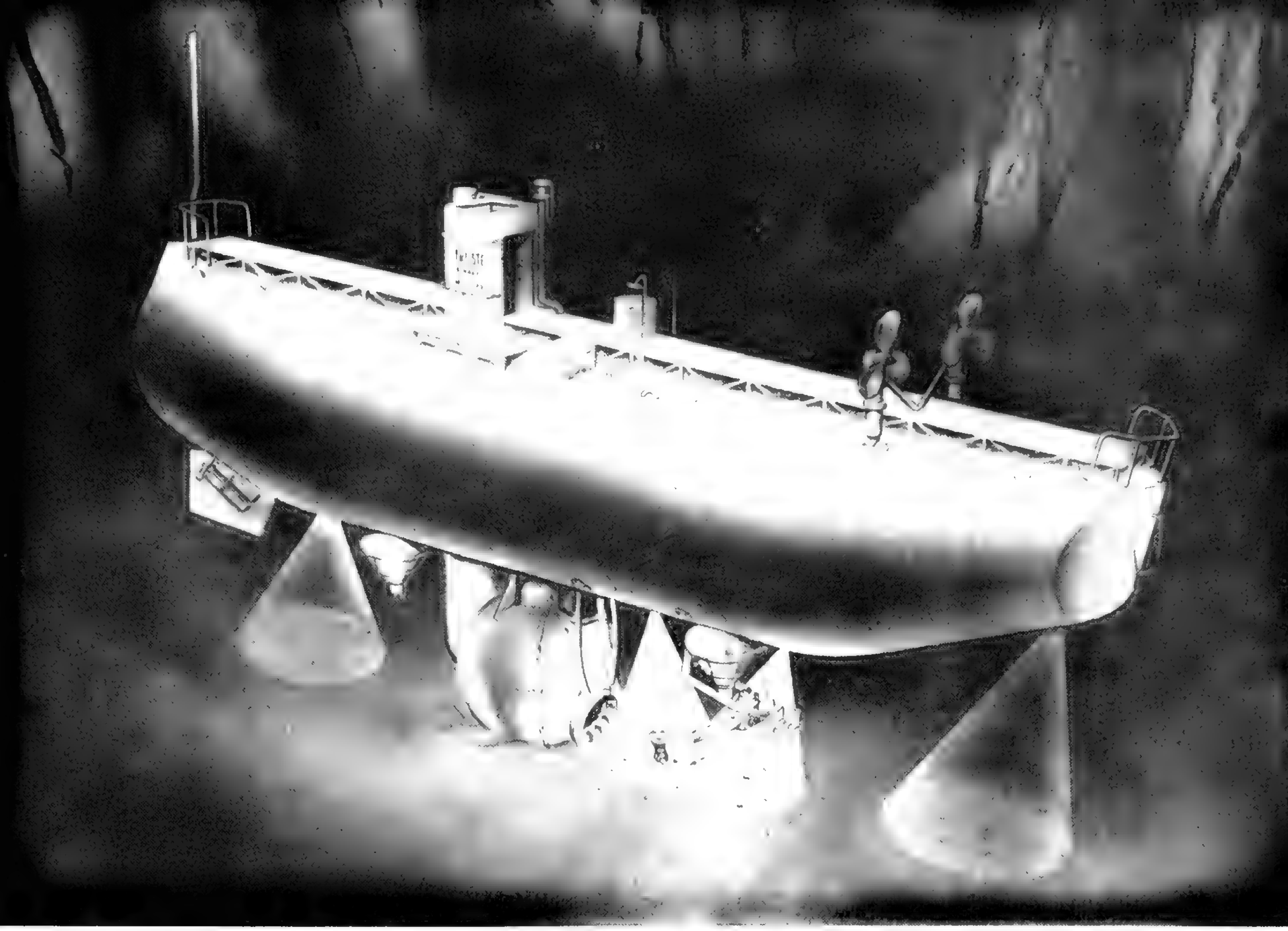


FIGURE **3.4**
TRIESTE REVISED

When the Navy's deep-diving Bathyscaphe Trieste makes its next descent to the ocean floor, it will be equipped with a mechanical arm that can reach out and pick up samples of material from the mysterious and little-known depths, some even seven miles below the surface. A General Mills mechanical arm manipulator adapted to withstand the tremendous pressures of 8-9 tons per square inch encountered at the deepest parts of the ocean, will provide this unique capability. The Trieste "arm" will be modified by means of special oil-filled units designed to equalize pressures on motors and other critical parts. Oceanographers riding in the steel ball suspended beneath the Trieste will control the device by means of a compact control box with individual lever action switches to provide direction and continuously variable speeds for each of six motions. The Trieste program is under the joint sponsorship of the Bureau of Ships and the Office of Naval Research.

A second thought concerns the efforts being made throughout Industry to develop capabilities and know-how using research funds available within Industry. These efforts should be directed, whenever possible, along lines which will be most fruitful. This can be determined again only by a close alliance of Industry and the ultimate users of the instruments. What we do not want to do is waste talent and money on things already done, already proved useless, or already determined not necessary.

In closing, I would like to mention briefly a few items for the guidance of your efforts.

I would not like to see anyone led into this instrumentation program on false premises. The number of instruments required in the oceanographic research program is small compared with a program like outer space. On the other hand, the market should be challenging and stable for many of you.

The marine environment is particularly troublesome for both man and his instruments. Neither seems to work at peak efficiency while at sea. Perhaps this has been the greatest single factor adversely affecting instrumentation at sea. Please keep it in mind at all times.

The last point I would like to get across concerns a problem which has plagued us in sonar research for many years. This has to do with the increased complexity and cost of sophisticated instruments. Along with this we have the problem of reliability and number of technicians required to keep the equipment operating. At this time oceanographic research needs rugged, reliable, long-lifed equipment rather than the ultrasophisticated expensive items.

4. SURVEY ASPECTS OF THE OCEANOGRAPHIC PROGRAM

Rear Admiral Charles Pierce

United States Coast and Geodetic Survey
Washington, D. C.

Since I retired on the first day of this month as Deputy Director of the U. S. Coast and Geodetic Survey, my remarks reflect my opinions and are also based upon the reports of the Committee on Oceanography of the National Academy of Sciences and the reports of the various panels of the Interagency Committee on Oceanography.

The greatly increased attention now focused on the marine environment has been caused by several factors. Spectacular developments in submarine design and use have resulted in an urgent requirement for knowledge of the water volume, its density, structure, acoustic propagation conditions, subsurface currents, bottom materials, as well as its physical dimensions -- depth, shoreline configuration, and location. Competitive factors in merchant shipping have also brought out deficiencies in our knowledge of oceanic and coastal conditions. Optimum ship routing and transit times require more extensive knowledge of water depths, coastal currents, prevalence of limiting sea and swell, etc. Similarly, the application of scientific principles to fisheries control and exploitation has pointed up the necessity for detailed seasonal data on water properties, biological productivity, water mass mixing process, etc. We need today, and have for some years, maps, charts, and pertinent data of the ocean basins comparable to what we now have of the land areas.

Ocean surveys must obtain data to show the shape of the sea bottom, types of sediments, gravitational and magnetic fields, distribution of temperature, density, and surface and subsurface currents, and must execute such other investigations that will least interfere with the primary mission of a ship underway. Multiple-ship and buoy operations may provide synoptic data on currents, temperature, waves, etc. The program requires an extensive collection of data, samples, recording of observations, analysis, and distribution of the data.

The assumption is that the participation of the United States in an international program requires the exploration of roughly 30 percent of the world's oceans. The vastness of the international program is apparent from the following figures: The oceans cover 360 million square kilometers; of these, 36 million comprise the continental and insular shelves; nearly 30 million are covered by Arctic ice; approximately 300 million square kilometers require exploration and investigation. If track lines are run at every 15 kilometers, survey ships have a task of sounding along some 20 million linear kilometers of ocean exclusive of development of unusual submarine features and cross check lines.

For an eight-month operating season, a ship cruising at 12 knots might theoretically accomplish this task in 200 years. The National Academy of Sciences' Committee on Oceanography estimates for the underway portion (hydrographic, magnetic, gravity, etc.) and the anchored or hove to station ships (physical, chemical, synoptic, biological, and bottom sampling surveys) will require 261 ship-years -- for the United States participation this is about seventy-eight ship-years, eighteen ship-years for the station ships, and sixty ship-years for the ocean bottom survey ships.

The great cost in ships and manpower demands that most expeditious and efficient methods be used to collect and process the data. Thus, many types of data must be collected simultaneously, and all instruments must be generating data of sufficient and known accuracy. With a ship cost of several thousand dollars per day, failure of a data system simply means failure of the program, as it is doubtful that, with the enormity of the task, reruns can be justified. Now this means that each instrument incorporate at each critical point in the operational sequence, alarms, or indicators of some sort, that alert the shipboard personnel when a casualty or a circuit failure occurs which degrades the system. Worse than no data is voluminous data of questionable validity. This quality control feature has been almost totally ignored in instrument design in the past. Frankly, we must accept nothing less than good quality control in the future.

Before completely dropping the topic of philosophy of instrument design (an area upon which I'm trespassing as it rightfully belongs to Mr. Snodgrass, scheduled later this morning) I must point to an instrument concept that is also properly a "Survey

FIGURE **4.1**
SHIP PIONEER

AVP conversion for oceanwide surveys.

FIGURE **4.2**
SHIP SURVEYOR

Latest design Hydrographic Ship.

Aspect."

We can readily give you data on the oceanic environment as it affects instrument packaging and ruggedness. The vibrations, humidity, voltage fluctuations, etc., which will make your design problems interesting are predictable, and we know you will compensate for them. Keep in mind, also, our management problems of personnel. Skilled electronic and mechanical personnel are hard enough for you gentlemen to recruit, train, and retain. The prevailing lower pay rates, long periods away from home, and frequently crowded living conditions aboard ship are not conducive to retaining sea technicians long enough to get their "20-year service pins." Accordingly, your instruments must not only be rugged but sophisticated, simple but flexible, precise but not broad in range, and primarily they must be maintained, essentially, by personnel with limited training.

Paramount requirements for an oceanographic survey ship assigned to ocean bottom surveys are seakeeping characteristics, an accurate and reliable navigational positioning system or systems, and a rugged depth sounder. These requirements are fundamental.

Depth measuring techniques have progressed steadily from the hand lead, to the steam and electric sounding machine before World War I, to the sonic depth sounder with the visual depth meter, to the graphic depth recorder in use just prior to World War II. Today we have the shoal and deep water depth recorders with the Precision Depth Recorder Auxilliary which can maintain constant frequency and from which recorded depths can be scanned to a fathom in the deepest water. Uncertainties in water sound velocity, of course, introduce errors in excess of one fathom. Development is continuing on narrow beam stabilized oscillators to provide vertical depths below the keel to replace the presently recorded composite profile of rugged submarine topography derived from echoes emanating from sources as divergent as 30 degrees on either side of the vertical.

Progress has not been nil in the development of electronic positioning equipment, but the requirements of ocean surveys place a strain on present systems.

Loran-A and Decca are examples of pulsed hyperbolic radio navigational systems for surface and air navigation which have proved invaluable to navigators worldwide. Loran-A does not provide sufficient worldwide coverage for ocean surveys; its 750-mile daytime range for ground waves is inadequate for the task and its accuracy is not substantially superior to a strong astronomical fix. Loran-A is found on most survey ships and should be standard equipment for standby duty.

Loran-C is a pulsed hyperbolic radio navigational system with five systems presently installed. Its superior accuracy and reliability is in part derived from its relatively low frequency of 100 kc., about 1/20 of Loran-A, and from its phase measuring techniques within the pulses to provide time differences to a few hundredths of a microsecond versus one microsecond for Loran-A. Loran-C has demonstrated accuracies in the order of one quarter of a mile using ground waves out to 1,200 miles from the stations and coverage to 2,100 miles for skywaves. However, the few systems installed to date are inadequate for oceanwide coverage and the cost of shipboard receivers in the initial stage of manufacture are relatively expensive. The Coast and Geodetic Survey has two Loran-C receivers aboard ocean survey ships operating in the Northeast Pacific.

Omega is a very low frequency, 10 kc., hyperbolic navigational system which tests indicate will provide accuracies of less than one mile over the entire globe, with less than 10 shore stations. Ranges are possible up to 6,000 miles during day or night. This system has been under development by the U. S. Navy since 1957. The system provides hyperbolic lines of position, the stations transmit sequentially in short bursts, and it utilizes skywaves. Indications are that when receivers are in production quantities, the price will be moderate. If and when the Omega system is operational worldwide, it appears to offer one solution to the need for an accurate and reliable navigational system.

The Transit Navigational System is in the research and development stage and until the reliability of the system and the cost of shipboard equipments is known, it offers no immediate solution for control.

My last comments concern the platforms we intend to use at sea. I favor for ocean survey ships a displacement of about 3,000 tons. I have served aboard all sizes of survey ships up to this displacement. There have been more occasions than I care to recall, with any degree of pleasure, when all efforts were expended in protecting life and property during storm conditions rather than executing the primary mission.

Ocean survey ships will encounter worldwide the gamut of sea conditions -- typhoons, hurricanes, short period anticyclonic storms, dangerous tide rips, and violent cross seas. They should be designed to keep at sea with a margin for all contingencies. They should have stabilization since excessive rolling interferes with acceptable depth recording, with handling oceanographic instruments, with winch operation, and with geophysical measurements. Further, due to inadequacies in seakeeping qualities and laboratory space, it has been the tradition to collect less accessible oceanographic data only during "good weather."

As the data of oceanography have accumulated and our knowledge of our deficiencies of knowledge becomes more apparent, we now know that seasonal variations occur. In some places significant mixing and transport phenomena may be restricted only to "bad weather." Surveys, therefore, must be made in bad weather if we are to understand our oceans. Some new ideas and new approaches are obviously required as the existing techniques are up against the "stops" as far as utilization is concerned.

Larger ships provide for adequate quarters for the authorized complement, for scientists and technicians, for trainees, and for visiting staffs. Laboratories, towed magnetometer space, deck space for winches, refrigeration space for specimens, and adequate storage space for long cruises, all, dictate for the larger ship and against the time-honored practice of using conversions, and makeshift craft of all descriptions.

We have not scratched the surface in the development of instrumentation for all the tasks confronting the oceanographic survey and research ships. The cost of these ships today is mounting steadily. A 3,000-ton ship can cost $3,000 a day to operate at sea. One approach to reducing the unit cost of obtaining data is through improvement in instrumentation which will result in obtaining more data in less time and with greater accuracy.

I think I have a couple of minutes left. I haven't made any conclusion, I found, after reading this, as to what a ship would use for control, right now, if it went to sea on this big program. We have one ship exclusively on oceanography in the Northeast Pacific. We selected the area because Loran-C which is available there has just recently become operational.

If we had to work in the South Pacific or if we had to do work in the Southern Atlantic, there is no modern equipment today that would give us the accuracy we need, nor the reliability. So we would have to go back to using whatever we could, which is going back to the sextant and to the astronomical fix.

We certainly need instrumentation and we need it quickly. I have enjoyed talking to you.

5. THE NAVY'S ROLE IN THE FIELD OF OCEANOGRAPHY

Rear Admiral E. C. Stephan
Hydrographer, United States Navy

Washington, D. C.

Because the ocean is the primary environment within which the Navy and its weapons must operate, it warrants special consideration in the Navy's program. Further, the propagation of energy within the ocean is more complicated and less understood than it is within the atmosphere. In submarine warfare, surface ship operations, and in the employment of weapons, the oceans and natural phenomena occurring in and over them introduce certain factors which must be considered. These factors are often critical in operations which involve:

1. Detection and location of objects below the sea surface;

2. Subsurface communications;

3. Maneuvering or maintaining a vessel or an object in a prescribed position and attitude on the surface or bottom or within the ocean; and

4. Habitability, as determined by temperatures, pressure, etc., for men and sensitive devices.

These oceanographic and geophysical factors and phenomena include:

1. Waves and the related water motion and pressures;

2. Variations in the earth's magnetic field;

3. Tides;

4. Sound propagation;

5. Currents;

6. Reflectivity and transparency of the ocean to electromagnetic energy;

7. Configuration and composition of the ocean bottom;

8. Habits and distribution of organisms within the sea;

9. Variations in the chemical and physical properties of sea water; and

10. The gravitational field.

Basic requirements for oceanographic publications for strategic planning and as a source of general information for use in developing weapons systems have been met by various studies and publications of the Hydrographic Office. These generally deal with mean conditions and in some instances, variations from these means. The more demanding problem of determining and documenting more exactly the variations and interrelationships of the oceanographic elements will require considerable effort. This is particularly true for the subsurface regions of the oceans. More sophisticated applications of oceanographic knowledge to the development of systems and tactics, as well as more precise forecasting of oceanographic changes, are dependent upon this work. It cannot be accomplished without a sustained serious effort by competent oceanographers. This constitutes one of the primary challenges for the Navy during the next decade. It will require improvements in our facilities for collecting, processing, and analyzing data rapidly.

At first glance, the task of adequately surveying all of the oceans of the world appears overwhelming. However, practical bounds can be established by coupling our survey plans to our study of the interrelationships and variability of the oceanographic elements. An appraisal must be made of the significance of these variations in the employment of naval weapons and tactics. For this work, also, a sustained effort is required, supported by ships designed, instrumented, and operated for this purpose.

In addition to publications directly related to military operations, the Hydrographic Office, as the primary center of applied oceanographic activity in the United States Government, publishes general oceanographic information. Variation of oceanographic elements, such as, currents, waves, and temperatures, are published for use by scientists, mariners, and the general public.

Future efforts in general atlas production will be keyed in with oceanographic data processing. The chief obstacle in the past has been that the huge volume of observational data from which such atlases were prepared had to be collected and tabulated by laborious and time-consuming hand methods. Reduction of the data to a form whereby computations and tabulations can be made automatically by high speed computers is underway at present. However, a considerable backlog of unprocessed data still exists. Once these data are processed onto punch cards or magnetic tape, a much more sophisticated treatment can be applied than has been used in the past. More accurate understanding of ranges of variation and probabilities of occurrence will be obtained from the large volume of data available only when the invalid observations can be eliminated and careful analysis performed.

General atlases are planned for all the major ocean areas of the earth. Each atlas will be composed of separate sections devoted to waves, temperature, currents, tides, bottom materials, sea ice, flora and fauna, and special topics. Information will be provided for subsurface depths as well as for the surface.

Despite the seemingly large volume of data on hand, a recent review of the data available for the North Atlantic reveals that for certain very large areas no data have ever been obtained. For ocean areas other than the North Atlantic the shortage is even greater. This points out a very definite need for a planned program of basic data collection. Several recent comprehensive reports have stressed the need for a much better understanding of the interaction of the submarine with its environment. The same may be said for all other aspects of naval operations. The first step in approaching this problem is to improve our knowledge of the oceans. The large gaps in the data must be filled.

The task of acquiring data in the deficient areas is only a part of the problem. Detailed, long-term continuous records are required in specific areas to permit a better understanding of the dynamic and climatic changes that are always taking place in the ocean. The total problem is therefore one of considerable magnitude and will call for a very careful assessment of our present holdings and the development of a well-planned and detailed schedule. This plan must insure that the program will actively support projects of high priority and primary interest.

The opportunities for collecting useful oceanographic information have often been more limited by the lack of proper instruments to sample the environment than by the availability of a vessel from which to sample. The initial cost of such a vessel and the operating expense greatly surpasses the expenditure required for proper instrumentation. Therefore, it is very clear that we must provide this instrumentation in order to make better use of these ships as information collectors.

In carrying out our mission over the years we have obtained a large number and variety of commercially available oceanographic survey instruments. The majority of these are nonstandard, not very reliable, and are seriously limited when it comes to rapid sampling in a manner compatible with machine processing of collected data. During recent years the Hydrographic Office has had the problem of supplying survey vessels with modern oceanographic instrumentation. This task has been extremely difficult for two reasons. One, reliable, sophisticated, and commercially available oceanographic instrumentation is practically nonexistent, and, two, the funds for researching and developing such instrumentation have been extremely limited. Our modern survey program calls for shipboard instrumentation that can be relied upon and that can be operated by technician class personnel rather than engineers. The funds that are available must be applied to the research and development of properly designed instruments and to the production engineering of these devices for use on a relatively large number of ships. The constant upgrading of instrumentation of poor basic design is a costly and ineffectual solution to the problem. Accuracy of measurement, reliability, ease of operation, and difficulty of maintenance are factors to be seriously weighed before going from prototype to production. An instrument of lesser accuracy and more reliability may often be suitable at considerably less expense. Similarly a device which is easy to operate but requires constant maintenance is impractical.

Later in the program other speakers will discuss the details of our requirements for instruments. The important fact to be kept in mind at all times is the urgent need to provide present and future ships with reliable tools for collecting oceanographic information. Such information is vital to the aims of the worldwide survey program as well as the problems of applied and basic research.

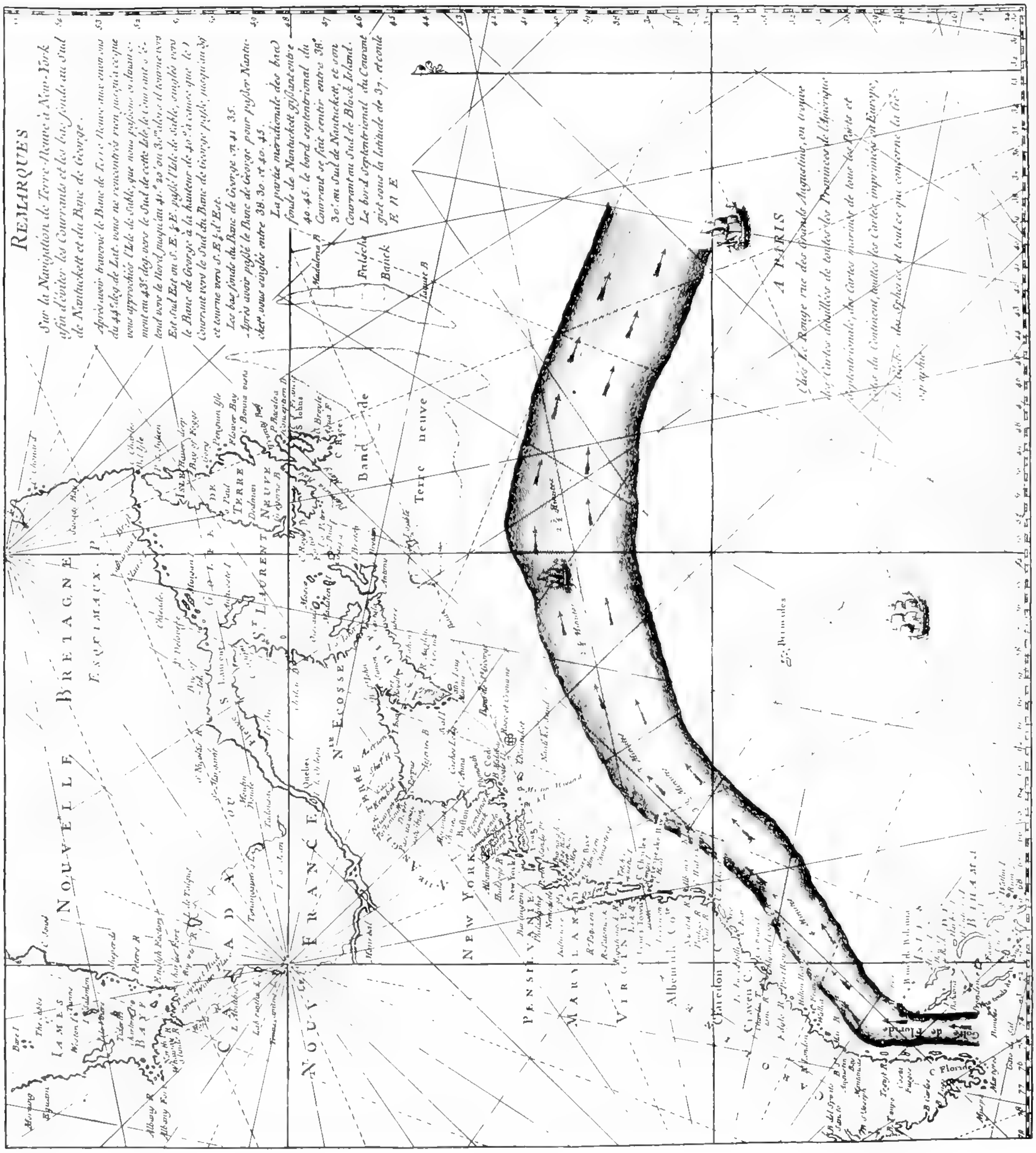


FIGURE **6.1**
GULF STREAM - BENJAMIN FRANKLIN

6. BRIEF HISTORICAL BACKGROUND IN THE DEVELOPMENT OF OCEANOGRAPHIC INSTRUMENTS, PRESENT STATE OF THE ART, AND SOME NEW CONCEPTS

James M. Snodgrass

Scripps Institution of Oceanography
La Jolla, California

It is rather difficult to know precisely what to say to a group of this sort. This is partly due to the tremendous spread of knowledge which you represent. Furthermore, I see a very large number of familiar faces in the audience. Some of the things which I am going to say you may well have heard before. Please excuse my repetition, but it is principally for the benefit of those who do not have the information you possess.

Some of the things which I shall choose to say are perhaps controversial. If so, I assure you that I have done this on purpose. I will attempt to give you some idea of the thinking that has gone into the development of oceanographic instruments, the nature of the background, principally the ocean environment, and the problems which the environment poses. Admiral Pierce mentioned the enormity of the problem. It is a truly challenging one.

Some idea of our problem can be gathered by the fact that 80 percent of the Pacific Ocean is over 3,000 meters deep. This corresponds roughly to a pressure of 4,300 p.s.i. (pounds per square inch). Some 27 percent of the Pacific Ocean, for instance, has depths in excess of 5,000 meters, which means that instruments near the bottom must be designed to withstand pressures in excess of 7,000 p.s.i. Further, there is an almost ridiculous contrast between the velocities which our oceanographic instruments must measure and those in the aerospace field. Manned vehicles measure velocities in Mach numbers; guided missiles and similar devices measure them in miles per second; while in the field of oceanography it is often necessary to measure velocities in centimeters per second.

For the sake of understanding better the scale of the problem, I will use an analogy that I credit to Mr. Thomas A. Manar of the Scripps Institution of Oceanography; it is this: Imagine, if you will, that we shrink the Pacific Ocean down to a lake 10 miles across. On this scale, the maximum depth corresponds to 60 feet. Further, let us place a toothpick on this lake. This toothpick represents the oceanographic vessels which we use. You have heard, of course, that the oceanographer uses cables to lower his instruments and to sample the bottom. On this same scale, it would take a filament finer than the finest spider thread to plumb this 60-foot depth. You can understand the apparent futility of trying to accomplish useful work with this extremely fine filament. This model illustrates the oceanographer's problem.

Many of you may be under the impression that the ocean is essentially a huge mass of homogeneous fluid. If this were the case, the ocean as we know it would not exist; it would be dead and without life. The inhomogeneities within the ocean make it tick, and in many cases make it possible for life to exist. These inhomogeneities are often small, but, due to the tremendous thermal capacity of the ocean, these small differences represent relatively large amounts of energy. Hence, the oceanographer often finds it necessary to make measurements with a precision which surprises his land-based colleagues. For instance, a temperature difference of one one-hundredth of a degree is often highly significant. Very small differences of electric conductivity are likewise important. Sometimes it is possible to take advantage of the geometry of a given system and measure a gradient directly. This is preferable to the common case where it is necessary to take differences between relatively large numbers.

Now I would like to turn back the clock about 200 years. Benjamin Franklin published a chart of the Gulf Stream in about 1782 (fig. 6.1). For its time it was a creditable task and well done. He discussed the work leading to it in correspondence as early as 1776. How he came to make this discovery is hypothetical -- probably by discussing and learning of variations in ship speeds or by talking with ship captains. He was an instrumental genius and proceeded to make measurements. He used two very simple devices, a bucket, probably a wooden bucket, with which he sampled water, and a thermometer, with which he made measurements of the water temperature. He was so impressed with his results that he developed what he called "thermometrical navigation," wrote considerably on the subject, and recommended it to many of his friends.

Nearly 200 years later marine technicians are still using the same tools (fig. 6.2). However, here, the bucket is metal, probably a retrogression and not as good as Benjamin Franklin's wooden bucket for thermal reasons.

At this point I will give you the other barrel. The oceanographer may find himself in the unenviable position of making measurements of dubious accuracy at uncertain locations. You heard Admiral Pierce mention the matter of navigational problems. You heard him say that the North Pacific was selected for the first ocean surveys because of the existence of a new Loran C installation. A tremendous mass of the Pacific and the South Atlantic has no modern electronic navigational aids. Ships operating in the equatorial areas often go for a week to ten days with no celestial fixes. You can understand why the oceanographer does not always know precisely where he is. Admiral Stephan referred to a dearth of adequate instruments. You can put two and two together at this point.

I will attempt to classify instruments -- a dangerous thing to do -- to give you some frame of reference: First are the pressure-protected instruments. These often take the shape of cylinders or spheres and are rigid, heavy-walled devices to withstand the pressure. Secondly, we have instruments designed to be in pressure equilibrium. These are often fluid-filled or they may consist of solid materials, modern potting compounds, etc. In these the internal components must resist the ambient pressure. It is sometimes easier to operate a pressure-equalized instrument than the pressure-protected type. Thirdly, there are surface or subsurface instrument buoys or instrument skiffs.

FIGURE 6.2
TECHNICIAN TAKING
"BUCKET TEMPERATURE"

There are three classes of pressure-protected instruments with which you may be reasonably familiar: Man-carrying vehicles, unmanned roving vehicles, and unmanned free vertical-moving vehicles.

A man-carrying vehicle may be a so-called free instrument like the bathyscaphe, Trieste (fig. 3.4 - 3.5), or a cable-connected device like the BATHYSPHERE (fig. 6.3) which preceded the bathyscaphe by nearly three decades.

Unmanned, roving, self-propelled vehicles may take the general shape of torpedoes. They may be preprogrammed devices which telemeter information to the surface and are controlled by acoustic telemetry.

The free vertical-moving instruments are designed to collect data as they go down and come back up to the surface without any connecting lines or wires. Some stay on the bottom and collect data and may be recalled to the surface at will.

In the pressure-equalized category there are a few manned vehicles. These include those made for carrying SCUBA divers. The cables of the unmanned cable-connected devices may be either electric or nonelectric. Some unmanned pressure-equalized devices are placed on the bottom.

Let us examine the effects of pressure on the individual components:

Resistors: The so-called composition types of resistors are in reality excellent pressure gauges which make them particularly treacherous if you haven't had experience. It is necessary to resort either to metallized-film resistors or to wire-wound resistors. Here, if you are being very critical -- though I don't think you need concern yourselves in general with this -- there still is a small pressure effect.

Capacitors: In general, the nonelectrolytic capacitors do not cause too much trouble. However, depending upon the type employed, one does need to be careful because of the residual space in the cases. Sometimes bubbles are left -- this is troublesome -- or the packaging is otherwise faulty. We have trouble with electrolytic capacitors which we would like to use for coupling transistor circuits. I am not referring to the so-called solid electrolytic types

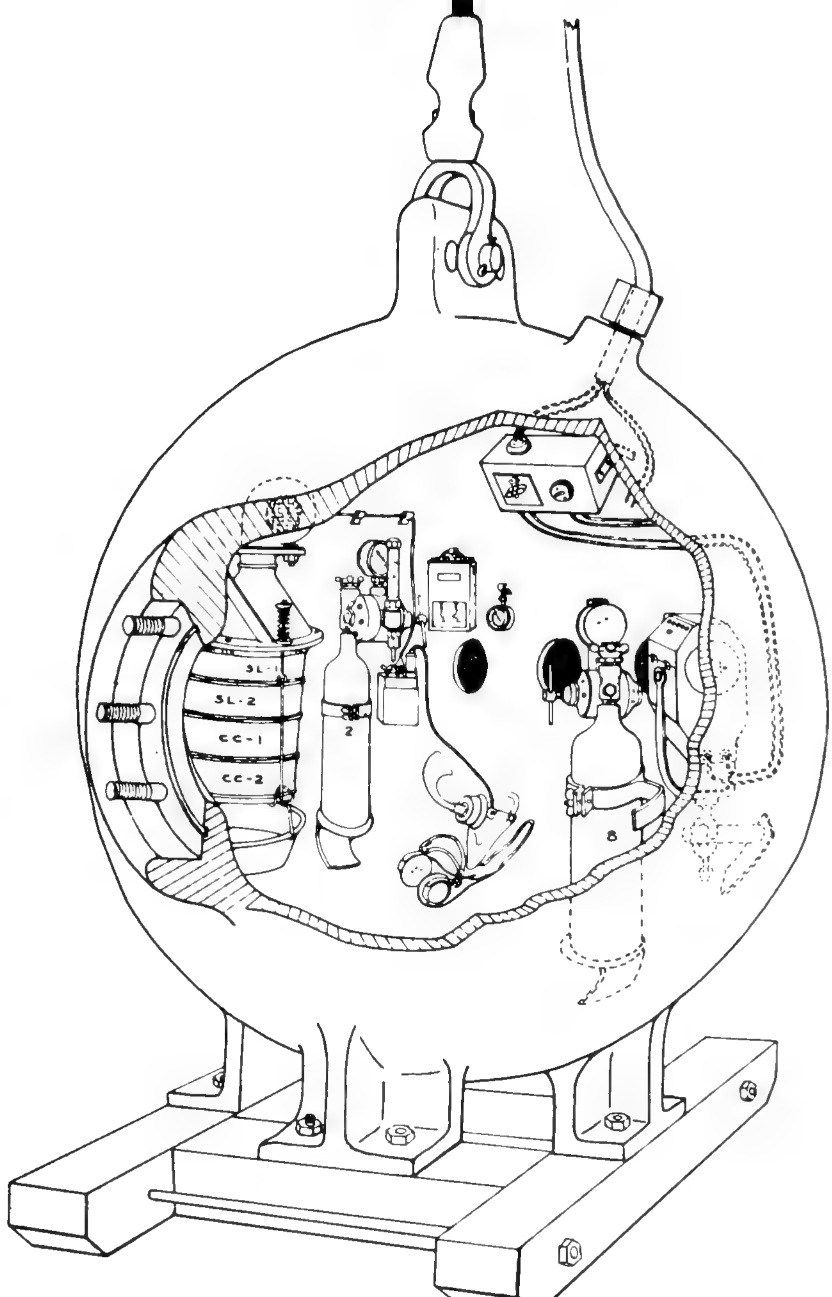


Diagram of the Bathysphere of 1934. Above: clevis for attaching supporting cable to sphere; above to right, communication cable entering sphere through stuffing box, two of its wires passing to the telephone box, and two to the switch box that distributes power to the searchlight and the chemical blower. Middle section of bathysphere, from left to right, chemical blower apparatus, oxygen tank and valve, telephone box and instruments, temperature-humidity recorder, barometer, emergency oxygen tank and valve, and searchlight. Drawing by John Tee-Van.

FIGURE **6.3**
BATHYSPHERE

(From New York Zoological Society Bulletin, Vol. 37, No. 6, P. 172) at the moment. The moist types of capacitors may undergo very peculiar changes. In this case we find that the leakage begins to go up as pressure increases. As the pressure increases further, the capacitors begin to get very erratic and often short out. But if we just keep with it, increasing the pressure further, we may find that around 8,000 p.s.i. the capacitor may begin to improve. In fact, some of them have been known to improve up to pressures of 20,000 p.s.i. Interestingly enough, sometimes a capacitor which has succeeded in operating satisfactorily at 20,000 p.s.i. may for all intents and purposes be a better capacitor when it is returned to atmospheric pressure than it was before. It is recommended that electrolytic capacitors which are to be operated under high pressure be substantially derated to operate at about half the rated voltage.

Lights: Often it is necessary to use lights for various purposes. Very cheap ones may be adequate. The ordinary flashlight bulb, which the industry classifies as a G-3 1/2 envelope, will withstand pressures of over 20,000 p.s.i. However, about 20 percent of the commercial supply is defective due to seal failures.

Electron tubes: The electron tube causes much less trouble than you would suspect. The subminiature series, the T-3 1/2 envelope of some manufacturers -- not all, for reasons, incidentally, which are not too clear -- will withstand pressures as high as 20,000 p.s.i.

Relays and switches: Relays operate perfectly well in fluids at high pressure. Microswitches or snap action types are also easily used in the fluid environment. Stepping switches operate well, but one must be sure to use a fluid with an appreciable lubricity because otherwise the stepping switch will fail.

Clocks: The automotive d.c. types, even using escapement mechanisms, will operate quite well if the viscosity of the fluid enveloping them is low enough.

Transistors: If transistors are fluid-filled, they become pressure-equalized devices and we have been unable to measure any pressure effects whatsoever. I must be very careful when I say "not able to measure," because someone may say we didn't go out far enough into the decimal places. By this I simply mean that when the transistor was used in an oscillating circuit (sine wave) which tests many of its essential parameters and was subjected to increasing pressure no change in the oscillator was observed.

Thermistors: Thermistors, used for measuring temperature, should be treated with a great degree of caution at high pressures. Here they may be erratic; they may be in error by as much as one-half degree centigrade per thousand p. s. i. in a temperature bridge.

Filling fluids: The temperature coefficient of expansion of filling fluids is very important. Many of the convenient hydrocarbons which may be used have a temperature coefficient of expansion such that their volume changes about one cubic centimeter per liter per degree centigrade. A word of caution here -- these instruments should be designed to withstand not only the cold ocean environment, but also the hot sunshine of the deck. The bulk modulus (the unit volume change with unit pressure) of the fluid is very important. Many of the fluids change only about 6 to 8 percent in volume when the pressure goes from 15 to 20,000 p. s. i. However, silicones, which are quite desirable electronically, change about 10 percent under these conditions and should be treated with caution or avoided if possible. Also, remember, if you are considering silicones, to be careful because many people are allergic to them. Fluid filling has a decided advantage with respect to a heat exchange. The fluid makes possible the ready conduction of heat by convection from the components to the world's best heat sink, the ocean.

No talk of this sort would be complete without mention of one of the early oceanographic instruments. This is the well-known BATHYTHERMOGRAPH or BT (fig. 6.4). This instrument has performed very well on the whole. Its record is made on a small smoked slide which you can see being stuck into the instrument at the side. Benjamin Franklin's thermometer was dumb and could not write; the bathythermograph, we may say, has learned to write, albeit it is still dumb.

The NIGHT SECCHI DISC (fig. 6.5) is a technique or device for measuring the transparency of sea water at night. This is not normally an easy thing to do, but this technique has proved to be quite accurate, very simple, and inexpensive, costing, I suspect, probably not more than $.50 including labor and overhead. It is a single flashlight cell with a bulb soldered on top. In use it is

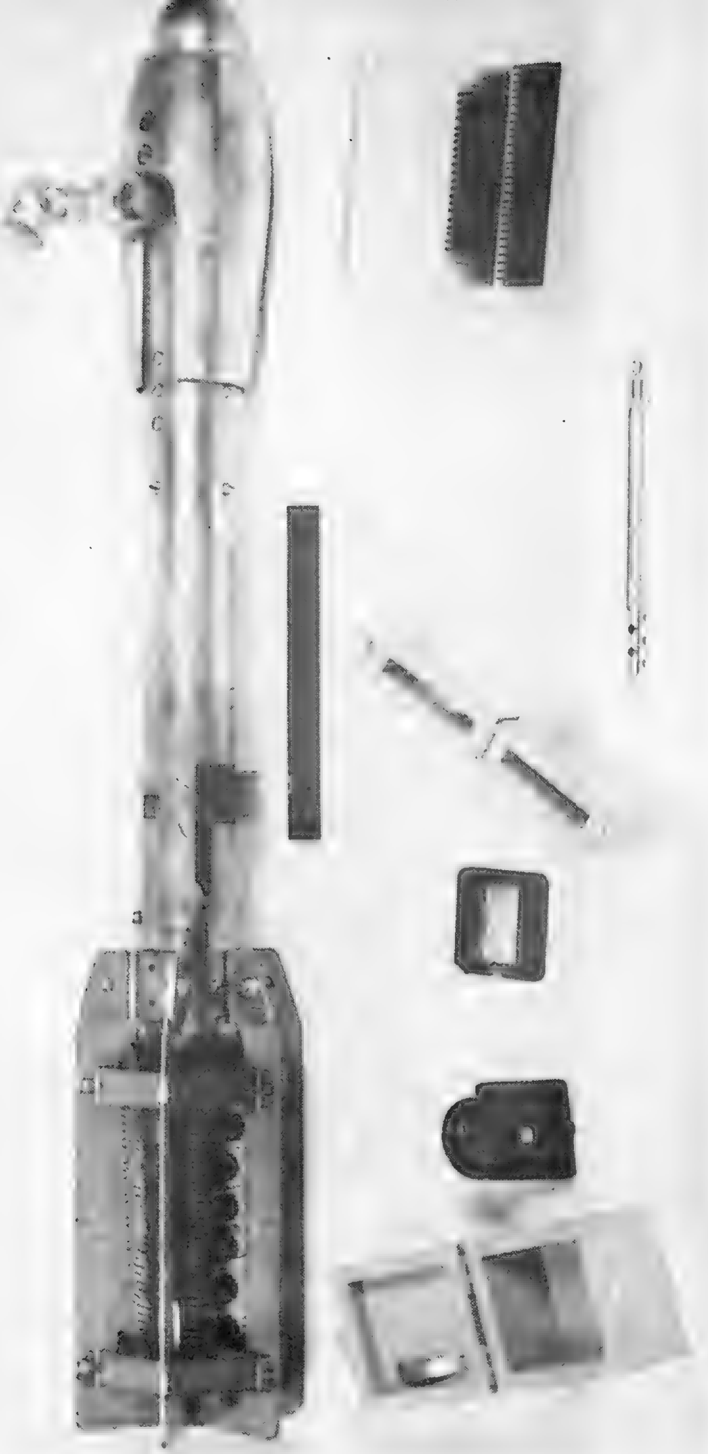
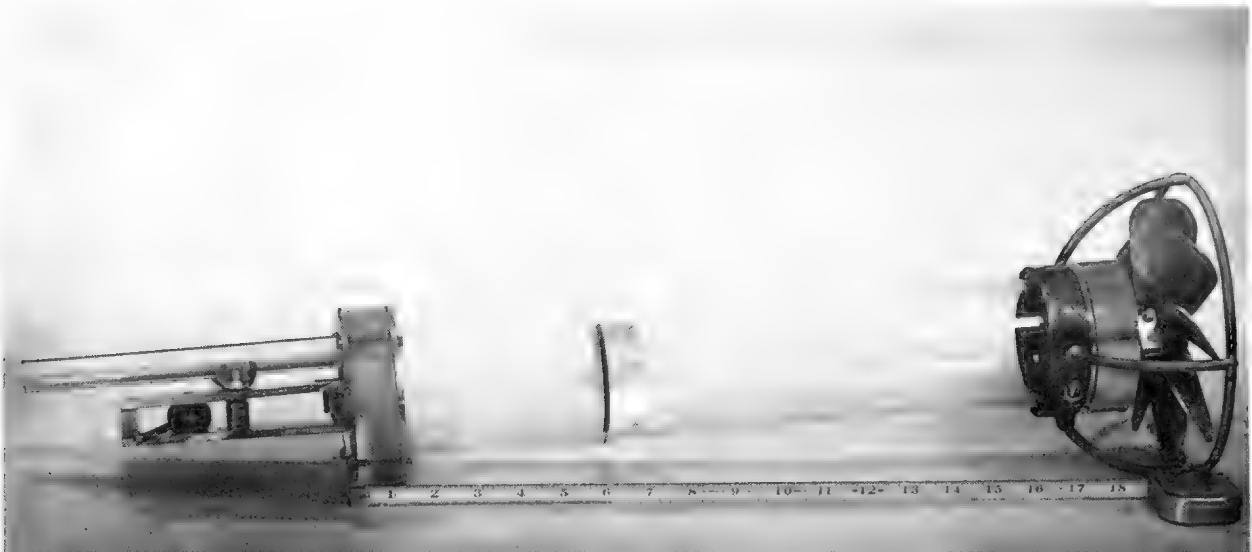


FIGURE **6.4**
BT (BATHYTHERMOGRAPH)

FIGURE **6.5**
NIGHT SECCHI DISC

FIGURE **6.6**
INTEGRATING PLANKTON COLLECTOR



simply pressed together and tossed over the side of the ship. A stopwatch is started when it hits the water and stopped when the point source of light disappears and the luminescence remains. The time obtained is an index of transparency. This is an example of the type of expendable instrument that we need to develop.

The INTEGRATING PLANKTON COLLECTOR (fig. 6.6) is a biological sampling device used for long horizontal tows at various depths behind ships. The inlet tube, on the left, is in the front portion and it fishes -- as the term is used -- ahead of the cable. It leads into a hollow chamber that is filled with fresh water. A free piston is shown approximately amidships, with water on both sides. A pump is driven by the propeller on the rear, which exhausts the volume to the right of the free piston, letting in sea water at a predetermined rate on the left side. This can be adjusted by gear ratios to fish quantitatively over short distances or long distances.

A modular concept is illustrated by a series of instruments plugged together as follows: The MODIFIED ROBERTS CURRENT METER (fig. 6.7) is a fluid-filled instrument and is thus not depth-limited; above it, mounted on the yoke, is a small pressure-protected module which measures depth. Above it, suspending the entire unit, is an electrical swivel. This system is designed to operate on a single conductor, sea return type of cable. The electric plugs, available from several manufacturers, can be used very readily to connect and disconnect the modules. These plugs are very simple. They will not leak at any depth in the ocean. In fact, some may be mated successfully under salt water with no trouble for the electronic circuits.

GLASS SPHERES (fig. 6.8) about three inches in diameter are shown partly to exhibit another concept which we need to keep in mind. We should not fight the ocean but do our best to use it. Hollow glass spheres are used to determine the time at which an instrument reaches the bottom. They are used in a device coupled in series with an instrument (fig. 6.9). When the instrument reaches the bottom, the heavy weight is released and when the weight falls, a sharp point ruptures the sphere. In deep water this hollow sphere represents a substantial amount of potential energy. By listening with a hydrophone over the side of the ship or even with the ship's fathometer, one can readily hear when the glass sphere implodes. The velocity of sound in water is roughly a mile a second.

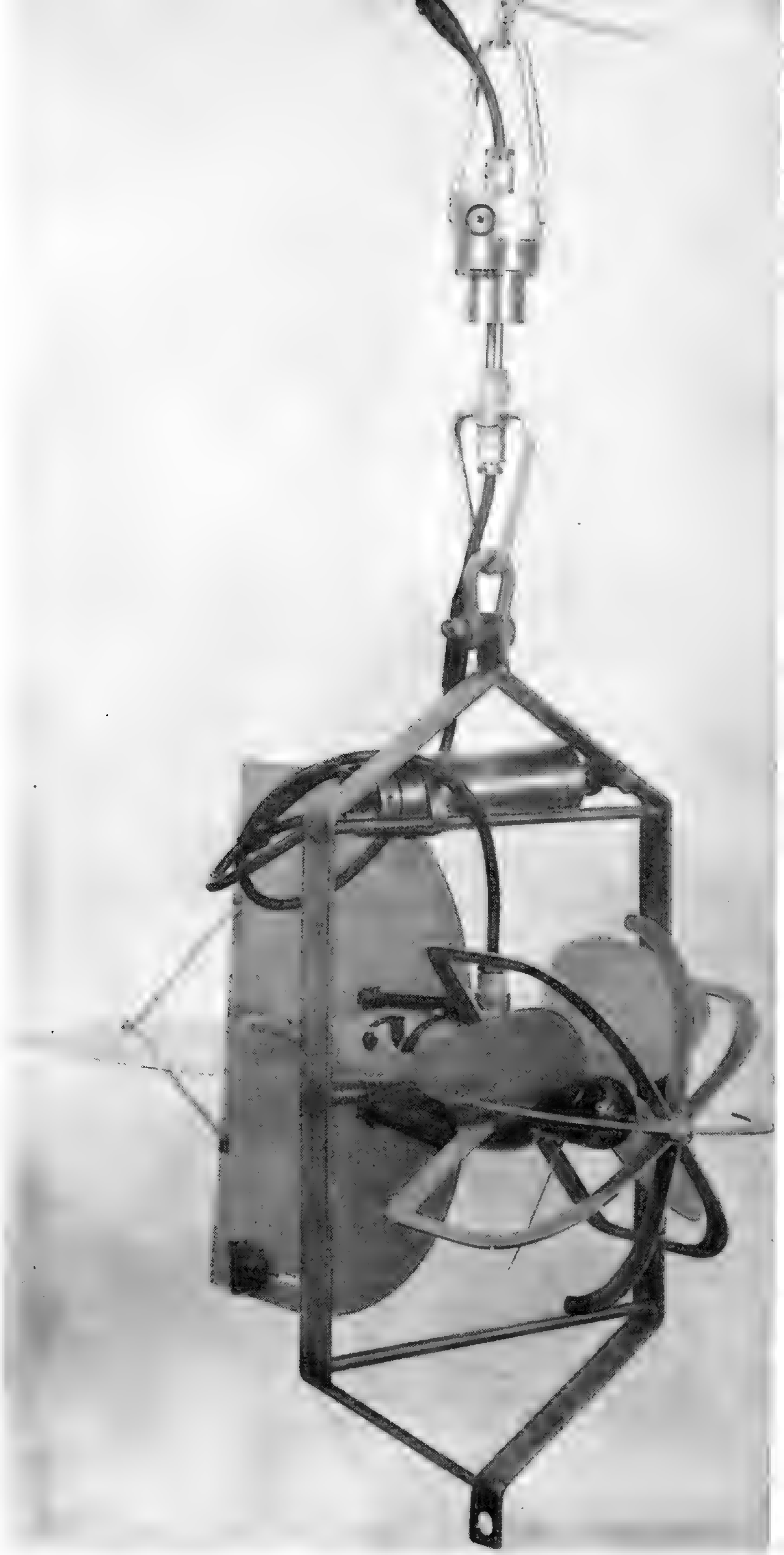


FIGURE 6.7
MODIFIED ROBERTS METER IN YOKE WITH PRESSURE MODULE AND ELECTRIC SWIVEL

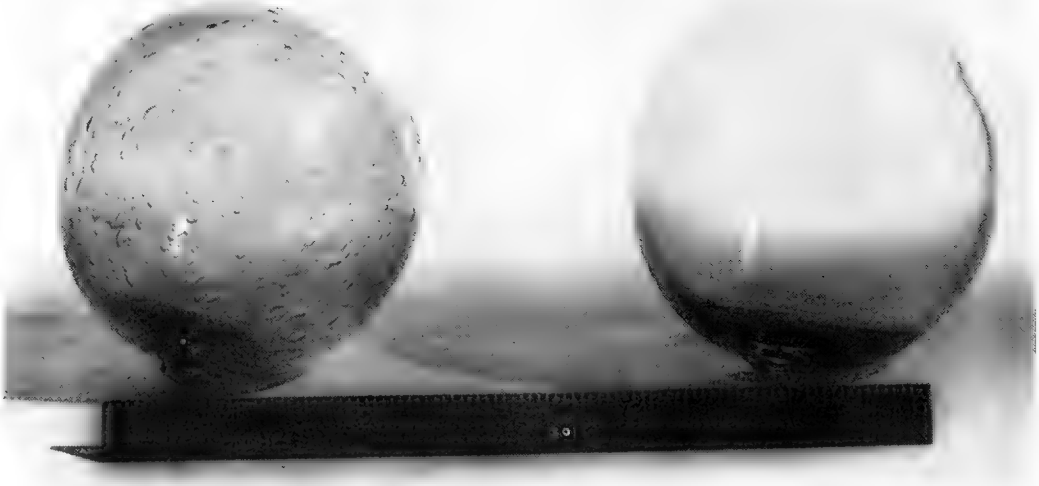


FIGURE **6.8**
GLASS BALLS

FIGURE **6.9**
BALL BREAKER - REAL AND PLASTIC

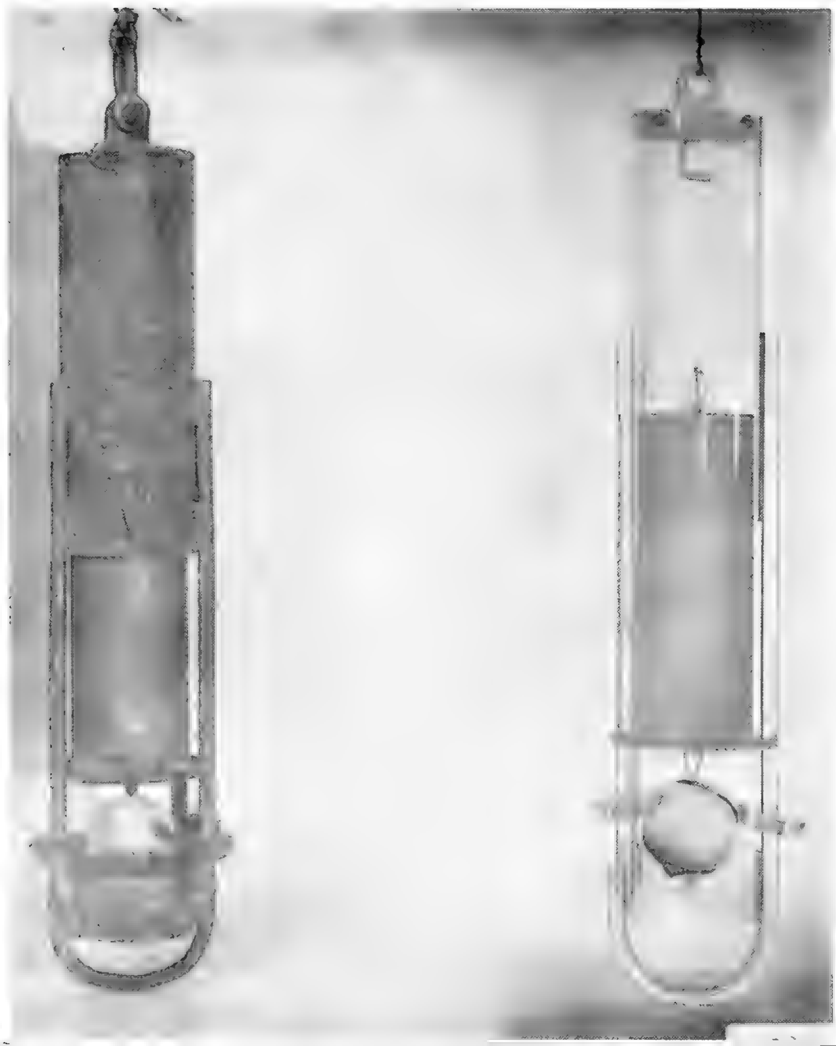


FIGURE **6.10**
PLASTIC CAST
OIL-FILLED
PHOTOCELL

Another device which takes advantage of the ocean and the environment is the early design of a fluid-filled barrier-layer type of photoelectric cell, potted with an epoxy resin with a cable connected (fig. 6.10). This can operate at any depth in the ocean without additional packaging.

For biological and other work it is necessary to determine the total and the instantaneous amount of solar radiation. The PYRHELIOMETER on top of the box (fig. 6.11) would normally be mounted on top of the ship's mast and stabilized. The output from this is amplified, chopped, etc., and fed to the current coil of a standard watthour meter. The watthour meter does the very simple arithmetic of integrating and giving readings in conventional units with which the biologist is familiar. The other meter indicates the instantaneous values.

Another device for biologists offers much greater possibility. Here the total amount of light reaching a given depth over, say, a week or a month, was measured by the AMBIENT LIGHT RECORDER, a self-generating type of photoelectric cell of the barrier-layer type (fig. 6.12). The total dimension of the device is about ten inches from top to bottom. It possesses sufficient buoyancy in the upper section so that it floats with the light-sensi-

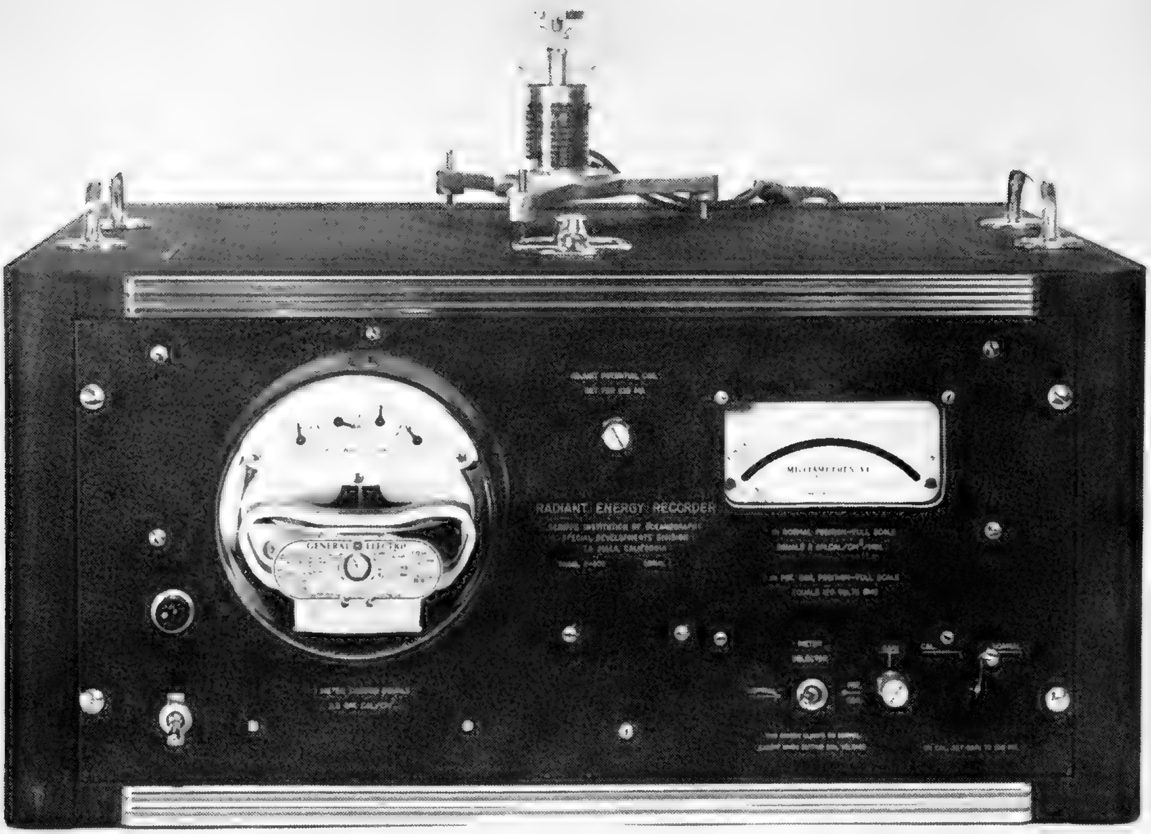


FIGURE 6.11
RADIANT ENERGY RECORDER

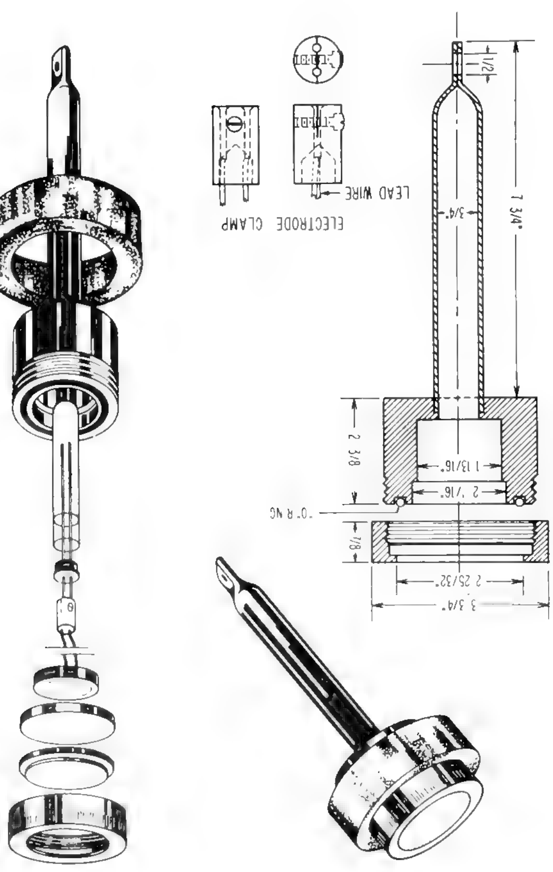


FIGURE 6.12
SILVER VOLTAMMETER
LIGHT INTEGRATOR

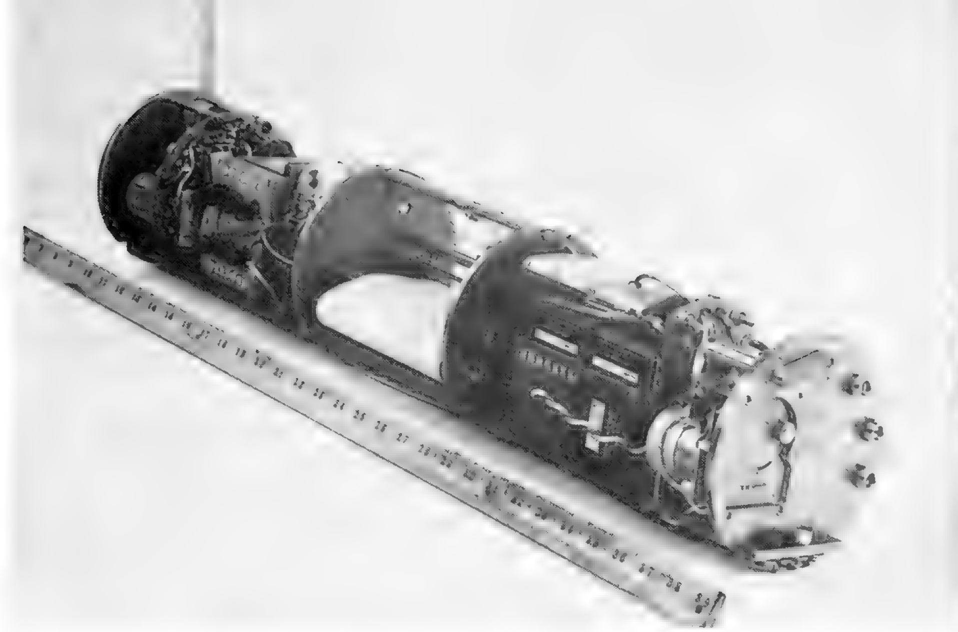


FIGURE **6.13**
GEOTHERMAL GRADIENT RECORDER

tive end up. The photocell is connected as shown here; two wires lead down into a suitable electrolytic solution which makes it a silver voltammeter. You may remember that the silver voltammeter is used to determine the standard units of current. By weighing on a standard analytical balance in the laboratory the amount of silver plated out, we can determine directly the amount of light that this instrument received over the period it was used. This is a simple instrument. It can be replaced in the field by SCUBA divers. The accuracy is very high. In fact, they are hard to calibrate with conventional D'Arsonval meters because they are based on the national current standard.

The GEOTHERMAL GRADIENT RECORDER (fig. 6.13) is listed in one of the handouts which you have. (It is a very early model of I-q, a Sea Floor Geothermal Probe. See appendix E.) This is a pressure-protected instrument. The strip chart recorder is in the center with the servosystem to the left. The amplifier, which is located toward the front just above the batteries, is a modified hearing aid amplifier. The instrument is highly sensitive, being accurate to less than a thousandth of a degree. The temperature range across the chart may be adjusted. It may be as great as half a degree Centigrade full scale. A socket is provided for plugging in a photoflash bulb which serves as an angle recorder. The recorder, when inserted in its case, is attached to a long thin probe that goes into the bottom of the ocean, and it is necessary to know the angle with which the probe goes into the bottom. The photoflash bulb is coated with a mixture of beeswax and lampblack so that when it flashes, as the stylus of the strip chart recorder goes from its reference position out to record, the heat liberated by the flash bulb melts the wax and the wax runs down to the lowest point on the bulb. This can be readily measured with accuracies of the order of plus or minus 3 degrees. It gives all the orientation information necessary without much complication.

In figure 6.14, Dr. Arthur E. Maxwell, ONR, is putting the instrument in its case. He is wearing a typical tropical oceanographic uniform. The instrument is then lowered over the side in its pressure-protected case with the ball breaker device (fig. 6.8) above it. Sometimes it is necessary to straighten the probe (fig. 6.15) because it can be bent by the drift of the ship. A good design will permit reusing the probe a good many times before it is permanently damaged.

More recently we designed a current meter to test certain basic principles (fig. 6.16). It is not necessarily a design that we would want to repeat or duplicate. It was made to measure a velocity profile while it was being raised and lowered. It included an electric swivel at the very top, an electrical plug which is simple to disconnect, the current sensing rotor on top, the electronic case hidden by the plastic fin, and the plastic fin. The electronics are principally all in one narrow deck, with the direction element below it (fig. 6.17). This instrument telemeters depth, current direction, and current magnitude simultaneously. We may say that it has learned to talk. It provides an output that is suitable for going into magnetic tape recorders.

If one wishes to make instantaneous readings, the onboard readout has four meters (fig. 6.18). The two on the left indicate current. The first reads from zero to three knots; the next, a dual scale meter, reads from zero to 0.3 knots, and from zero to 0.03 knots. The third dial is a depth meter, which is also a dual range instrument. The direction indicator is on the right. The inputs to the depth meter dial (fig. 6.19) are linear. The nonlinear characteristic is obtained by shaping the magnetic pole pieces. The scale is quite open for shallow water. If one wishes to work in

FIGURE 6.14
GEOTHERMAL GRADIENT RECORDER IN PRESSURE CASE

FIGURE 6.15
STRAIGHTENING PROBE, GEOTHERMAL GRADIENT RECORDER

FIGURE 6.16
SCRIPPS INSTITUTION OF OCEANOGRAPHY CURRENT METER

FIGURE 6.17
CHASSIS - SCRIPPS INSTITUTION OF OCEANOGRAPHY CURRENT METER

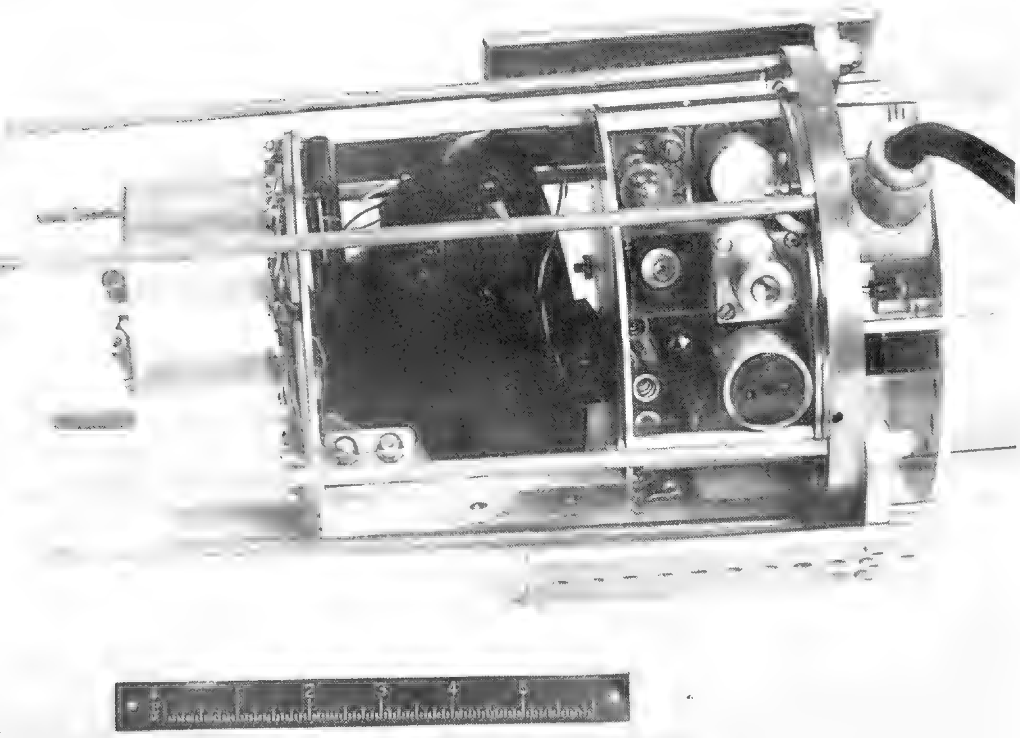
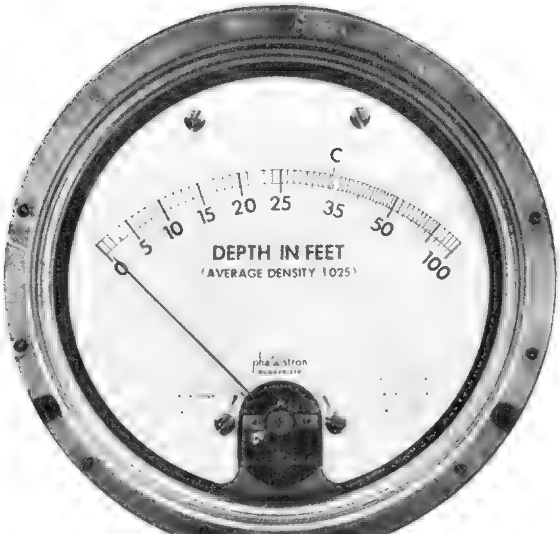


FIGURE **6.18**
DECK READOUT, SCRIPPS INSTITUTION OF OCEANOGRAPHY CURRENT METER

FIGURE **6.19**
DEPTH READOUT METER, SCRIPPS INSTITUTION OF OCEANOGRAPHY CURRENT METER



harbors, one can still read with fair accuracy. If we get down below fifty feet, the smallest scale unit on the dial is five feet.

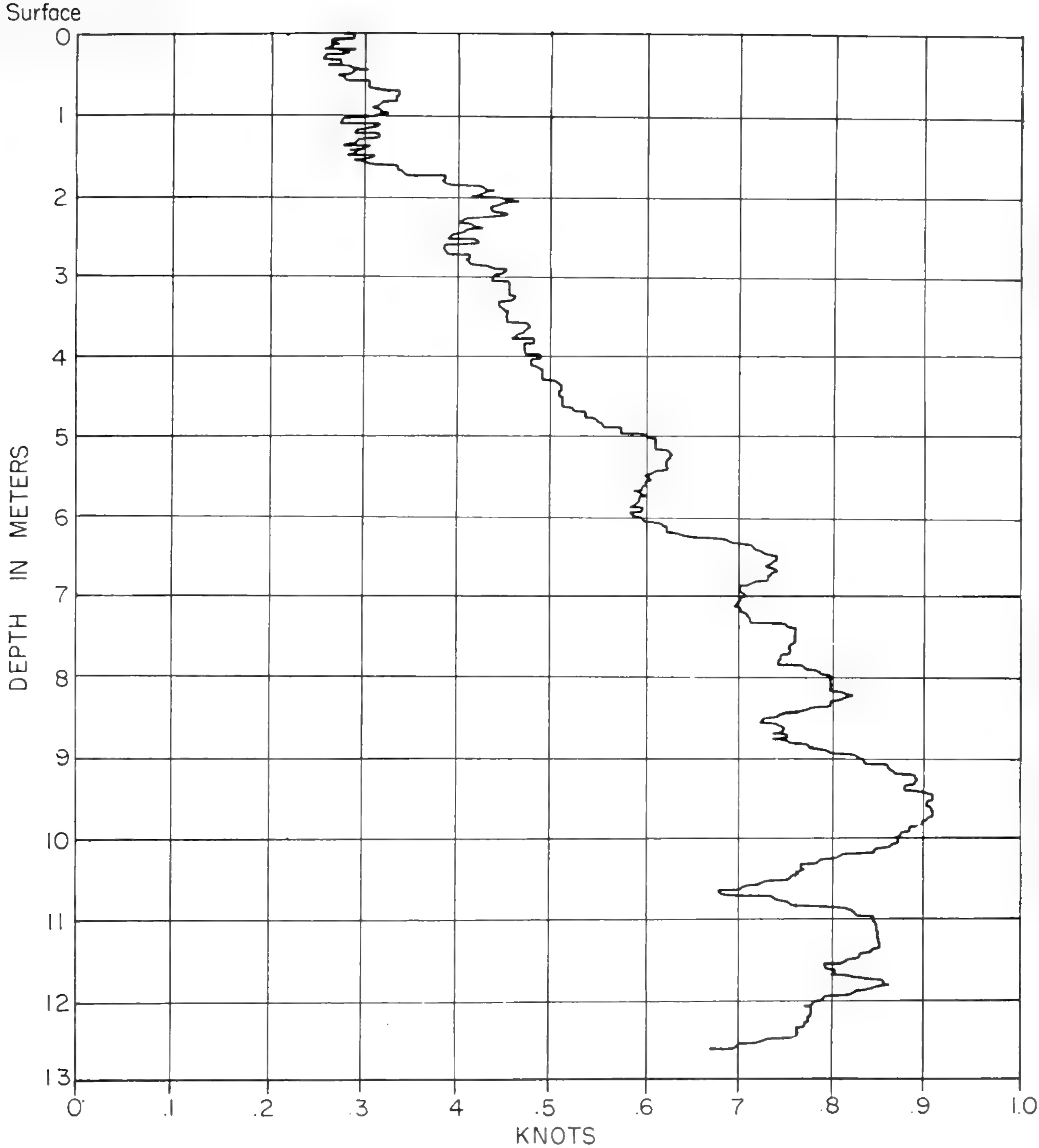
It is possible to obtain a current profile when velocity is plotted against depth by a function plotter. The direction trace is not recorded in figure 6.20, but does exist on the magnetic tape original.

A more recent model used circuit boards (fig. 6.21). These are assembled in stacks one above the other. The circuit boards shown are multiple binary decks with associated telemetering amplifiers and filters.

There are electrical background problems in the ocean (fig. 6.22) of which you should remain cognizant if you are going to telemeter electrically or make certain types of measurements. Electromagnetic energy exists in the ocean. The electrical spectrum in the audio frequency range from about 0.2 kc. up to around 20 kc. has been integrated and recorded as a function of azimuth. The sensor was towed behind a submarine as the submarine was turning at a constant depth. There are directional characteristics to this. This is basically generated by what the meteorologists call sferics, electromagnetic disturbances that are propagated great distances from electromagnetic storms, lightning, and so forth.

Everything isn't quite what we might expect in the ocean. The more you work with it, the more you realize this is true. For instance, data was taken to measure the amount of light as a function of depth on a moonlight night. One would expect that it gets darker as you go deeper. One record shows that such is not always the case (fig. 6.23). Down to about 100 meters, the light intensity does decrease. However, at about 100 meters the light intensity stops decreasing and may increase. In this case the record only goes down to about 300 meters. The light is essentially due to the presence of luminescent organisms existing within the ocean in this region.

Power sources, of course, are extremely important to the oceanographer. Here we can only scratch the surface, and I shan't attempt to make anything like an all-inclusive coverage. Primary batteries represented by the Leclanché cell, the common dry cell, are quite reliable in the ocean. They have to be protected, of



SP 109A
BuSHIPS CURRENT METER - CURRENT PROFILE RECORD, 23 AUGUST 1957, TIME : 1603.

FIGURE 6.20
X - Y PLOT CURRENT, SCRIPPS
INSTITUTION OF OCEANOGRAPHY
CURRENT METER

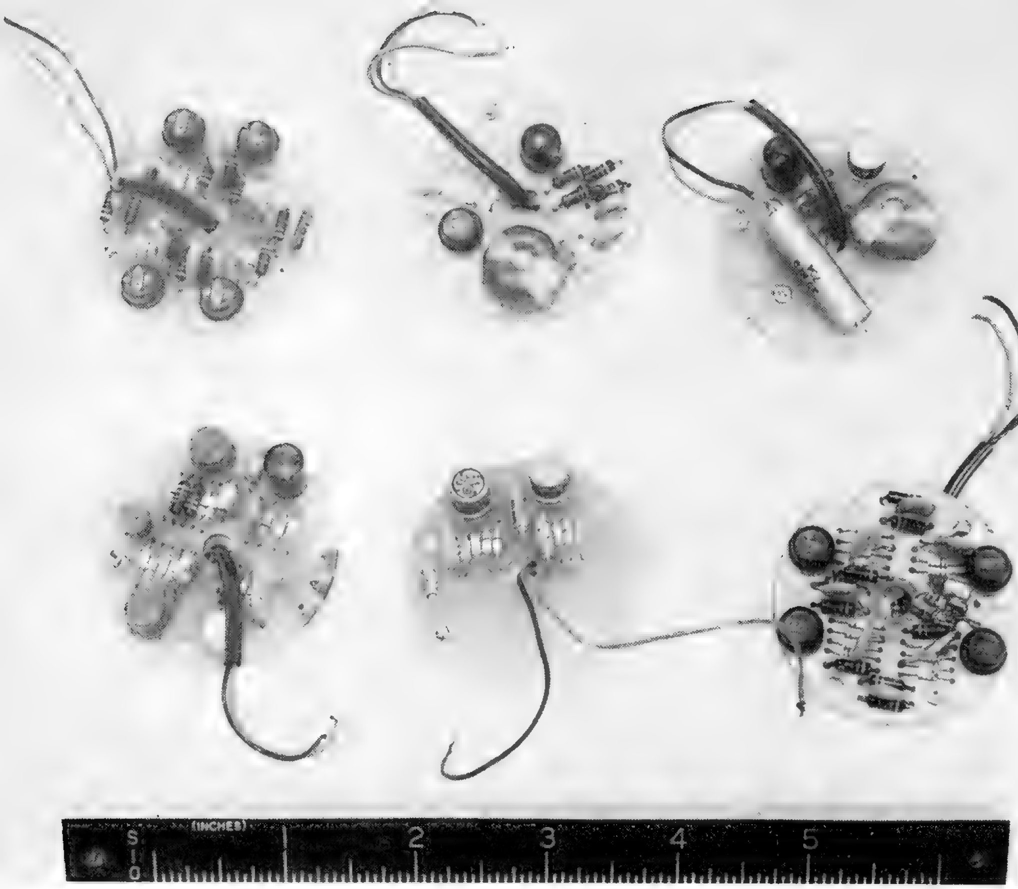


FIGURE 6.21
CIRCUIT BOARDS FROM BINARY SWITCHING MODULE

FIGURE 6.22
ELECTRICAL NOISE IN THE SEA, AZIMUTHAL VARIATION

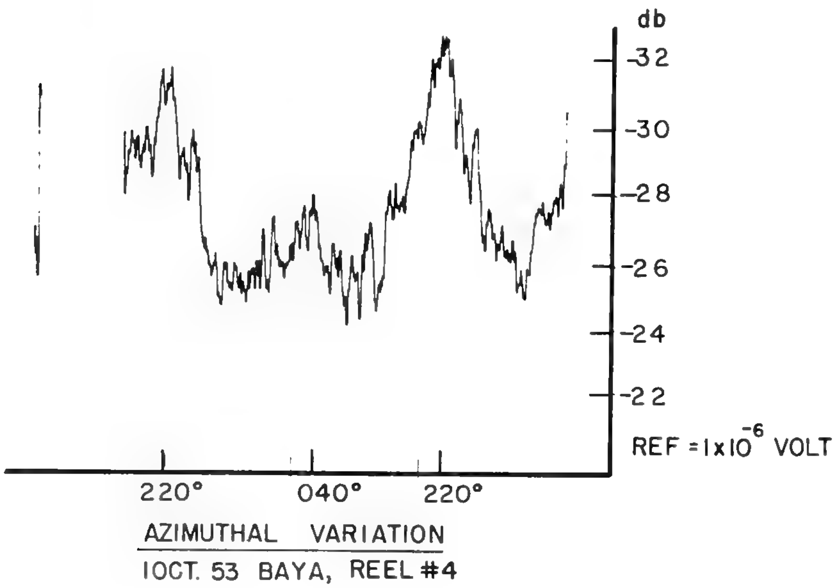
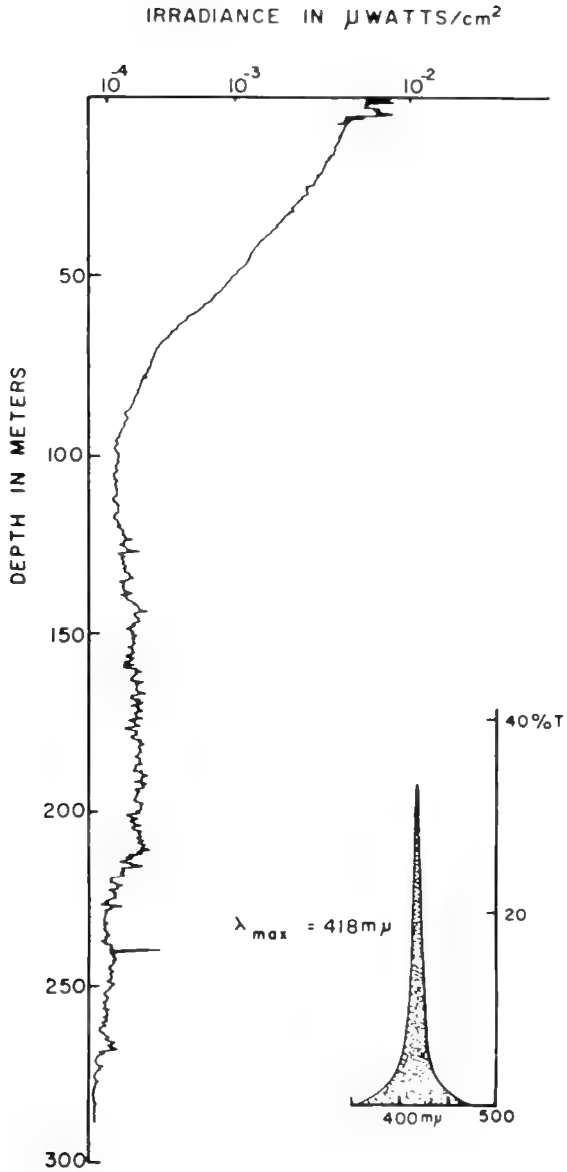


FIGURE 6.23
IRRADIANCE AS FUNCTION OF WAVE LENGTH AND DEPTH



course, from salt water. Pressure effects are minor, particularly if one gets new batteries before some of the moisture has evaporated from the mix within the case. However, at the ocean bottom where temperatures may approach 0° C., one should expect to lose something like 20 percent of the capacity which batteries have at 23° C. Mercury cells are so complex that I think a word of warning should be given to test each and every batch because changes in construction and things of this sort make them either suitable or not suitable. Many of them will utterly refuse to perform at temperatures much below room temperature and become very erratic. In fact, we had a rather sad experience that cost us a good many thousands of dollars because of a minor design change in the battery which was unknown to us; the catalog number or anything of that sort had not been changed. What had been a previously useful battery became useless with a small temperature drop.

The introduction of unannounced changes is one of our problems. I referred to the problems of the electrolytic capacitor earlier. One may find a type of battery that is acceptable for high pressure operations. You attempt to replace it by ordering a new lot. For some reason, the new batch simply will not perform. Small changes have been made in manufacturing techniques which ruin it for high pressure use, but which probably make it better for other people.

Storage batteries are probably one of the brightest lights that we have as far as useful power supplies are concerned. The ordinary, homely, lead-acid automobile battery works very well. All you have to do is to protect the terminals from salt water, fill the cells clear up with acid of the proper gravity, and provide a small expansion chamber. They will operate very happily at any depth. The low gravity, low self-discharge types may actually give you the order of 80 percent of their capacity after being on the bottom for times as long as one year. Silver cells which are a more sophisticated storage battery have been tested up to pressures of 80,000 p.s.i. These, too, show a very satisfactory performance.

There are air-breathing types of power supplies, some undergoing very rapid development at present, particularly those classified as the propane-fueled thermoelectric cells. These, at present, are essentially low wattage devices; they apparently possess high reliability. However, the reliability in the marine environment has not yet been, as far as I know, thoroughly established and needs to have a great deal more work done. For example, it would appear that something like 200 grams of salt would have to pass through a modestly small burner in the course of a year's operation in a buoy at sea. What is to be the fate of this salt, what reaction it will have on the burner, its materials, and so forth, I do not know. Mr. Allyn C. Vine of Woods Hole Oceanographic Institution is very partial to the concept of another air-breathing device, namely, the diesel electric generating system. This has high reliability, and, if one needs substantial amounts of power, they should not be overlooked.

Of course for certain specialized applications, for example, permanent bottom-mounted installations, where it is not possible to get air, the thermonuclear, thermoelectric unit represented by the SNAP series and their successors are obviously very promising. I won't argue on the economics of these because factors other than simple economics will determine their use.

Environmentals have been referred to earlier. Here may be the place that requires our greatest attention and the most work in the future; we need to approach this ocean environment with a great deal of caution. For instance, the failure of submarine telegraph cables at depths approaching one mile caused by entangled sperm whales is well documented. Their skeletons have often been hauled back up with the cables. The general problems of marine fouling varies as a function of depth, location, and season. It takes a long time to check out an instrument's ability to withstand this type of environmental hazard.

Dr. William S. Richardson of Woods Hole Oceanographic Institution encountered a little-understood corrosion at the junction between nylon line and stainless steel thimbles. We now avoid this combination. Cables jacketed with neoprene, one of the families of plastics used for cable insulation, must also be used with great care. Some marine organisms flourish on this cable. They attach themselves at points where there has been a small abrasion or scratch and proceed to grow and spread, just like a root growing in a rock. They may ultimately cause insulation failure. Optical windows foul quite readily, depending on the environment.

The hazards of environment are well illustrated by an account of "mine-eating" bacteria. A number of experimental mines were shipped from the east to the west coast for testing in a given environment. These mines had a design life of six years. They were planted at various locations in sufficient quantity so that they could be sampled from time to time to determine the effects of the environment. Imagine the chagrin of the experimenters when they picked up their first sample at the end of six months and found that vital parts of the exploder mechanism had disappeared. This was critical. The mine could not have operated, and it probably didn't work very long after it was planted. A substantial amount of metal had simply disappeared. In the particular environment tested there dwell a species of sulfate-reducing marine bacteria, anaerobic in their action. They form their own little electrolytic cell and corrode the metal. They work fast. Our Navy colleagues, acquainted with the problems of mothballed ships, are well aware of these troublesome organisms. These things happen and I urge you to exercise all kinds of caution in this regard. Plastics, too, often fail due to the presence of sulfur in the bottom environment. Many of the sediments have a high sulfur content, and many of the plastics are adversely affected under these circumstances.

We have negligible data on the combination of high hydrostatic pressures and marine organisms. Yet we know this is a very potent combination. We need more work here. Accelerating such environmental tests is difficult. For instance, plastic changes its properties under pressure. Can we accelerate these effects by simply increasing the pressure still further? Under this greater pressure it is not the same kind of material that it was before.

Also, you in industry, and the Navy, are becoming cautiously aware that synthetic salt spray tests simply do not represent the normal environment.

I am sure of only two safe materials in the plastics or near-plastics: gutta-percha and polyethylene. The first is very old, selected by Lord Kelvin, who did better than he may have realized in selecting it for the insulation of the marine telegraph cable. This has stood up over many, many years. The other, a much more modern material, polyethylene, has been used a much shorter time but shows promise. However, it would be very dangerous to assume that because polyethylene stands the environment, that polypropylene will also. Maybe it will, but I do know that there could be some little marine organism sitting around that would just love to work on this molecular modification. This is something we may learn more about, but we must be very careful in extrapolating our experience.

You have heard references made to telemetry. The oceanographer must collect data over a very large area. Radio, of course, appears to be the answer. But here again the oceanographer runs into problems, partly because the space in the electromagnetic spectrum is already overcrowded, and interference is tremendous, particularly in that part of the spectrum he prefers, mainly the high frequency bands. These wave lengths are both the most crowded and the most advantageous. The VHF and UHF portions of the spectrum are line-of-sight at ordinary power. Thus, two alternatives are being proposed: First, the use of aircraft for highflying interrogation and recording devices may sound relatively expensive but per bit of information it is not; second, communication satellites appear to be particularly promising as interrogators because low flying types, such as the Courier, which operates at altitudes of between 300 and 400 miles, has recording equipment on board, and can receive RF that buoys can transmit. Lower power requirements improve reliability. As Admiral Stephan mentioned, high reliability is vital. This should be underscored and underscored again. An installed telemetering buoy represents a substantial investment. If some little component fails, the whole thing is useless! This puts the same kind of reliability concept on components that we face in our space program. My ideas represent only a small sample of new concepts and needs.

We need various types of recorders, say magnetic tape, punch paper -- you name it -- for use in instrument buoys and at remote stations. These must stand very severe conditions. There are angular accelerations to be encountered, vertical accelerations and long-time operations in an adverse environment. We cannot hope to telemeter all information so we must have suitable and reliable recorders.

Then, of course, this matter of getting data in the first place, the matter of data acquisition. This, if we may focus on it, is our greatest weakness -- the lack of adequate transducers or sensors for use in the marine environment. I have no pat answer or suggestions. The requirements of high reliability, long life, and accuracy make this truly a real challenge. I can think of few transducers that satisfy these requirements. This whole field needs a great deal of work, partly because it has not been emphasized in the past. Most of the present work in sensors has gone to fields unrelated to this environment. We have tried to convert instruments to oceanography and use them, but this has not been satisfactory.

I mentioned earlier the use of an expendable optical device for measuring water transparency. The principle of expendability should be extended. I think you have design and inspiration capability within your own companies, within your own minds -- ideas that can be very useful. The value of any expendable device should be based on its ability to get more and better data, at less cost. This doesn't necessarily mean the instrument system itself need be so cheap, providing it gets the data. Reliability and size are important. We can't hope to make something very large if it is going to be expended in quantity; logistics is a factor of cost.

Of course, if someone comes up with a satisfactory solution, they can use the truly high-production techniques which American industry possesses. Using modern methods that are just getting underway, such as moletronics, they can turn out very large quantities at reasonable prices. There are obviously a lot of gaps in this, but I think these are some of the things that we do need to examine.

Finally, no matter what you read, no matter what I tell you or someone else tells you, there is no substitute for a first hand feel for the ocean. I have talked about this with some of my colleagues, and it is safe to say that the research institutions are glad to extend an invitation to serious-minded engineers to take you to sea, to give you some sea experience, if you demonstrate that you are sufficiently well motivated in this regard, because I think this will pay real dividends to you and you will better understand the problems. I could talk all day. I could show you more pictures. It won't do any good until you can get a first hand feel and understanding of this.

7. ASPECTS OF OCEANOGRAPHIC INSTRUMENTATION DEVELOPMENT AS RELATED TO IN-PUT INTO THE NATIONAL OCEANOGRAPHIC DATA CENTER

Dr. Woodrow C. Jacobs

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Washington, D. C.

At the time I was invited to participate in this Symposium I had just been appointed Director of the National Oceanographic Data Center. In fact, I had been Director for exactly two days. Even in this age of extreme acceleration of things scientific, I doubt that this constitutes sufficient experience for me to pose as an authority on oceanographic data centers. I have had, however, a number of years of experience in matters pertaining to the acquisition, storage, retrieval, and processing of geophysical data -- particularly meteorological data. If it is true that one learns primarily from the mistakes one makes, I am eminently qualified to pose as a world authority on matters of this sort. I think that I have made them all, and should have no further ones to propose to oceanography -- either for action or for research and development.

Though my statements so far can hardly be said to constitute the "positive approach," caution is not without merit. The charter for the National Oceanographic Data Center is indeed positive. The NODC is a "National Oceanographic Data Center, organized for the purpose of acquiring, compiling, processing, and preserving oceanographic data for ready retrieval." If we took these objectives literally and gathered data indiscriminately, particularly those that are most available and that produce the most impressive production figures, and from these produce even more impressive stacks of punched cards, computer tapes, data summaries, etc., then we could sit back and wait for some oceanographer to be smart enough to guess what we had on hand and allow him to ask for it. It would be mainly coincidence if the materials available would specifically meet his requirements. Such a story is not farfetched. Many data centers, information centers, and libraries, are operated, in effect, on just such principles.

The farsighted individuals who are responsible for the creation of NODC had an entirely different kind of center in mind. The single objective of the Center is that it become "the primary source of ocean data required by the research oceanographer, by the scientists in related fields, and by the maritime operational interests." Any other statement in the charter simply describes one of the means for achieving such an objective. I hope that in a small way I can make you appreciate the magnitude of this objective, and I also hope that I can impress upon the instrument people the importance of the role they must play in the creation of a successful long term operation.

I want to point out with all the emphasis that I can muster that the instrument designer and fabricator have it within their power to completely swamp the scientist with data beyond all hope of his recovery. The constant addition of improved mathematical techniques and powerful computing equipment can only serve to keep him afloat for a short time longer but will never allow him to compete on a "bit-for-bit" basis.

A good example of the competition you afford us in this area is provided by the common TV set in your living room. You may ask, "What has this to do with oceanography?" A TV, as you know it may not be an oceanographic instrument, but a TV scanning system is and it has already had highly successful application in ocean survey work. If you have not already heard about the development, I am not about to let you in on it. After all, we are going to have a hard enough time keeping two jumps ahead of you fellows.

But to get back to this TV set. It takes 4×10^7 "bits" of transmitted information per second to produce the black and white picture on your screen with its customary resolution, and this resolution is not nearly as high as it could be and it can be in color. Now to store in digital form, let us say, the total information contained in a two-minute commercial from an "I Love Lucy" show, approximately 5,000,000 punched cards would be required. In fact, it would be beyond our present capability in NODC to store many such commercials in this form. Obviously, it would be foolish to store this type of information on cards. A tape is the obvious storage medium. But this reminds me of the Soviet experience with last year's moon shot. I understand that the coded magnetic and ionospheric data telemetered back from that flight are contained on a tape which is of the order of 400 miles in length and packed with digital information. Furthermore, it seems that the Soviets

FIGURE 7.1
COMPUTER
FACILITIES,
NATIONAL
OCEANOGRAPHIC
DATA CENTER

have found it necessary to edit manually the entire tape -- centimeter by centimeter. And mind you, these are data from only one space "expedition" and one which had rather limited scientific objectives.

However, I don't want to give the impression that all things are black as far as data centers are concerned; the "shoe is as frequently on the other foot" as not. I recall an incident of several years ago when several individuals approached our organization for some computing and tabulation assistance on a research project. Since there were only three individuals assigned to the project, they wanted their work facilitated by having data from a large number of weather stations collated in a particular manner and the results to appear as a series of individual machine listings. We raised some questions as to the magnitude of the proposed job but their reaction was one of impatience more than anything else. They were not interested in our excuses, they simply wanted to know "could we or could we not undertake the project?" We allowed that we could do the job but we felt we were obliged to point out that even if they could read the tab sheets at the rate of one line per minute and they would do this 24 hours per day, seven days per week, 365 days per year, the three of them couldn't possibly live long enough to complete the reading task, let alone analyze the contents or do anything else with them.

I have already had some experience with the impact that some of the new and uncoordinated observational programs can have on an unsuspecting data center. I was for a time associated with one data center whose relative efficiency over the years appeared to decrease almost in geometric proportion to the amount of data it had acquired. This occurred in spite of the addition of the most modern analytical techniques and computing equipment that served to increase total production tremendously.

There are many concrete examples that can be cited as illustrations of developments that have had staggering impact on data centers and research institutions. One example is the meteorological satellite developed by NASA. A single Tiros- or Nimbus-type satellite can acquire, in a few orbital passes, more atmospheric data than can be analyzed by all of the U. S. meteorologists working together as a team for a year. Then add to this, the constant supply of data from some 100,000 surface weather stations, some 3,500 or more ships at sea, the pilot reports from countless aircraft, the autographic records from reconaissance aircraft, rocket probes, automatic weather stations, constant level balloons, and hundreds of pilot balloon and radiosonde stations, and then add to these the three-dimensional radar scope depictions of cloud and precipitation systems from a multitude of radar installations and the atmospheric-electric data from sferics stations over the globe, and you may begin to have some idea of what I mean when I say you have it within your power to swamp us beyond all hope of recovery.

The only long term solution to this big problem is to begin to take some steps that are long overdue. In our own particular case these steps include the bringing together of the instrument designer, the oceanographer, the data custodian, and the processing equipment expert for the purpose of developing an economical and efficient data system. A bit of data is really of no consequence until it has contributed to some bit of oceanographic research or has been used in reaching an operational decision. The instrument designer and manufacturer may pride themselves on the fact that they have been able to produce an instrument that can be sold for $100 and that the operating costs are only $1 per observation. However, if one followed the course of the data it produces, from the instrument to the point where it has contributed to oceanographic knowledge, we might well find that the instrument is far more expensive than we can afford. It is essential that an observational system be produced which is economical and efficient in the total sense.

Before becoming specific it might be worthwhile to outline several very broad instrumentation objectives as far as a data center is concerned.

In the first place, it is our feeling that in the future design of instrumentation a great deal more obeisance should be paid to the concepts involved in "information theory." It will be mandatory that the final observational record present the maximum amount of information with the smallest possible number of "bits." It may be necessary to pay some attention to instrumentation that does not record or transmit all the information possible but only that information which departs in some way from what has already been recorded or departs from what oceanographers already know. Information that is redundant[1/] or irrelevant should be filtered

1/ As I note the word redundant here I recall that when my secretary out wherever possible. In some cases, internal data processing may be required such that the final record is of the parameters desired rather than those which are actually sensed by the instrument. There should be no loss of useful information in this process, however.

In the second place it is my feeling that the final material records of all instruments should be "modular" in nature as far as is possible. I realize that I am using a meaningful word in a rather unusual sense but I am unable at the moment to find another one that expresses the rather elusive thought. What I am trying to say is that the economy of storage, transcribing, and processing cannot stand too great a variety of final record. We cannot afford a special curve tracer or transcriber for each instrument nor can we afford to employ an excessive variety of storage and handling equipment. Moreover, the collation of records demands that the utmost in uniformity of record be achieved.

So much for broad objectives. Now perhaps a word is in order as to how the NODC fits into this picture.

Many technical and commercial fields have provided adequately for a centralized data processing facility and a decentralized operational and research activity. They most commonly fail, however, to provide the function that serves to knit the two together into a unified operating system. This function is obviously COMMUNICATION. NODC intends to do its part to provide this function. Communication is obviously a two-way proposition. In the first instance it means that adequate provision must be made to disseminate to the research or operational individual the materials he requires in a rapid and economical fashion and in the form most suitable for his use. In the second instance it means that adequate provision must be made for the communication of requirements between the research and operational interests and the data center. This must be accomplished in both the short and long term senses.

1/ (Continuation from page 61)
first transcribed the word from her notes it came out reluctant. I don't think she realizes how appropriate the mistake actually was. In fact, the term was so apropos of the discussion I was almost tempted to add a section on "reluctant data." Certainly we have numerous data in our files that are aptly described as "reluctant" and I have no doubt but that some of you could have offered suggestions as to how we might cope with some of this "reluctance."

It is necessary that the data center keep itself informed of developing techniques (and instrumentation) and requirements as far in advance as is possible in order that it can gear itself to meet these new requirements and technical capabilities when they arise. This the NODC expects to accomplish.

In the matter of communication I have discussed only two functional interests. One has been the researcher or operational oceanographer himself; the other has been the supporting data center. There exists a third interest that occupies equal stature to the other two. This is the interest that designs and provides the instruments, recorders, and sensing devices that produce the bulk of the data that form the background for our entire discussion. In the final analysis it is also the function that justifies a data center in the first place. I might add that the factor of communication is just as important here as in the other areas and, as a matter of fact, this is the function I am attempting to perform at this moment.

It has not been traditional for close liaison to exist between the instrument and equipment designer and the individuals concerned with the longer term aspects of the use of the observational product of these instruments. This statement is, fortunately, not as true in oceanography as it has been true in most sciences. Oceanographers in the past have constituted a small, closely knit group and most of them, almost by definition, have had a large personal interest and competence in instrumentation. Unfortunately, this happy circumstance will probably end. Many a research oceanographer of the future will have no firsthand familiarity with the instrumentation that provides his research data. It is quite probable that he will have to rely on the Data Center for an instrumental evaluation of the record because the Center will be the only organization in position to exercise quality control in the broad sense.

The Data Center expects to develop this function to the best of its ability and to offer its assistance to both groups as an aggressive and continuing activity.

Now let us consider some of the specific detail that is of immediate concern in this Symposium. An examination of the observational programs maintained in the earth sciences makes it appear that they serve three separate and distinct purposes:

(1) Provide data for support of research;

(2) Provide data used for survey purposes; and

(3) Provide current data for operational uses.

The relative weights given each class of use varies considerably. In oceanography the first two have been predominant and I believe that this has been fortunate. In the field of meteorology the reverse has been true. Here, almost the entire emphasis has been placed on the current use of data for weather forecasting and particularly for aircraft operations. Instrumentation and the more sophisticated observation networks have been created primarily to satisfy these needs. The individuals engaged in atmospheric research and in climatology have had to be satisfied to use data which were largely designed to serve exclusively an entirely different purpose. It is my opinion that the science of meteorology has suffered immeasurably because of this course of evolution. I mentioned previously that it has been fortunate for oceanography that instrumentation and observation practices have been designed primarily to meet the needs of oceanographic research and ocean survey work. We in the Data Center, however, have some reason to be concerned that, under the impetus of newly-developed environmental prediction systems, the emphasis might be changed to the extent that the specifications of the operational interests may be met at the expense of those of the oceanographer.

It is possible to design instruments to satisfy both classes of requirements. This is done by being certain that the final record is in standard physical units and not in some operational unit that has more than one physical interpretation.

An example of a device that does not fit this principle is one of the meteorological instruments called a transmissometer which is actually a visibility (or extinction) meter for use at airports. The aircraft pilot is interested in visibility but is not concerned particularly with what meteorological phenomenon it is that reduces the visibility. Since the transmissometer records visibility only, when its record is the only one telemetered from a remote location, it is meteorologically meaningless to the scientist. There are many opportunities for such types of operational instrumentation in oceanography and these we should avoid except where we can maintain oceanographic integrity through the use of economical and efficient supplemental instrumentation.

In closing I would like to list very briefly a few other features in instrumentation that would be highly desirable from the standpoint of NODC and the interests it is dedicated to support:

1. Where telemetry is involved, there should be no loss of data through failure in electrical transmission or through failure of some raw data processing facility.

2. Data should be in format which is either immediately compatible with the most advanced data processing system or it must be in a form rapidly and economically convertible to compatible format without manual steps.

3. In cases of sequential data, the format of the data record should not irrevocably determine the sequence and order of data storage.

4. Provision should be made for the permanent retention of semi-processed as well as raw data.

5. Whenever possible, the records from two or more related instruments should be such that adequate quality control through cross-checking is facilitated.

8. OPERATIONAL ASPECTS OF OCEANOGRAPHIC INSTRUMENTATION

PART I. FOR THE HYDROGRAPHIC OFFICE (OPERATIONS)

Captain R. D. Fusselman

Navy Department
Washington, D. C.

I would like to elaborate on the background which has shaped both our requirements and approach for the instrumentation aspect of oceanographic surveying. The military, scientific, and commercial demands for a national effort to execute a broad ocean survey program have been well established by the preceding speakers. We are prepared now to concentrate on the tools or hardware with which to do the job.

My remarks are aimed at supplying background material supplementary to the handouts which you have received. (See appendices E, F, and G.) I would like to pay tribute to the many people who have participated in this effort on the Panel on Equipment, Facilities, and Instrumentation of the Interagency Committee on Oceanography -- and particularly to Captain C. N. G. Hendrix -- whose dedication to this project has resulted in a clear-cut expression of our needs for instrumentation for oceanwide surveys.

Our present, coordinated national effort to obtain better instrumentation came about in the following manner: Last November, the Office of Naval Research and the Hydrographic Office conducted an oceanographic instrumentation conference at which some 45 specialists in the field were assembled to help determine what oceanographic data was to be collected and to what accuracies. In view of the many and diversified interests in all areas of oceanography, the early phases of the conference were chaotic with little agreement. From this conference, however, working groups were formed and patterns of requirements began to take shape. It was an encouraging and significant sign of recognition of the problem when Assistant-Secretary James H. Wakelin established the above-mentioned ICO Panel to extend and coordinate the national oceanographic instrumentation effort. Intensive liaison has been carried out for 10 months to resolve the general and specific interests of all government agencies and private institutions contributing data to the ocean survey program.

In the light of this background I will discuss survey instrumentation and its use by 20 or more government agencies. My examples are primarily Navy requirements and Navy applications but the instrumentation involved has been determined applicable to the needs of other members of the ICO.

The instruments, instrument "suits," and instrument "systems" of the oceanographic survey agencies must be standard and the data collected must be in standard or compatible form to facilitate the gathering and exchange of data for immediate application. This will insure a contribution to the storehouse of readily available and useful knowledge for scientific and commercial purposes.

Our handouts emphasize the desire for "suits" and "systems" of instruments which are compatible and which can be developed and produced soon. The oceanographic agencies need material improvement in the reliability and accuracy of their instruments and the speed at which oceanographic measurements can be made. For example, it now takes one ship 24 hours to complete what we refer to as an oceanographic station. This means measuring and observing possibly two dozen physical, chemical, and biological characteristics at a specific location at sea. Our objective is to reduce this time to two hours because one survey ship would then be able to cover approximately twice the area in the same amount of time. We may not be able to achieve our objective of two hours but any reduction in this time will aid the total effort materially. Referring back to the remarks of Dr. Woodrow C. Jacobs, we will gain even more time when the data gathered is compatible with data processing and electronic computing equipment in the NODC.

I am sure that this highly selected audience is familiar with Navy's principal problems in instrumentation. Many points were brought out in detail at the NSIA meeting in May, the Mil-E-Con meeting in June, and several subsequent articles that have appeared in various professional periodicals. Although the Navy has a wide variety of military applications for all known variables of oceanographic data, I am purposely limiting myself to the paramount problem of sonar and its reliance upon accurate and comprehensive bathymetric and temperature data.

Unfortunately the terms -- detect, identify, classify, and destroy are thrown about so loosely, with understandable emphasis on "destroy," that I'm afraid many of us are inclined to overlook the fact that we are still wrestling with "detect." Detection, of course, is done with sonar. To use sonar effectively we must understand the environment. There has been a substantial increase in the range of detection by sonar and this has been due in large part to our greater knowledge of the ocean environment through oceanography.

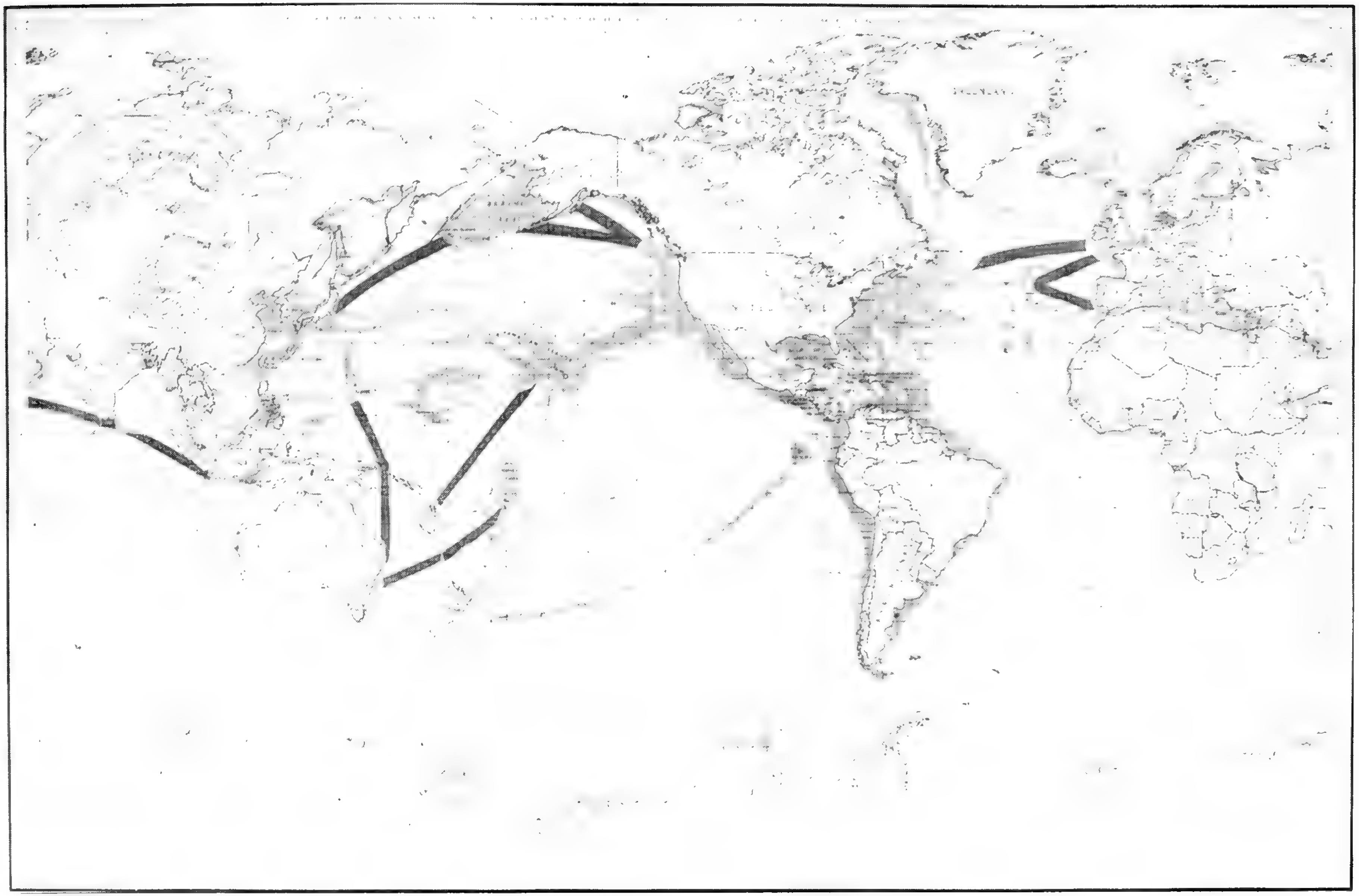
How much do we know about the oceans? A typical example is portrayed by figure 8.1 which reveals the present inadequate coverage of bathymetry on a worldwide basis. Practically all oceanographic factors affect sonar performance.

Bathythermograph data holdings are similarly scanty. Figure 8.2 illustrates large oceanic areas of strategic importance for which we lack sufficient temperature data.

Acquisition of adequate bottom and temperature data will assist us to furnish sonar operators with charts, tables, and special publications with which they may predict various environmental conditions affecting sonar performance in specific operating areas.

We estimate that we have adequate coverage for about 3 percent of the oceanic areas involved. It is fairly obvious that existing or even planned survey ships are inadequate for completion of the task within any reasonable length of time. This then leads to the conclusion that we must get the maximum use from each platform at sea in order to collect all of the oceanographic data required by the numerous agencies involved. Within limitations posed by operations and dollar considerations, the Navy intends to assist to the maximum extent possible. Occasionally, oceanographic data collection can be consistent with the primary mission of a combatant unit but it now appears that the best application in the Navy can be achieved with service forces and combatant units during rotation voyages.

FIGURE **8.1**
U. S. BATHYMETRIC HOLDINGS (1961) . . . .


LEGEND
SPACING OF SOUNDINGS EXCELLENT FOR CHARTING PURPOSES.
SPACING OF SOUNDINGS FAIR TO GOOD FOR CHARTING PURPOSES.
PRIORITY AREAS REQUIRING SOUNDING DATA.


LEGEND
ADEQUATE
INADEQUATE
NO DATA

The Navy is but one of the sources from which platforms might be obtained. An analysis of all ships available and their characteristics has led to the establishment of three general categories: (1) ships of opportunity, (2) synoptic ships, and (3) survey ships. Ships of opportunity may be tankers, freighters, fleet units, fishing vessels, etc.

Considering a few aspects of applied oceanography, we have refined storm and ice prediction techniques to the point where millions of dollars are saved each year in cutting transocean crossing time and minimizing damage to ships and cargo. The merchant marine has been contributing information for years but more emphasis and better instruments are required. The fishing industry is intensely interested in temperature, the presence of plankton, and the location of sea mounts. Navy is also vitally interested in all three.

The next category, synoptic ships, is directed toward environmental prediction surveys -- such as ASWEPS -- Anti-Submarine Warfare Environmental Prediction System. Synoptic ships might be called ocean station ships which maintain the same position at sea over long periods of time. They are stopped or underway at very slow speeds. The best examples of these are: (1) Weather ships, (2) picket ships, (3) missile tracking and recovery ships, etc.

The third category comprises research and survey ships of government agencies as well as those of private laboratories and some educational institutions. Examples are the Bowditch, San Pablo, and Rehoboth.

Our existing survey ships are conversions. Six ships now under construction were specifically designed for research and survey purposes.

In addition to characteristics, missions, and schedules, a major contributing factor to the categorization of these various ships has been the type and numbers of instruments that it would be practicable to install.

. . . . FIGURE 8.2
U. S. BATHYTHERMOGRAPH HOLDINGS

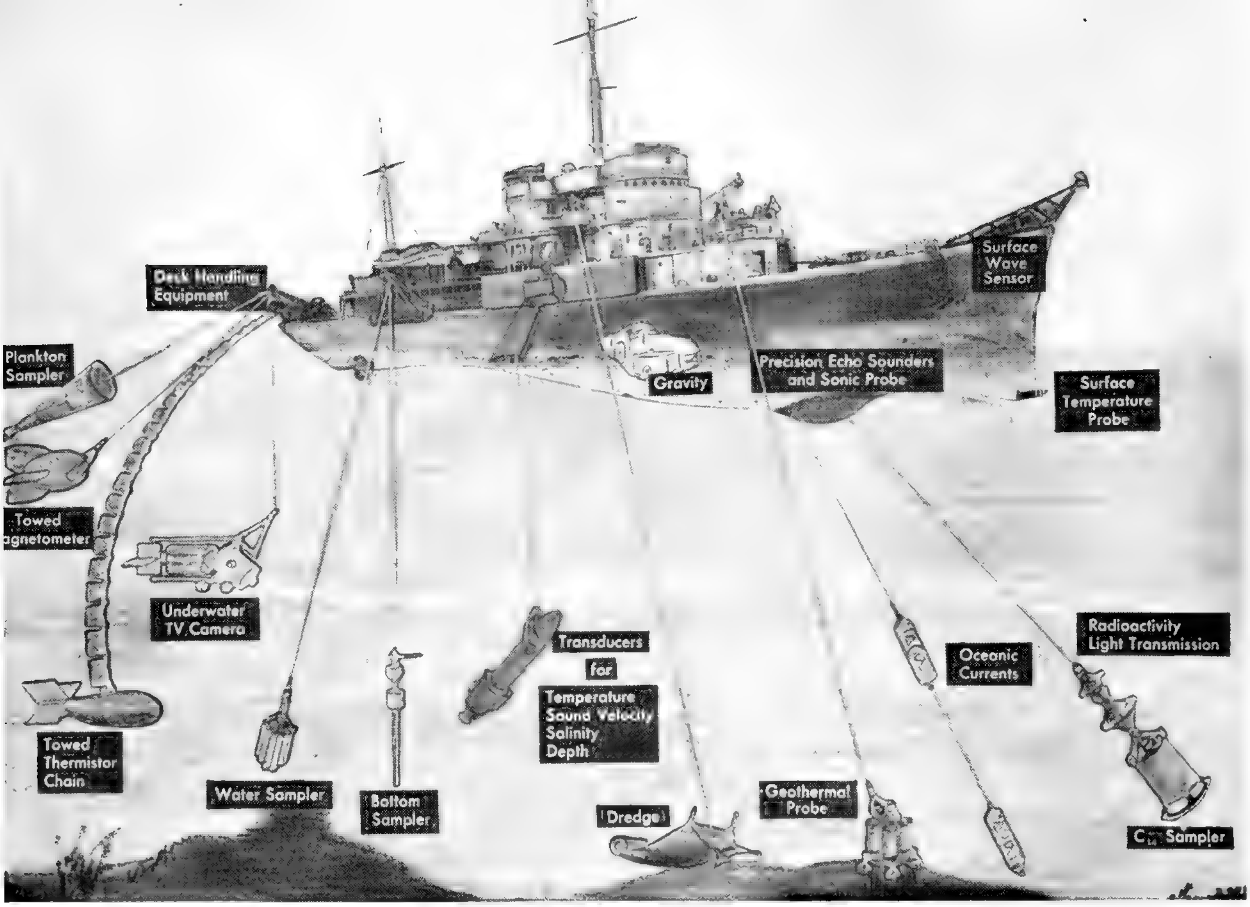


FIGURE **8.3**
RESEARCH SHIP

Figure 8.3 gives some appreciation for the instrumentation now carried by a research or survey ship. Merchant or commercial ships on tight schedules cannot be expected to instrument in this manner nor can fleet units accommodate installations such as these.

For example, there is a hull-mounted surface wave sensor and a surface temperature probe. Separate measurements to varying depths are taken on such items as radioactivity, light transmission, and Carbon 14.

Separate installations for current meters, a geothermal probe, a dredge, and a bottom sampler are deep, brute force equipments. Many separate hoists and many separate instrument trips are necessary to measure the variables involved.

In the center of figure 8.3 and still under development is what we refer to as the basic system. This is the one -- at this moment -- that appears to have best possibilities for early and widespread application in all three instrument suits. The objective is to include in a single housing, as many sensors as feasible to measure electronically various oceanographic variables.

We have mentioned suits and systems of instruments and I think it would be helpful to spend a little more time on each of these terms. When we speak of "suits" of instruments, we are speaking of the vertical columns in figure 8.4. There is a suit contemplated for each major category of platforms, survey ships, synoptic ships, and ships of opportunity.

	DATA MEASUREMENT	SHIPBOARD SURVEY	SYNOPTIC ASWEPS	SHIP OF OPPORTUNITY
BASIC SYSTEM	TEMPERATURE	Underway, Stopped	Underway, Stopped	Underway
	SOUND VELOCITY	Underway, Stopped	Underway, Stopped	
	SALINITY	Underway, Stopped	Underway, Stopped	
	DEPTH	Underway, Stopped	Underway, Stopped	Underway
	POSITION NAVIGATION	Underway, Stopped	Underway, Stopped	Underway
	DENSITY	Underway, Stopped	Underway, Stopped	Underway
EXPANDED SYSTEM	BATHYMETRY	Underway		Underway
	WAVES	Underway, Stopped	Underway, Stopped	
	MAGNETICS	Underway, Stopped		Underway
	GRAVITY	Underway, Stopped		
	CURRENTS	Stopped		
	LIGHT	Underway, Stopped		
	GEOTHERMAL PROBE	Stopped		
	ACOUSTIC	Stopped		
	DYE DETECTOR	Stopped		
	RADIOACTIVITY	Stopped		
INDIVIDUAL INSTRUMENTS	PLANKTON	Underway		
	CAMERA	Slow speed		
	TELEVISION	Slow speed		
	DREDGE	Underway		
	SEAFLOOR PROBE	Underway		
	BOTTOM SAMPLERS	Stopped		
	WATER SAMPLER	Stopped		
	METEOROLOGY	Underway, Stopped	Underway, Stopped	Underway
	CHEMICAL ANALYSIS	Stopped		

SLOW SPEED   Underway   Stopped

FIGURE **8.4**
OCEANOGRAPHIC SURVEY INSTRUMENTS REQUIRED

"Systems" refers to groups of instruments where possible combinations of sensors in common housings appear feasible. The "data measurement" column represents the oceanographic variables in which we are interested and their relationship to the various instrument suits is indicated.

The basic system offers the biggest early potential market as the appearance of most of the variables across the board indicates.

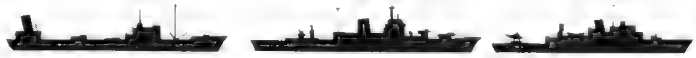
From an engineering standpoint, the expanded system appears to be a logical and feasible extension of the basic suit. Automatic data processing is extremely significant for these variables. Here, there is immediate need for the application of data processing to the survey product.

The last system, individual instruments, takes us back to some of the measurements that I noted previously where ponderous or extremely complex equipment is involved. At this time, there appears little possibility of incorporating these in compact sensor housings.

Although we have analyzed and broken down this problem by general groupings of platforms and suits and systems of instruments, I'm sure that everyone understands that this is just a method of organizing our approach. These various lines and boxes are by no means fixed but simply represent planning assignments. Because of the present unsatisfactory state of instrumentation generally, breakthroughs should occur and we may well wind up with many changes in this graph. Such improvements would point toward a greater capacity to carry out survey work. It is not practicable to discuss each of the oceanographic variables involved. They are fully covered in the handout.

Closely related to each platform are the major required operational characteristics of these three suits of survey instrumentation. (The engineering aspects of these three suits will be described later by Mr. Gilbert Jaffe, Director of the Instrumentation Division at the Hydrographic Office.)

Certain aspects based on the mode of operation for each of the three types of ships are better understood by a better understanding of the operation itself (fig. 8.5): (a) Ship of Opportunity. This type ship must remain underway in order to maintain tight operating schedules. It is a straight dollar loss if he is required to slow



	SHIP OF OPPORTUNITY	SYNOPTIC SHIP	SURVEY SHIP
ACCURACY	MEDIUM	MEDIUM	HIGH
MODE OF OPERATION	U	U/S	U/S
DATA PROCESSING	NONE	LIMITED	EXTENSIVE
DATA VOLUME	MEDIUM	LARGE	LARGE
DATA VARIETY	LIMITED	LIMITED	EXTENSIVE
PORTABILITY	EXTREME	LIMITED	NONE
TELEMETRY	OPTIONAL	MANDATORY	MANDATORY
DEPTH	MODERATE	MODERATE	EXTENSIVE
	(Ruggedness and Low Maintenance are Critical)		

U - *Underway* S - *Stopped*

FIGURE **8.5**
SPECIFICATIONS FOR THE THREE INSTRUMENTS SUITS

or stop to collect oceanographic data. (b) Synoptic Ship. The present early developmental phases of instrumenting these ships have been limited to preparing them for making observations when stopped. As the program develops, similar instruments for the synoptic ship will include concepts for handling instruments when underway. This system will be described in some detail during tomorrow's session. (c) Survey Ship. Underway and stopped operations are necessary in order to cope with the large variety of oceanographic observations made by this type of vessel.

Another factor bearing on the design of required instruments is the amount of portability required: (a) Portability is a very critical aspect for instruments used on ships of opportunity. Here we are talking about many varied types of platforms which require shifting of instrumentation installations from one vessel to another. (b) For the synoptic ship, portability is less of a problem, in view of a heavier and larger shipboard installation. (c) For survey vessels it is visualized that practically all instrumentation will be more or less of a permanent nature.

Depth requirements and the design problems connected with them are different for different types of service: (a) For the ship of opportunity and the synoptic ship, oceanographic instrumentation will work at varying depths down to 2,500 feet. (b) The survey vessel by comparison operates over a much deeper range going generally to 4,000 fathoms. It is clear that winch size, cable strength, and toughness of sensor housing are all related to the depth factor.

The onboard readout also varies for the kind of ship in use: (a) Ships of opportunity which work on a worldwide basis will have a punched tape type readout from their sensors. These tapes will be mailed in to the NODC for normal processing or will use dispatches for priority messages. (b) The synoptic ship might be compared to rapid handling requirements of Weather Bureau data collections. Oceanographic data received on board will utilize radio telemetry, forwarding information to the Task Force Commander and to shore-based plotting centers in order to expedite oceanographic synoptic charting. (c) The survey vessel would, of course, have the most modern data handling and processing techniques which would include computer facilities on board. Telemetry of oceanographic data might be a requirement in some instances.

I would like to point to one bright spot in the overall instrumentation program. It is the submarine instrumentation suit which we have on display here today (fig. 8.6). This suit approaches what we are looking for in the way of modern sensors and automatic data processing. Admittedly, there are only a few variables involved, but this approach and this system of rapid data handling is a big step forward and indicates that we are on the right track in our general approach to other types of platforms.

By way of summary I know that all of you are interested in the practical aspects of hardware production and specifically the numbers and value of these individual instruments and instrument systems.

Figures on the Navy's planned "Ten Years of Oceanography" program have been published earlier. We have coupled these estimates with the presently known plans of other government agencies and have summarized requirements as follows. I cannot emphasize too strongly the planning nature of these figures and the lack of sufficient data to make more reliable estimates. Allowing for

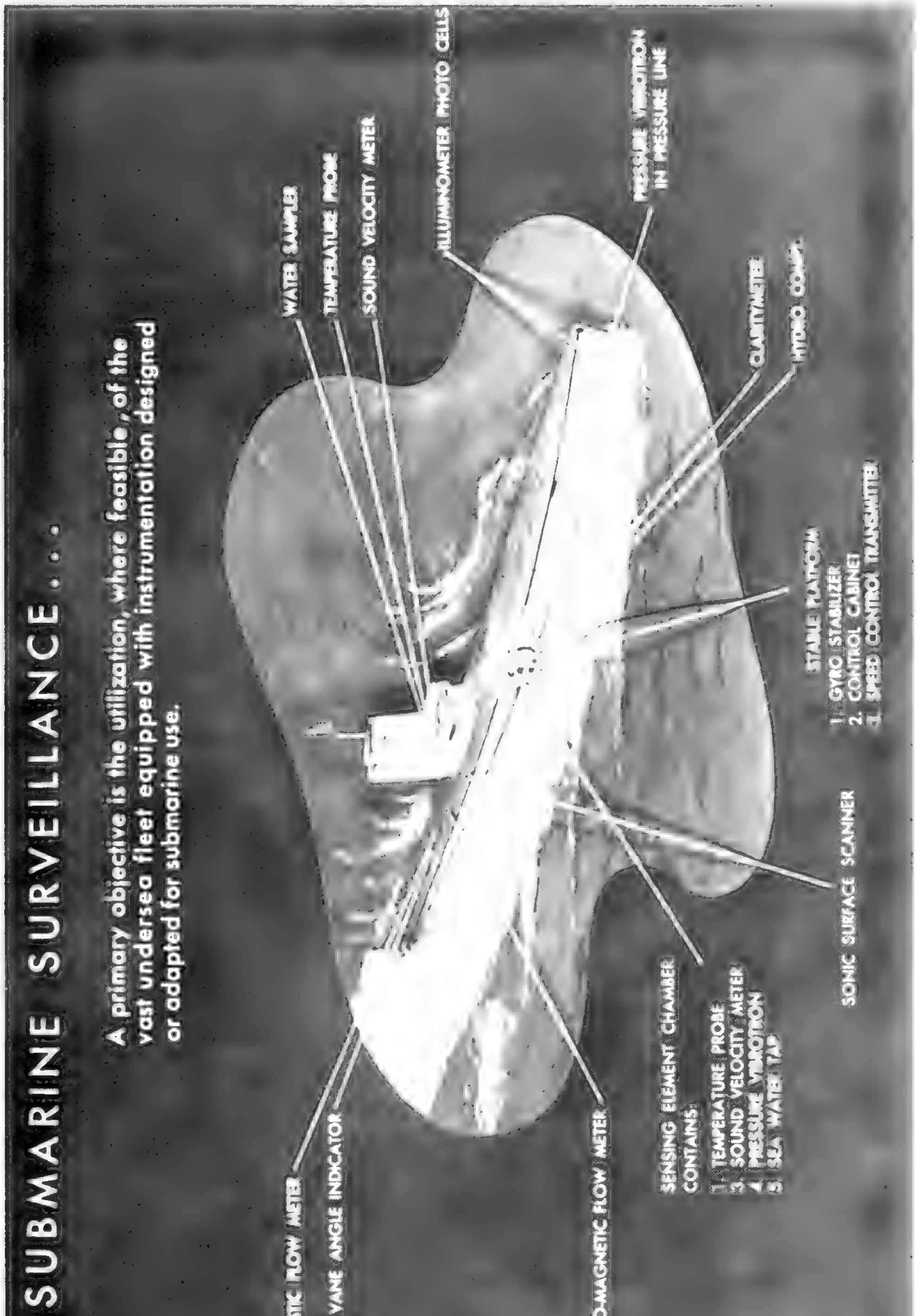


FIGURE **8.6**
SUBMARINE INSTRUMENT SUIT

APPROXIMATE NUMBER OF INSTRUMENTS REQUIRED FOR RESEARCH AND SURVEY OPERATIONS

BASIC SYSTEMS	
ASWEPS	45
SHIP OF OPPORTUNITY	56 - 163
SURVEY/RESEARCH	42 - 69
EXPANDED SYSTEMS	
SURVEY/RESEARCH	50 - 100
INDIVIDUAL INSTRUMENTS	
SURVEY/RESEARCH	
PLANKTON	41 - 52
CAMERA	42 - 88
TELEVISION	25 - 60
DREDGE	41 - 52
SEAFLOOR PROBE	40 - 65
BOTTOM SAMPLERS	41 - 52
WATER SAMPLER	62 - 130
METEOROLOGY	52 - 93

FIGURE 8.7

budgetary changes, it appears that over a ten-year period there will be three to five new ships a year that will require a complete set of survey instruments. This, coupled with hull-mounted equipment such as a precision fathometer, easily totals 10 percent of the value of the ship.

Of lesser significance individually will be the ships of opportunity and synoptic ship suit requirements, but lower individual expenditures are offset by the volume involved.

The broad estimates given on figure 8.7 are intended to give you ball park figures for planning purposes.

In conclusion, it is hoped that this brief review will give you a better appreciation of our oceanographic survey instrumentation requirements. It is also hoped that industry, exploiting the latest techniques in sensors, sensor housings, and data collection and processing will take this phase of the oceanographic program forward at the pace required.

8. OPERATIONAL ASPECTS OF OCEANOGRAPHIC INSTRUMENTATION

PART II. FOR THE HYDROGRAPHIC OFFICE (ENGINEERING)

Gilbert Jaffe

Hydrographic Office
Washington, D. C.

The improvement of oceanographic instrumentation is an engineering problem and so I will make a few remarks about some of the engineering aspects. Our organization at the Hydrographic Office has been the bridge between the survey instrument user -- the survey scientist, if you will -- and Industry. It is from this experience that my remarks will be drawn.

The activity of our Instrumentation Division, the constant flow of survey instruments in and out of our facilities over the past ten years, has given us an objective, firsthand picture of some of the shortcomings of our present-day oceanographic instrumentation.

Essentially, what we have to work with now is divided into three categories.

Some instruments that are relatively off-the-shelf devices of a rather ancient vintage are shown in figure 8.8. This is a group of WATER SAMPLERS, relatively simple mechanical bottles. They do a very fine job, but, of course, they do not lend themselves to automatic machine processing of the data collected. The most famous of these is the _Nansen_ bottle on the extreme right. Paired with the _Nansen_ bottle are the traditional REVERSING THERMOMETERS (fig. 8.9) which go back many, many years. They are essentially mercury in glass thermometers and measure the temperature of the sea in situ. The BATHYTHERMOGRAPH (fig. 6.4), the reversing thermometer, and the _Nansen_ bottle have collected the largest amounts of oceanographic data to date, and, in fact, most of the data in the National Oceanographic Data Center today, has been collected with one of these three instruments.

The second group of instruments consists of commercially available devices that have been put together in a single system,

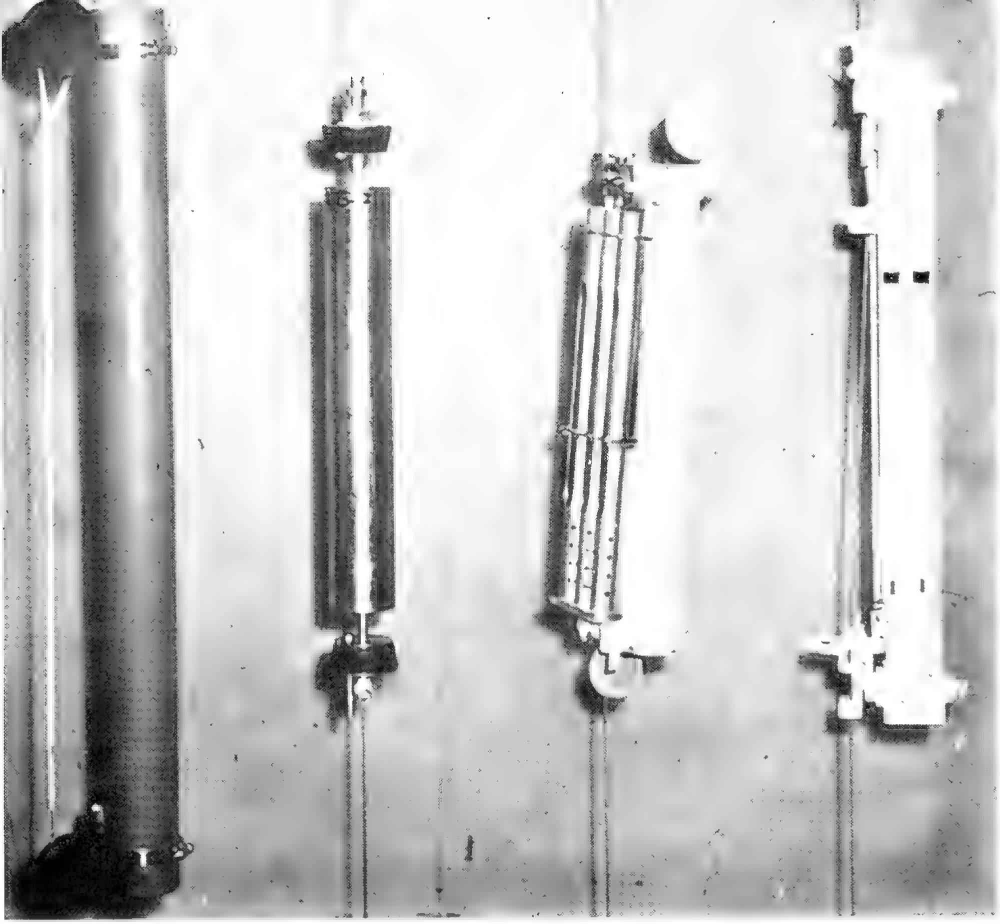
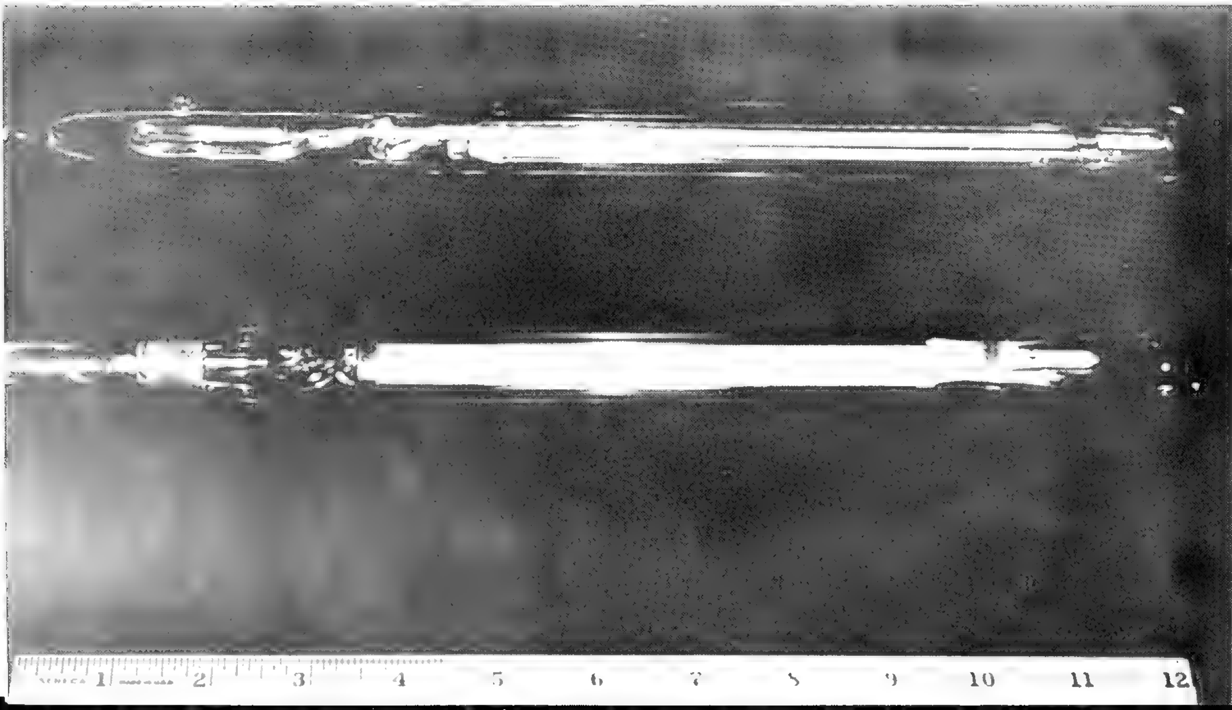


FIGURE **8.8**
WATER SAMPLERS

FIGURE **8.9**
REVERSING THERMOMETER



or a group of systems, to serve a specific requirement. For example, our SUBMARINE RECORDING UNIT (fig. 8.10) is a consolidation of commercial electronic counters, commercial converting units, and commercial flexi-writers. The sensing elements that are attached to these devices for temperature, for depth, and for sound velocity are either not specifically engineered for the purpose, or if they have been engineered, they have not been sufficiently tested in the field to assure us that information being collected on a continuous basis is valid.

The third group of instruments with which we are concerned are experimental devices. For instance, there was no adequate recording system for the CURRENT METER shown in figure 8.11. The previous recorder for this instrument did not lend itself to automatic machine processing of its data output. Shown in the illustration is an experimental unit which takes the data from the current meter and applies it to an ordinary electric typewriter which can also be utilized with punched paper tape. The idea here is to use relatively standard instrumentation with some modifications and some conversions. This, by and large, constitutes the engineering state of the art -- a good bit of our present-day information is obtained from these instruments.

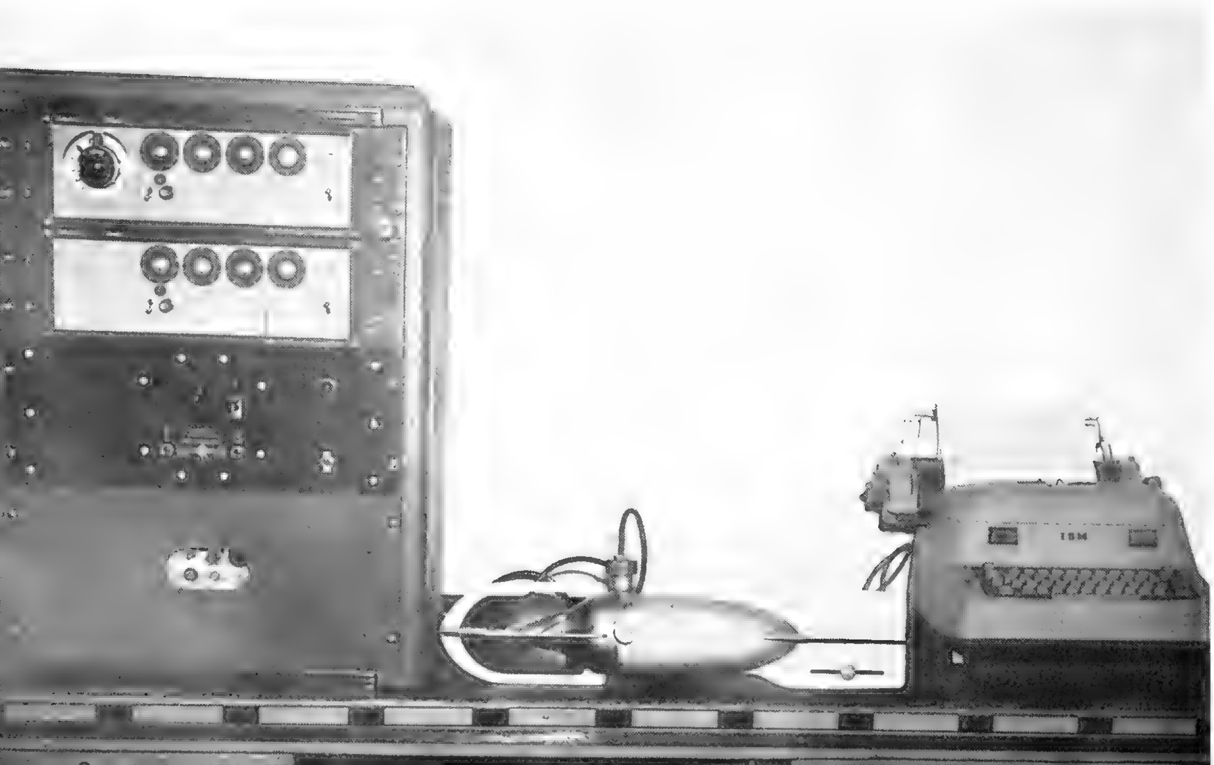
Most of the newer oceanographic instruments have come essentially from research prototypes that have been developed by various laboratories in and out of the Government. They have been developed in support of oceanographic research. These devices are usually excellent for their original purpose, but there is where the development stops.

An urgent requirement for survey instrumentation is to engineer the research tools into rugged, reliable instruments that can be used aboard the classes of vessels that Captain Fusselman has just described. Industry can play a major role in the conversion of the research tool into the survey instrument.

The Hydrographic Office probably has one of the largest collections of oceanographic instruments. However, in spite of this, our total investment amounts to only about three million dollars. However, the rate of this expenditure has been increasing markedly during the last few years, and, according to the proposed instrument program, this trend is likely to continue.

FIGURE 8.10
A SUBMARINE RECORDING UNIT

FIGURE 8.11
CURRENT METER



Now, I would like to review a few of the engineering requirements and if I repeat some of the things that have been said before, it is because these points need emphasis.

Basically, oceanographic instruments must be durable. These devices, in most cases, will be used for long periods and will be used under relatively severe shipboard conditions so that durability is an absolute must, for this is one of the most serious shortcomings of what we have available now.

Throughout the design and manufacture of oceanographic instrumentation components, interchangeability is a primary concern because of the difficult logistical problems at sea. We have a problem of having sensors and components which are not standardized and are not interchangeable. Each time we go out, we need a whole new bag of devices rather than a relatively few standard ones. In line with the requirements for present-day oceanographic instruments, I would like to refer back to figure 8.5 to re-emphasize some things that Captain Fusselman has already said.

The instrument suits of the Ships of Opportunity, the Synoptic Ships, and the Survey Ships are relatively different.

Accuracy: The Ships of Opportunity with their underway measurements and the Synoptic Ships with their large number of measurements require instruments of medium accuracy. The Survey Ship, which carries a very high degree of specialized instrumentation, requires instruments of high accuracy.

Mode of Operation: The Ship of Opportunity makes observations only when underway; the Synoptic Ship and the Survey Ship can be both underway and in a stopped position.

Data Processing: There is no data processing on the Ship of Opportunity; some is done on the Synoptic Ship; on the Survey Ship data processing is extensive and is performed by computing facilities.

Data Volume: The Ships of Opportunity, because of their nature, collect a moderate amount of information; the Synoptic Ship requires large quantities of synoptic data; the Survey Ship collects large quantities of information on station for long periods of time.

Data Variety: Both Ships of Opportunity and Synoptic Ships collect rather limited types of data; a few measurements can be taken on a continuous basis. On our Survey Ship, of course, we have the very extensive collection of measurements of a great number of variables.

Portability: Ships of Opportunity carry very portable devices which can be put on any ship at any time. This is less so for the Synoptic Vessels. On the Survey Ship, of course, we have fixed installations.

Telemetry: On the Ships of Opportunity telemetry is really optional but when this ship serves as a part of the Synoptic net, telemetry should be aboard. However, on many occasions this is not necessary. In the Synoptic Ship, we must have telemetry to get the information back, and the Survey Ship must have equipment for telemetering back to base stations to carry out its mission.

Depth Requirements: The Ships of Opportunity and Synoptic Ships make observations at moderate depths; the Survey Ship, at these and at greater depths.

A critical factor in the success of our oceanographic program would be the number of ships which can be instrumented; this depends on how difficult it is to operate and maintain these instruments. Since the shortage of qualified technicians is acute in the oceanographic field, it is very important that the operation and maintenance of instruments for this purpose be simplified to the greatest extent possible. This is especially true of our Synoptic Ships and their instrument suits.

Another important engineering area is the design of self-calibration and/or calibrating circuitry, which allows shipboard checks from sensor to recorder. There is, by and large, a tendency on the part of engineers at sea to take the measurements of the operating instruments at face value. The quantity of data flowing in and out of our National Oceanographic Data Center demands upgrading our quality control. This can be done through instrument calibration.

Along with calibration, we have the test and evaluation problem, and we find that most of our oceanographic instruments are reluctant to go to sea. We have seen many instruments perform beautifully in the laboratory, only to fail miserably under actual sea conditions. There is the need for field testing and evaluation of newly-developed, production-engineered instruments under actual field conditions. They must be subjected to the same environmental factors as they will be during regular usage.

Next, I would like to say a word about the method by which our specifications are drawn. There are the usual two types: The performance specification and the engineering specifications. The handouts that you have received on survey instrument requirements contain a combination of both. Any requests for quotation would probably contain one or the other, depending on the state of the art.

In summary, while we have some sort of prototypes for most of the measurements desired, they are, for the most part, a long way from being the well-engineered, durable, reliable devices required for shipboard survey operations, and they lack interchangeability of components and systems. They do not generally collect information in a manner amenable to rapid machine processing, and they do not lend themselves to quantity production at relatively low cost.

At present, the need to define requirements, the analysis of available data, and the solution of vast numbers of oceanographic problems can keep every available oceanographer busy full time. The qualified oceanographer should not have to be additionally burdened with developing and manufacturing his own instruments to collect data. Here again, is where industry, with its extensive background and facilities, can play a major role to relieve the situation. Volume-wise, the survey requirement probably represents the largest market in the oceanographic instrument field.

Reviewing the market, the SHIPS OF OPPORTUNITY (fig. 8.12) require navigation equipment, temperature equipment, and depth equipment. Again, we have prototypes of all of these, but at present they are either not in production or they are not reliable and compatible with our present data processing capability. Each system is composed of many individual components such as sensors, sensor housing, cable, winch, monitor, recorder, power supply, and telemetering equipment.

For the SYNOPTIC SHIPS (fig. 8.13) we need instruments to measure position, temperature, sound velocity, salinity, and depth; we need a wave-measuring device in the expanded system, and

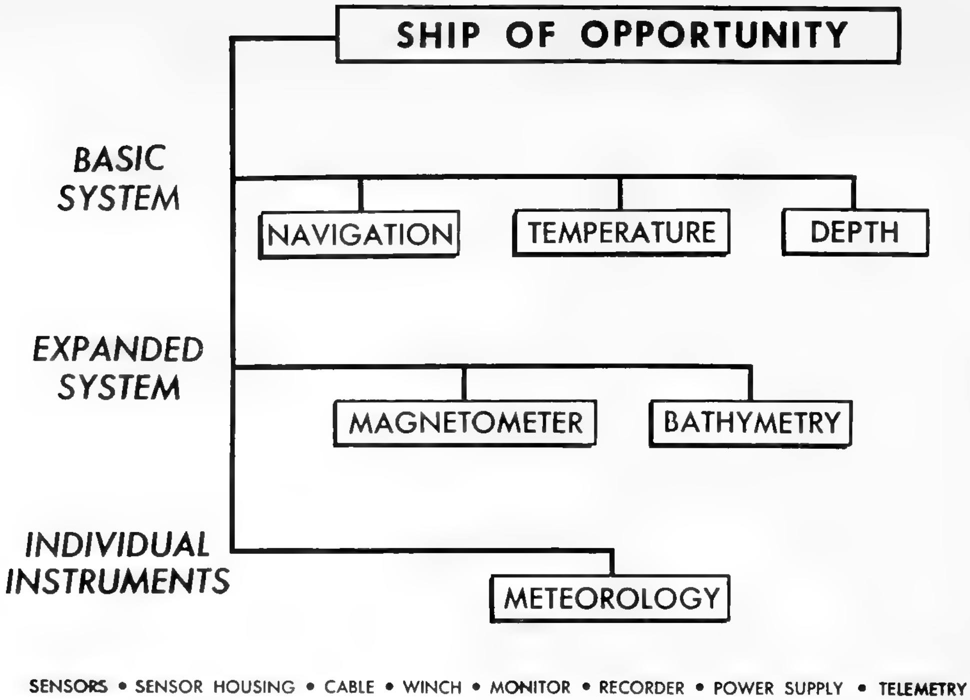


FIGURE 8.12
INSTRUMENTS NEEDED FOR SHIPS OF OPPORTUNITY

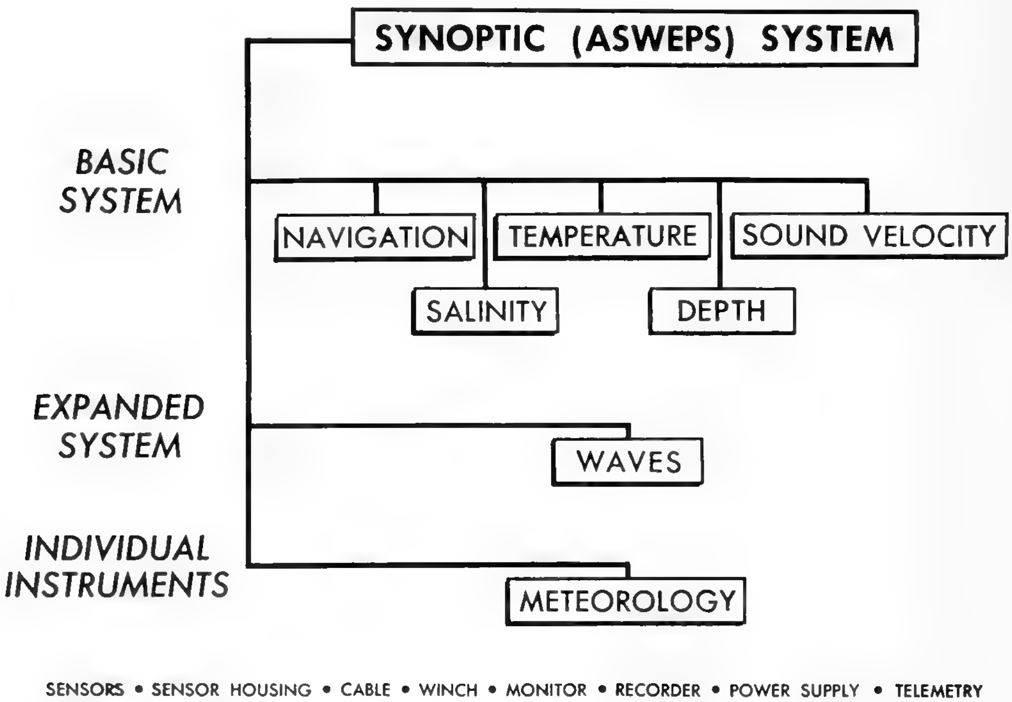


FIGURE 8.13
INSTRUMENTS NEEDED FOR SYNOPTIC VESSELS

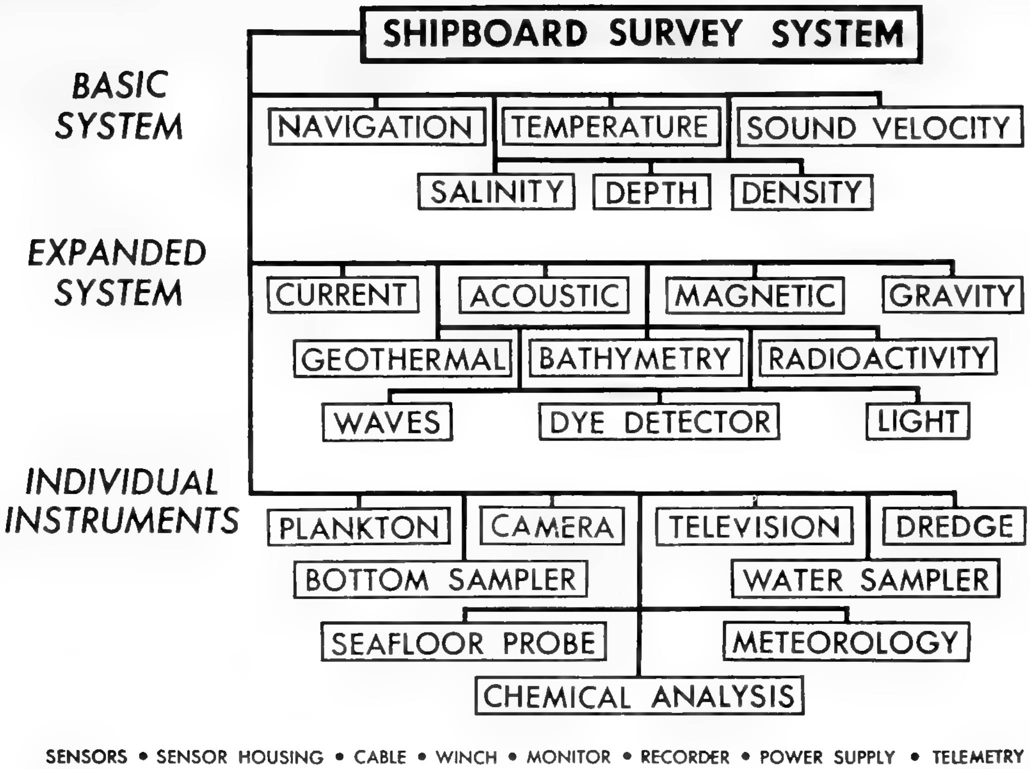


FIGURE 8.14
INSTRUMENTS NEEDED FOR SURVEY SHIPS

meteorological instruments.

The most difficult system concept is that for SURVEY SHIPS (fig. 8.14). Again, I would like to repeat, because it is extremely important, that we have a semblance of a prototype for each of these devices mentioned here, but they do not really fulfill our present-day survey requirement.

If we can reduce the time required to conduct oceanographic surveys by properly instrumenting vessels, and at the same time, increase the accuracy and flexibility of those data, we will have more than paid for the cost of developing and manufacturing the instruments. At the same time, we will have added immensely to our national oceanographic effort.

8. OPERATIONAL ASPECTS OF OCEANOGRAPHIC INSTRUMENTATION

PART III. FOR THE BUREAU OF COMMERCIAL FISHERIES (BIOLOGICAL)

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The instrumentation requirements for the investigation and charting of the biological parameters are less easily defined than the physical and chemical ones. The measurement of biological parameters are of lower accuracy and the things measured are frequently complex, making measurements difficult to compare and to define accurately.

The measurements that physical and chemical oceanographers take have value for their own sake; these measurements can be employed very usefully without reference to the biological parameters. Measurements of biological features are of less value and are more difficult to interpret if taken alone; they are most useful when they are taken in conjunction with physical measurements.

Biological measurements should be quantitative and reproduceable. It should be possible to define precisely the quantity measured. This is easier said than done. In figure 8.3 was a PLANKTON SAMPLER, a device to collect organisms from the sea. This was a towed conical net. The catch of organisms can be estimated in a variety of ways, such as by volume, weight, or species composition. However, the character and volume of catch may be different in various places and it is often quite a problem to determine what these differences reallv mean. The problem of the qualitative differences may be attacked by considering perhaps the quantity of bound nitrogen in the catch as a measure of protein, but even here the differences in average sizes of the organisms in various parts of the ocean may occasionally introduce an unknown error in the results. In addition, even the simple matter of estimating how big a change in the catch can be considered as representing a significant change in the density of organisms in the sea itself has not been satisfactorily solved. This is essentially a sampling problem and is inherent in all observational data. These problems are not restricted to survey observations, but are of greater concern in surveys since the comparability of data taken by standardized procedures over the oceans of the earth is an important goal.

Oceanographic instruments can be grouped into two general categories: Sensing instruments and capturing instruments. SENSING INSTRUMENTS are used to obtain measurements by light or sound or some other attribute of the thing measured; a CAPTURING INSTRUMENT is used to capture the thing to be measured, and the measuring generally follows capture.

Examples of visual sensing systems are submerged automatic photographic or television cameras. Variations in the light absorption of the water itself has biological connotation, especially when taken well off shore on the high seas. Also, such a simple thing as an experienced man with a good pair of binoculars on his vessel's bridge sweeping the sea for evidence of surface schools of fish, can provide quantitative data. We used two divers to count fish observed along a line laid on the sea floor in Hawaii to estimate quantatively the abundance of inshore fishes by species and size. The object here was to compute the weight of the fish stocks per unit area of sea floor. This is, perhaps, a specialized technique but biologists have complicated problems, and tend to develop special ways to get the information they want.

In addition to visual sensing systems, there are sonic systems. Passive listening devices, such as the hydrophone, may be useful; active devices employ echo ranging equipment.

The other group is the capturing instruments. The simplest is the Nansen bottle or others of this type which collect a sample of water at a preselected depth. The Nansen bottle takes water for physical measurements such as temperature, or chemical measurements such as salinity or oxygen. Included with the water samples are animals or plants that happen to be in it.

Next is the plankton net which has been generally used for a long time by biologists as a standard instrument. It is generally used with a flow meter in the mouth. In some cases it is modified so that it can be opened and closed at various depths. A clever development of the plankton net is the continuous plankton recorder which has been used for many years in Great Britain. In it, a strip of silk is pulled over an orifice through which water is passed. This silk is rolled up in a little chamber along with some formaldehyde to preserve the catch and thus provide a continuous record of the life that is captured at a given depth along the path of the vessel.

In addition to these small nets, there are the large nets such as mid-water trawls which are useful for sampling the larger animals of the open sea. There are many kinds and sizes, built for a variety of purposes. They are in active development; some may be modifications of commercial gear and others special designs. Stationary gill nets take in animals by entangling them and are quite selective. All nets are selective, in fact, which renders interpretation of results difficult.

The old-fashioned way of catching fish by a baited hook is still a method of capturing biological samples. Japanese longline gear and modifications thereof can be used to obtain quantitative estimates of the predators in the open sea. This gear is composed of a horizontal buoyed line which in commercial applications may be upwards of 60 miles in length. Baited hooks on droppers are hung from this, usually about 30 fathoms apart. This gear takes sharks, large tunas, marlins, and other sizable carnivorous fishes.

I have listed a number of means by which biological observations of the ocean may be taken. The sensing instruments are likely to prove more compatible with survey requirements in that they may permit continuous observations while underway or simultaneous observations with physical measurements while on station. Certain of the instruments that depend upon the capture of organisms require, in effect, a full scale fishing operation and would be difficult to coordinate adequately with the other aspects of a survey. This means that the equipment for measuring certain biological parameters, or certain trophic levels -- especially those at the peak of the food pyramid -- will not be included within the ordinary survey ship suit of instruments, but must be used on special vessels. The means of estimating these biological parameters are not perhaps adequately developed or standardized enough to justify their inclusion in the ocean survey suit of instruments at this time; they are better left as missions for research ships.

Ocean surveys will serve to give us maps of the seas in terms of physical, chemical, and biological parameters. The usefulness of these maps will depend in part on the kinds of parameters we measure and the accuracy of measurement. The problems of measurement are more acute for the biological parameters than for the others since some of the measurements to be taken have not yet become generally accepted or standardized. Without careful intercalibration, changes in measurement techniques will make comparisons of data taken prior to such changes difficult. Also, the problems involved in qualitative differences of some biological parameters even when measured by the same instrument have not yet been satisfactorily solved. However, in spite of such problems, the survey maps of the oceans will serve as a very useful basis of planning fisheries research programs and as a landmark in man's understanding of this planet.

8. OPERATIONAL ASPECTS OF OCEANOGRAPHIC INSTRUMENTATION

PART IV. FOR THE COAST AND GEODETIC SURVEY

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The Coast and Geodetic Survey is a pioneer of more than one hundred fifty years in the field of ocean surveying. The original purpose for which the Bureau collected data from the oceans was a basic requirement to further its scientific study in aids to navigation. Gradually, over the years, new techniques for refining its aids to navigation have demanded expansion of studies of physical oceanography. In most recent years, the Survey's improved ship facilities for collection of marine data and a desire to cooperate with intergovernmental agencies, institutions, and industry have dictated participation in biological studies of the ocean.

At long last, oceanography in both physical and biological aspects is recognized as one of the most important of the earth sciences. In addition to influencing our climate and weather, the oceans contain the greatest unexploited supply of minerals and organic food on earth. It is, also, the greatest potential medium for transportation, such as underwater cargo. Two-thirds of the earth's surface lies beneath three hundred twenty-seven million cubic miles of sea water. Of immediate importance to the national defense and economy is information hidden under the water -- information about the topography of the ocean floor, direction and rate of the current flow, the location of oil and mineral dèposits, and the vast revenue of foodstuffs for a growing population. We cannot escape the influence of the oceans nor our dependence thereon. Despite this fact, development of techniques for systematic studies of the oceans is in its infancy.

Although some of the work of the Coast and Geodetic Survey at sea is motivated by specific research problems in which the Bureau is engaged, the greatest portion is of an exploratory type aimed at, first, description of the physical and chemical characteristics of the oceans and, second, acquisition of oceanographic research data for the Bureau and for others working in the field of oceanography. The Coast Survey is undertaking comprehensive oceanographic investigations in cooperation with scientists from other agencies. Currently a program is being carried out by the USC&GS ship, Pioneer, in the North Pacific, referred to this morning by Admiral Pierce in regard to navigational problems, wherein information is being compiled on many phases of oceanography, i.e., bathymetry, gravity, magnetics, temperature, salinity, dissolved oxygen, plankton, currents, bottom sediments, and meteorological measurements. In addition to the work of the Pioneer, other USC&GS ships are adding increasing amounts of oceanographic work to their charting activities and the working season of the four major ships is being extended. However, at the present, our knowledge is limited largely to waters one hundred miles from shore and even here it is inadequate for present and future needs.

Marine science, with the support of the United States government, is being expanded at an accelerated rate. In the long run the rate of progress in the basic marine sciences will determine progress in the applied marine sciences, the success of which depends upon the size of our reservior of fundamental knowledge. Military defense, marine resources, and marine radioactivity are areas of paramount importance for oceanwide, ocean-deep study. The Committee on Oceanography of the National Academy of Sciences -- National Research Council has recommended that either the Coast and Geodetic Survey or the Public Health Service should be made responsible for engineering studies in and near disposal sites of radioactive materials in the oceans, for routine monitoring of disposal areas and their surroundings, and for a continuing assessment of the effects on the environments of added radioactive materials.

Since the Coast and Geodetic Survey is primarily a survey organization, it is felt that the expansion of this urgently needed data collection program, during the interim period while research vessels are being constructed, can most economically be effected through long-period monitoring of stabilized platforms and buoys. An oceanwide buoy system has already been recommended for operation by the Survey. Such a system could economically be assimilated into the Bureau's normal work, with the ships acting as tenders while pursuing their usual duties.

Development of such a buoy system can best be categorized into three problem areas: First, buoys designed for use in incorporated systems; second, sensors for each parameter to be measured; and third, ultimate data recording.

Although considerable work and study have been expended toward developing various buoy applications, very little has been done toward implementing a system capable of operating at predetermined intervals for long periods of time. Dr. William S. Richardson, Woods Hole Oceanographic Institution, is presently engaged in such a program and has much information on the problems involved. In addition to solving the problems of environmental deterioration resulting from the marine biology, stress, etc., encountered, planting and recovery methods must be improved and greater insurance provided for the overall system to withstand extreme sea states. Recent developments by industry of new alloys and plastics which have considerable resistivity to environmental deterioration and greatly improved strength-weight ratios surely will aid in this instrumentation problem.

The second category is the development of sensors. Most sensors used today for procuring oceanographic data have been developed by industry for other applications and, through modifications, have been adapted to serve our purpose. As a result, the attendant problems of preventing deterioration by corrosion, of being able to withstand severe ocean pressures, of remaining stable at different depths for long periods of time, and of possessing the required resolution have resulted in the incorporation of complex electronics in an attempt to approach our requirements.

Present sensors leave much to be desired. A discussion of them often results in controversy as to the best approach. Basically, sensors can be characterized as mechanical or electromechanical. The mechanical type utilizes delicate parts to obtain the required resolution, and, therefore, is not practical for buoy or rough weather usage. The electromechanical type can be subdivided into three classes: Analog, digital, and variable frequency (FM). Although the digital and variable frequency systems may be analog in origin, for comparison they will be discussed separately. Analog systems, by their very nature, require environments which permit extremely stable operation since any degree of allowed instability results in error in the ultimate data. Generally the dynamic range of an analog system is restricted. Any improvement can only be accomplished by the use of very complex and expensive electronics, with an expected decrease in the system's reliability. Digital and variable frequency systems are somewhat similar in that the data signal can be transferred reasonably undistorted over long distances, but each requires a transponder which is highly sensitive to temperature effect. Digital systems readily available are presently restricted because of the encoder size and complexness and because of their excessive power requirement. The variable frequency system, in addition to presenting a difficult tracking problem due to center frequency deviation, also becomes complex and costly because of required filtering, frequency counters and converters or printers to record the data in a usable form. Mention of many attractive features has been intentionally avoided and troublesome features stressed in the hope that from this vast assembly of talent may come the development of a simplified, reliable, and economical sensor principle. If sensors are developed to operate from buoys and stable platforms, it is logical to assume that they can be economically adapted for underway operations.

Data recording, the third problem area, is not considered to be as difficult to solve. Certainly from the vast number of techniques in current use, adaptions can be made which can operate from the limited power supply of a buoy to record sensor outputs. Perhaps the most stringent requirement is that the record be compatible with automated techniques employed at the National Oceanographic Data Center.

As has been mentioned in previous talks, use of sound offers another means for measuring the ocean's physical characteristics. The Coast and Geodetic Survey program for utilizing sound to probe the oceans' mysteries requires the development of a narrow beam stabilized transducer for better bottom delineation in deep water, as well as a bottom scanner to define more clearly the shape and contour of the bottom. Further instrumentation is needed to make possible deeper penetration of the sea and to reveal the geological structure beneath the ocean floor. Development of instrumentation is needed, for both underway and stopped operations to measure bottom sound absorption and sound velocity useful in underseas warfare. Improved instrumentation using sound could make possible measurement of the little-known internal ocean wave motion so that the wave characteristics could be quickly and accurately determined. Sound could be used more effectively to study the structure of water density for a better understanding of changes due to temperature or biological factors. Further refinement of methods of studying the deep sea scattering layer could provide knowledge of the ocean food potential and of circulatory studies important in radiation contamination.

Other important instrumentation needed for development are accurate electronic measuring devices for geodetic distance measurements, offshore water level measuring equipment with recording and telemetering links to remove the uncertainty of the tidal gradient between the survey vessel and the tide gauge ashore, means for studying seismic sea waves, and an early warning system for destructive seismic waves.

Time does not permit a detailed discussion of all the ways in which industry can contribute to man's knowledge of the oceans, therefore, only major areas for profitable research development have been mentioned.

9. DISCUSSION OF WORLDWIDE NAVIGATIONAL REQUIREMENTS AS RELATED TO THE NATIONAL OCEANOGRAPHIC PROGRAM

Rear Admiral Donald McG. Morrison

U. S. Coast Guard
Washington, D. C.

One of the primary duties of the United States Coast Guard is the development, establishment, maintenance, and operation, with due regard to the requirements of national defense, of aids to maritime navigation for the promotion of safety on and over the high seas. Thus, the Coast Guard is vitally concerned with the navigational requirements of the National Oceanographic Program.

Loran, which is a long-range aid to navigation operated by the Coast Guard, may be installed anywhere in the world to meet the needs of the Armed Services or the commerce of the United States. This system, which I will describe in detail later, will be useful to the National Oceanographic Program. Coast Guard interest is not confined to the navigational aspects of the program. In past years, we have conducted a limited amount of oceanographic study in connection with the International Ice Patrol, aboard our vessels assigned to ocean station duty, on lightships, and at fixed structures. Legislation is now pending before Congress which will enable the Coast Guard to increase its effort in this field.

In any planned, systematic, oceanwide survey program a paramount requisite is accurate navigational control. The other speakers today have emphasized this particular point. It is of questionable value to collect and report voluminous environmental data unless it is accompanied by reliable positioning data. Without quality control in navigation, the collected data cannot be intelligently and effectively correlated in our National Oceanographic Data Center, or serve a useful purpose in exchange situations with other nations. In the U. S. National Oceanographic Program, the Survey Task will be one of the most time consuming and difficult to accomplish. Many existing systems of navigation, visual or electronic, are capable of providing precise navigational data in areas adjacent to inhabited coastlines. Conversely, relatively few systems are capable of providing this information over the broad ocean expanses of the world. Coverage of some of these areas, particularly in the Southern Hemisphere, will be extremely expensive and difficult. Existing navigational systems and those now being developed which show promise, must be reviewed to determine their capability to meet the requirements of the oceanwide survey.

All phases of the National Oceanographic Program will require accurate positioning information. Certain of these phases require the maximum possible precision. An accuracy of 1 nautical mile or less over all water areas of the world would be desirable. However, economic considerations will undoubtedly dictate acceptance of a lesser accuracy for the overall program. Because the surveys will be conducted by ships of different classes with varying primary missions and manned by personnel with varying degrees of technical skill, certain other criteria have been established. Basically, for any navigational system to be capable of fully meeting the requirements of the National Oceanographic Program it should be founded on four cornerstones:

First, continuous navigational information, day and night, regardless of weather conditions, over all ocean areas of the world;

Second, an accuracy of at least 3 nautical miles, with 1 nautical mile desirable;

Third, reliability, ruggedness -- and here we get that word ruggedness again -- and ease of operation and maintenance. For certain classes of vessels, volume and weight of shipboard components are important and these must not be restrictive. Shipboard equipment must be such that it can be dismantled and relocated to other ships with minimum effort, expense, and interruption of ship schedules.

Finally, shipboard and shore-based components must not be prohibitively expensive.

I can state categorically that no existing system is capable of meeting all of these ideal characteristics. The requirements of other users of navigational information, air, surface, and subsurface, are similar to those of the oceanwide survey program. All require extended coverage, reliable service, accurate information, and economic operation. Because of the costs involved in implementing shore-based systems, any such method chosen for the National Oceanographic Program should also serve other users.

There are two general types of aids capable of providing navigational information over broad ocean expanses. These are self-contained systems and shore-based systems. Under each of these general types there are existing aids and those undergoing research and development. All have certain advantages and disadvantages. Let us consider the aids under these two categories. The first are the self-contained systems, which are not dependent upon any signal from the shore.

The most primitive method of celestial navigation is the time-honored use of a HAND-HELD SEXTANT. Although an experienced navigator can obtain fixed accuracies of about two miles, the use of the sextant is limited to periods when both the real horizon and the celestial body are clearly discernible.

The usefulness of celestial navigation could be extended by increased telescope power and inertial techniques to determine either horizontal or vertical references. The OPTICAL STAR TRACKER embodies these features. Essentially, it is an optical telescope used in conjunction with a stabilized platform and a computer. Despite these improvements, the benefits of optical data will continue to be limited to periods when the celestial body is visible. This limitation, coupled with the complexity and cost of the equipment, makes the optical star tracker of questionable value for widespread use in the oceanographic program.

Because of solar microwave radiation, a method of foul-weather celestial navigation is possible. The RADIO SEXTANT combines the best features of radio, celestial, and inertial techniques. This instrument tracks the sun or moon by sensing the direction of thermal microwave radiation from these bodies. Current evaluation of this system indicates an average accuracy of about two miles. Principal disadvantages of the system are the weakness of radiation from the solar bodies and the restriction to only two sources. Despite these two disadvantages, the radio sextant comes close to attaining the ideal characteristics. It is less expensive than the optical star tracker, on the order of $150,000 as compared to $600,000 per unit, and is capable of providing nearly worldwide coverage. Coupled with inertial components for dead reckoning functions, it could provide almost continuous data. So, although the radio sextant does have limitations, it may be the only aid available which will provide coverage in the immediate future over the large ocean areas of the Southern Hemisphere. It should be considered for this area of operation.

It is evident that improved service could be obtained if more sources were available and if their angular rates were appreciably higher than sidereal rates. Better coverage would be obtained and the dependence on dead reckoning would be reduced.

The TRANSIT NAVIGATIONAL SATELLITE SYSTEM, which is now being developed by the U. S. Navy, has these features. Briefly, navigation by a transit satellite is expected to be accomplished in the following manner. Once the satellite is placed in orbit, tracking stations on the surface of the earth will measure the doppler shift of one or more radio signals transmitted by the satellite. From these measurements the future orbit of the satellite can be predicted. Corrected orbital data and accurate time signals will be transmitted from a master computing and injection station to the satellite where they are recorded for rebroadcasting to the mariner. The navigator's receiving equipment will measure the doppler shift of the radio signals transmitted by the satellite for a finite period of time while the satellite is above his radio horizon. From the observed doppler data, the time signals, and orbital information transmitted by the satellite, the navigator can compute his latitude and longitude. The frequency of reception of the navigational data will depend upon the number of satellites in orbit. It has been stated that four satellites in circular polar orbits would provide fixes every one and one-half hours over most of the earth's surface. Thus, the entire transit system, as presently envisioned, will consist of four orbiting satellites, 10 tracking stations, a master computing and injection station, and the shipboard receiving equipment. It has been estimated that this system will be operational in 1963 and will be capable of providing worldwide, all-weather fixing information with an accuracy to one-half mile. Present tests utilize complex receiving equipment, including a computer, to realize the full accuracy of the system. However, it is estimated that by 1965, there will be available relatively inexpensive portable shipboard receivers which will provide 1- to 3-mile accuracy. There are many technical problems in the transit system. However, the potential to the national defense effort for this system is obvious and its continued development is mandatory. If its technical problems can be resolved, it may provide the ultimate solution to the navigational requirements of the National Oceanographic Program.

DEAD RECKONING is another of the self-contained systems. By adding course and speed inputs to a previously known position the present position of the vessel can be determined. When accomplished manually this is referred to as a dead reckoning track. The dead reckoning analog indicator does the computation mechanically and the present position can be read from instrument dials or determined by the position of a "bug" on a chart. In order for either plot to be accurate, the ship's speed over the ground and true reading must be precisely known. Neither DRT or DRAI is sufficiently accurate for the oceanographic program.

The "SINS", SHIPS INTERNAL NAVIGATION SYSTEM, is a more precise dead reckoning method which establishes the navigation coordinates through measurements made by its gyroscopes and accelerometers. SINS uses two accelerometers, one oriented north-south and the other east-west, to determine ship travel over the earth. The effects of gravity accelerations and ships roll and pitch are eliminated by use of three gyroscopes. By integration, present latitude and longitude, velocity and heading can be determined. SINS would be an ideal navigator if it could maintain accuracy for indefinite periods of time. However, due to imperfections in these inertial sensors, SINS develops errors that increase with time. Therefore, the system must be periodically corrected by navigation data from independent sources. This limitation, coupled with the cost, size, and complexity of SINS, will probably preclude its widespread use in the Survey Program.

Now, let us consider the shore-based electronic systems. There are a number of such systems in operational use today. However, most are designed for short-range or limited accuracy. Consequently, I will confine my comments to those systems having potential to the National Oceanographic Program.

Prior to the outbreak of World War II, a need for an all-weather, high-accuracy, long-range aid to navigation was evident, since before that time the radio beacon system, with its limited range and accuracy, was the only electronic aid to navigation. LORAN, which is an abbreviation of LOng RAnge Navigation, was developed to meet this wartime requirement. The system has been used extensively by both surface and aircraft since that time; to differentiate it from newer loran systems, this is now called loran-A.

LORAN-A is a radio navigation system in which the transmitting stations operate in pairs to provide the navigator a line of position. The operation of a loran system can be summarized as follows: A master ground station transmits signals consisting of short pulses of radio frequency energy on a channel in the 1,800 to 2,000 kc. band. A slave station receives these pulses and uses them to synchronize its transmitter, which in turn transmits similar short pulses of radio frequency energy. The two signals are received aboard a ship or aircraft on a specially designed radio receiver. The difference in time of arrival between the master and slave signals, measured in microseconds, is shown on the receiver. This time difference determines a unique hyperbolic line of position on the earth's surface. The same procedure with another pair of signals provides an additional line of position which is crossed with the first line to obtain a Loran fix.

Loran-A is useable twenty-four hours a day and is not limited by weather conditions. Its accuracy is comparable to celestial navigation and is approximately one percent of the distance from the transmitting stations. The limit of groundwave reception is about 700 nautical miles during the day; at night, skywave signals can be obtained up to 1,400 nautical miles from the stations.

The U. S. Coast Guard maintains fifty of the sixty-eight Loran-A stations in operational use; eleven more stations are now under construction. Present and proposed Loran-A coverage is confined to the Northern Hemisphere, and groundwave fixing information will soon be available in 30 percent of its water areas; skywave fix and line-of-position information will be available in much of the rest of that area.

Additional stations could be constructed. Although the receivers are relatively inexpensive, $1,500 - $6,000, the transmitting stations are not. Most of the complexity of the system is incorporated in the shore component, and the average cost per transmitting station is about 1.3 million dollars.

Although Loran-A will never fully meet the requirement of the oceanwide survey program due to its short range, particularly during daylight hours, it has certain advantages. These are primarily that extensive coverage is now available, and that Loran-A receivers are relatively inexpensive, reliable, and require little or no training in their operation.

Another of the operational Loran systems is called LORAN-C. Like Loran-A, it is a pulsed, hyperbolic, electronic system employing shore-based transmitting stations and specially designed receivers aboard vessels or aircraft. Basically, a Loran-C fix is determined just as in Loran-A. The significant features of Loran-C are its high degree of accuracy and extended range. It is useable twenty-four hours a day during all weather conditions. Its precision is obtained by matching the Loran-C pulses for a rough measurement and matching the phases of the carrier frequency within the pulse for fine measurement. While Loran-A master and slave stations maintain synchronization of one or two microseconds, in Loran-C it is maintained to two-tenths of a microsecond. The extended range of Loran-C results from a lower transmission frequency of 100 kc. Loran-C will provide positional information of one-quarter-mile accuracy within the limit of groundwave coverage, approximately 1,200 nautical miles. Skywave information, which is available both day and night, has an accuracy of two miles at ranges up to about 2,000 nautical miles.

Loran-C receivers presently cost from $30,000 to $60,000. These receivers weigh approximately 75 pounds and are about two cubic feet in size. A production cost of approximately $10,000 per receiver is believed possible on quantity orders. These costs are for instruments capable of realizing the full accuracy of the Loran-C system. Receivers using modified techniques and supplying accuracies of one to two miles can be produced at reduced costs.

Present Loran-C coverage is confined to the Northern Hemisphere, and all five of the operational chains in use today are maintained by the Coast Guard. These chains, comprised of seventeen transmitting stations, provide extensive coverage over the Mediterranean Sea, Norwegian Sea, east coast of the United States, and the Hawaiian and Aleutian Island areas. The latter coverage is presently being used by the Coast and Geodetic Survey Vessel Pioneer for oceanographic survey work. Preliminary results have been very favorable. Additional chains could be constructed at a cost of about ten million dollars per triad.

Of all the aids discussed thus far, Loran-C appears to more closely meet the ideal characteristics. However, because of its range, it does not have the capability to provide suitable coverage to some of the vast ocean areas of the Southern Hemisphere.

There is, however, a shore-based electronic system which may have the potential to provide this coverage. The OMEGA System has been under active development for many years.

Omega, like Loran, is a hyperbolic navigational system employing synchronized master and slave stations. It differs from Loran in that only phase difference between two transmitted signals is measured rather than phase and envelope differences. Because the Omega system utilizes radio frequencies in the 10-14 kc. band, ranges up to 6,000 miles are possible during day and night. The baselines between stations will be much longer than those of either of the Loran systems. This will greatly reduce the geometrical errors of the system. Three experimental Omega stations are presently in operation. For worldwide coverage the shore component of the Omega system would consist of a synchronized chain of approximately 10 stations, each costing about 12 million dollars. Tests conducted to date indicate that line-of-position accuracies of about 1 to 3 miles may be available on a baseline in the daytime. This error will be slightly greater at night as the distance off the baseline increases. Due to the long range of Omega, a correction factor for the 4 to 5 hours duration of sunset and sunrise on the baselines will have to be determined if the system is to be useable during these periods. It is estimated that an operational receiver in quantity orders should cost about $10,000 to $20,000 each. The receiver should not weigh more than 200 pounds nor be larger than 4 cubic feet. Receivers, which do not incorporate all the precise accuracy features, may cost less.

The Omega system has an ambiguity problem. Identical phase comparison readings are obtained at locations a given distance apart. With the 10.2 kc. equipment planned, these ambiguous zones of operation occur approximately every 8 nautical miles. Some other means must be available to position the vessel within the correct 8-mile zone if synchronization is lost. Also, the remaining research and development required in Omega is the determination of whether or not propagation characteristics can be accurately predicted over large areas.

It is obvious that existing navigational systems do not fully meet the requirements of the National Oceanographic Program. No single navigational technique presently employed has all of the ideal characteristics. Nevertheless, this does not mean that the National Oceanographic Program must await development of a single such aid. Rather, it appears likely that the required navigational control can be achieved more reliably and economically with a combination of techniques. Large areas of the Northern Hemisphere are covered by precise Loran-C signals. Loran-A, with a lower accuracy, fills in much of the remaining areas of the Northern Hemisphere. These existing aids should be used to their fullest extent in the immediate future. Additional implementation of these aids, although costly and time consuming, would increase the area available for survey. The radio sextant, coupled with a dead reckoning device, may be feasible for operation in the Southern Hemisphere. Either Omega or Transit may be found technically feasible and operationally useable. Research and development of these systems continues and may well result in the ultimate answer to precise navigational data necessary for the successful conduct of the National Oceanographic Program.

10. GENERAL DISCUSSION AND QUESTION AND ANSWER PERIOD RELATING TO THE FIRST DAY'S TOPICS

Donald L. McKernan, Chairman, and Panel[2/]

MR. GLENN R. CARLEY (Naval Ordnance Test Station, Pasadena): What type of acoustic measurements are planned for the expanded system for survey ships? Will they include measurement of the absorption or reflection properties at the bottom?

CAPTAIN R. D. FUSSELMAN (HO): The subject will be discussed tomorrow by Mr. John J. Schule, Jr., in the ASWEPS program. A rather active project is under consideration to try and resolve this absorption and reflection problem, but again, Jack Schule will touch on this in a little more detail tomorrow.

DR. RALPH L. ELY, JR. (Research Triangle Institute): Is the free submarine vehicle pictured in the lobby operational or proposed?

CAPTAIN R. D. FUSSELMAN (HO): This is an unclassified project, and as I mentioned earlier, one of the products that we point to with pride. We were up to New London recently, and the suits of instruments shown are in use in the nuclear boats.

THE CHAIRMAN: Can you tell us the speed and going power of the free submarine vehicle pictured in the lobby?

CAPTAIN R. D. FUSSELMAN (HO): I am sorry. I got off on the wrong track. I had reference earlier to the submarine instrumentation equipment which we have in the lobby. I think this directs itself to the free vehicle.

This is a torpedo-size vehicle, hopefully being able to program itself over a distance of about 20 to 25 miles, taking a series of successive dives to some 1,000 or 1,200 feet, recording the variables in which we are interested to smoke out the oceanographic features between ourselves and the suspected target. It is a joint contract between ONR and HYDRO, and it is barely underway.

2/ The addresses of panel members and of those asking questions may be found in the List of Attendees. (See appendix D.)

DR. JAMES W. FORD (Cornell Aeronautic Laboratory, Inc.): The Radiomarine Sextant was mentioned. Will someone identify the instrument by AN/System number and say at what microwave frequency it operates?

ADMIRAL D. McG. MORRISON (USCG): The Radiomarine Sextant recently evaluated by the U. S. Navy is designated as an AN/SRN-4. It was used to investigate solar radiation and lunar radiation in the 8.7 mm. and 1.9 cm. region.

MR. L. S. CHURCHILL (Lockheed Electronics Company): What periodicals publish articles on ocean instruments? What other publications are available?

MR. J. M. SNODGRASS (SIO): Well, there is the Journal of Marine Research, which is just getting a new lease on life, and is publishing a section, I believe, on oceanographic tools. There are some trade publications being passed out here that carry a few papers. Underwater Technology, I believe, is the title of one. Then, there is the new series beginning in the August issue of the Journal of the Instrument Society of America which would be a whole series on oceanography and marine instrumentation. I think one has to look a bit through the literature to find these. There are also some in the publications of the American Geophysical Union. I think that about covers it at the moment.

MR. ANGELO J. CAMPANELLA (HRB-Singer, Inc.): Correct me if I am wrong: '62 budget for oceanography is about $92 million. About half is for research vessels. About 40 percent or more is for research institutes. The remaining 10 percent, about $10 million, goes for hardware. Perhaps 500 companies are represented here. That comes out to $20,000 apiece. How much do you expect them to invest in research --

(Laughter . . . . . . Applause)

-- to justify this gross business for one year? We have spent more than that already with no return. Do you expect Industry to continue to invest in this sort of market?

THE CHAIRMAN: I am sure a number of you, as indicated by the canvass of members given, are interested in this matter, but I do not think that the answer is difficult. We have only begun to consider the development and procurement of these instruments, and most of us in the development of this National Oceanographic Program believe that a great deal more is going to be needed, both for development and procurement, than we are spending now. We do not know much about this yet. This particular meeting is really the first step in informing not only Industry but ourselves of what our job is ahead.

So I think the amount we will budget will partly be determined by improved communication between you people and those of us in Government who are budgeting for the National Oceanographic Program.

I would also like to point out, however, that there is other money in Government in various classified projects that are not shown in the National Oceanographic Program. A considerable sum of funds -- I have no idea how much -- will be spent for both the development and procurement of such instruments.

In summary, even though the sum for fiscal year 1962 is very small, we have called this meeting together because we are planning this important program. The more we get into it, the more it may cost but exactly how much more will depend a little bit upon cooperation and communication and ideas from you people. It is difficult to say exactly how much it is going to cost or how much the Government is going to spend in this particular area, until we do get some response as a result of this meeting from you as to the cost of some of these items we are requesting. This is our first step.

MR. STERLING FISHER (Electro-Mechanical Research, Inc.): Can you give me any concrete indication of the amount of money which will be spent in oceanographic instrumentation in 1962 and 1963 or in successive years?

THE CHAIRMAN: I believe that in 1962, the amount that will be spent in development and procurement will be several million dollars. In 1963, this will jump substantially and in 1964, I am sure, it will jump again in perhaps some geometric ratio.

I am not, of course, at liberty to discuss the fiscal 1963 budgets, but an examination of the TENOC Program of the Navy and a knowledge of the developing of 10-year programs in the rest of the Government Departments indicates that a considerable portion of the Oceanographic Budget, in the early phases of developing ships and laboratory facilities, will have to be spent in the development of oceanographic instruments.

MR. THOMAS W. ROGERS (Maxson Electronics Corporation): Have guidelines been established for uniformity of data storage which would control, to some degree, instrument design? If so, where?

MR. H. W. DUBACH (NODC): We have established guides for physical and chemical types of data. By and large, our general idea is that we conform to some type of standard units. We are not so concerned at this time with the format as we are with the units. A considerable portion of our time is now spent in reducing these to common unit denominators. This does not hold for geological and biological and other types of data.

We are just now embarking on a research effort to try to establish standard units in these other areas.

MR. STERLING FISHER (Electro-Mechanical Research, Inc.): Can we get information about the prototypes of the sensors you have mentioned?

MR. G. JAFFE (HO): I think you are talking about the sensors that we intend to use for the measurement program. If so, there are a number of publications that will describe these. One that comes to mind is one that we published at the Hydrographic Office called Special Publication No. 41 which went into a great deal of detail on the sensor requirements.

In addition, I think you will find that the handouts which you receive today (appendices E, F, G, and H) will cover the sensors in quite a bit of detail.

MR. ENDEL PEEDO (Electro-Chemical Corporation): Will any agency or organization prepare and publish Standard Test Procedures and Equipment Description for Oceanographic Measurements?

MR. G. JAFFE (HO): The entire subject of tests, calibration, and evaluation of oceanographic instruments has been under very careful consideration for some time.

We need a center to handle this problem and while I prefer not to get into the details of such a center at this time, we ought to remember that national standards for physical measurements are set by the National Bureau of Standards, and that basic physical measurements will be compared through that Bureau.

However, I think it is quite reasonable to expect that most industrial firms carrying on a development program or production program should have test and calibration facilities at their disposal for quality control if for no other reason.

Also, the Instrument Society of America has a Reference Standards Group and they are actively considering the problem of oceanographic instrumentation. I think eventually they will publish this and it may eventually be part of the ASTM Standards.

MR. P. F. WHITAKER, JR. (Orbit Industries, Inc.): Please express "short-range" and "extended-range" (vessels) in terms of miles of cruising or miles to station.

CAPTAIN R. D. FUSSELMAN (HO): I think there are two general categories. One was explained by Rear Admiral Charles Pierce this morning. One is the heavy duty oceanwide survey vessel of some 3,000 tons with an operational range of about 12,000 miles. The other type is almost a research vessel, down to about half that size, and it is used more or less for specific coastal oceanographic research and survey projects. So you have two types of ships: The little fellow, roughly about 1,500 and the oceanwide survey vessel of about 3,000 tons.

MR. STERLING FISHER (Electro-Mechanical Research, Inc.): The leaflet (Appendix F) describing the requirements for the meteorological suitcase on the ship of opportunity specifies an air temperature sensor with an accuracy of plus or minus 0.01 degrees centigrade. Is this a typographical error? If not, wouldn't consideration of Rear Admiral Edward C. Stephan's comment on the need for realistic compromise between accuracy and reliability conflict with this?

CAPTAIN C. N. G. HENDRIX (HO): The figures as stated in that handout, if you are referring to that, are correct, and they have been coordinated for about ten months across the country with the scientific community, with the U. S. Weather Bureau, and with Navy's aerologists. It is time that we tried to obtain data with the accuracy that we need, not only for general purposes, but for detail as well. The figures stand as they are and we should strive to reach that goal.

THE CHAIRMAN: I take it then, Captain, that you believe it is possible to get both a reliable and an accurate instrument in that range of accuracy?

CAPTAIN C. N. G. HENDRIX (HO): Yes, sir.

MR. WILLIAM R. DILLEN (Lockheed Aircraft): Is the program being described here contingent upon the passage of the Marine Sciences Bill, Senate Bill 901?

THE CHAIRMAN: The program is not necessarily contingent upon the passage of this Marine Sciences Bill. This is the Bill which is also known as the Magnuson Bill, although it has much broader support than Senator Warren G. Magnuson, himself. The Bill would set up certain mechanisms within the Government for handling the enlarged Oceanographic Program. It provides Congressional recognition for this program and specifies both agencies and general sums of money to be authorized for expenditures on oceanography. It certainly is a progressive step in recognition of the needs in this general field.

On the other hand, the Government itself, with existing legislation, is proceeding in funding the National Oceanographic Program.

I think that all of us in Government would agree that with the passage of this Bill and its increased funding, the Oceanographic Program would be accelerated. I believe that this is one of the reasons that some Senators and Congressmen are so interested in the passage of this Bill.

MR. WILLIAM R. DILLEN (Lockheed Aircraft): Is it expected that the Bill will be passed in this session of Congress?

THE CHAIRMAN: I would not be in any better position than anyone else to indicate the status of this legislation in this particular session of Congress.

MR. WILLIAM R. DILLEN (Lockheed Aircraft): Will future budgeting for this program be by individual department and agency budgets, or done so separately, under a "lead" department with ICO coordination?

THE CHAIRMAN: This is a good question. I might take just a moment to explain what the Government has done to coordinate the budgeting for oceanography.

Essentially, the Departments will budget for oceanography separately. In a sense, we can consider this a vertical kind of budgeting that has gone on for years with the Defense Department, for example, not only funding for oceanography but for all their other activities, oceanography being one of these.

The Department of the Interior, the Department where I work, also will fund for oceanography, along with other funds for our Bureau and for the several other Bureaus of this Department.

On the other hand, the Federal Council for Science and Technology, which is made up of secretarial level people, has set up this Interagency Committee on Oceanography as a body to function under the Federal Council. This particular Committee, composed of largely senior career officers from the various departments, is headed by Assistant-Secretary James H. Wakelin, Jr., whom you heard this morning. This takes a look at the whole oceanographic picture through Government, prepares a budget for oceanography across Departmental lines, and discusses this budget with the Federal Council.

Remember again, that the Federal Council is made up of secretarial level officers from each of the interested Departments, including, by the way, the Bureau of the Budget, and is chaired by the President's Science Advisor, Dr. Jerome B. Wiesner.

Thus, budgetary proposals pass from the Departments to the Bureau of the Budget and the President's office, and also from the Interagency Committee on Oceanography through the Federal Council and into the Bureau of the Budget, wherein these two views are coordinated. We have already seen, in the last three years of extensive study of this program, that sometimes the Departmental budgets do not coincide exactly with the budgets that are recommended by the Interagency Committee on Oceanography and the Federal Council.

Then there is, in a sense, negotiation between these head career officers, members of ICO and the Federal Council, members of the Departments, and secretaries of the Departments to bring about a well-balanced program not only within the individual agency but also in the National Oceanographic Program of which the agency program is a part.

This is the way it works at the present time and as a participant, it appears to me to be a very satisfactory way for insuring special emphasis in certain areas of the science.

I might add that this particular mechanism of looking horizontally across Government, in special science programs, is being studied for other essential areas. We have gone further in oceanography than in some other areas of science.

Essentially, the budgets will be provided through the Department, but they are coordinated on a Government-wide basis in oceanography.

MR. PAUL D. FRELICH (General Instrument Corporation): What is reliability? What do you mean when we are talking about reliability? Can you discuss this in a general way and a quantitative way?

MR. G. JAFFE (HO): "Reliability," for those of us who have struggled with instruments for a number of years aboard ships and on test programs and in laboratories, is simply the ability of the instrument to perform over a reasonable period of time. The durability and reliability problem in the oceanographic field is slightly different than in the missile field in that the time scale is significantly different. We would like our instruments to operate over long periods of time, at sea, under relatively adverse conditions, and this is contrary, of course, to the very short time that most missiles are in flight.

Generally speaking, I would define reliability in this case as the ability of the instrument to operate under its environment for a reasonable period of time, and with a certain amount of accuracy.

THE CHAIRMAN: Adding to that just a little bit, Mr. Jaffe, would you not agree, in a sense your reliability means reproducibility within some kind of measurable limits? These limits might be fairly broad, providing they can be measured; that is, a certain accuracy with a standing measurement of error, which we can compute.

MR. G. JAFFE (HO): True. We may all be guilty of not seeing the forest for the trees when we talk about the terms, reliability, durability, and reproducibility. These are all part of the same problem, the ability to have a device which will perform as the specifications say they shall perform. This is really a package problem. I do not think you can speak about reliability without thinking of accuracy and without thinking of reproducibility and long-term stability.

DR. WILLIAM L. DAVIDSON (Food Machinery and Chemical Corporation): How can "new" firms acquire familiarity with present "prototype" instruments in order to use this knowledge as a "jumping off place" toward the objective of greatly improved devices?

MR. J. M. SNODGRASS (SIO): In one of the letters of invitation that were sent was a reference to the starting of an Encyclopedia of Oceanographic Instruments. Apparently, there is sufficient momentum behind this, and it begins to look as if this will actually come to be. I think this will be a proper place to refer to it at the moment. Also, the Instrument Society of America has a Marine Science Division which is scheduling two meetings in September. They run concurrently. One is in Los Angeles; the other is at Woods Hole Oceanographic Institution in cooperation with the American Society of Limnology and Oceanography.

This will be a good opportunity to get acquainted with some of the instrumentation and thought in the field. I urge you to look these up if you are interested.

I think the program reprints will appear again in the August issue of the ISA Journal. Also, proceedings of these meetings will be available.

MR. MORRIS PLOTKIN (Auerbach Electronics): What computer-type equipment does the National Oceanographic Data Center now have, and what are its expansion plans?

MR. H. W. DUBACH (NODC): The present equipment we have now is all of the IBM type. We use on a rental basis the 7070, which is located in the Hydrographic Office.

As far as expansion plans are concerned, this depends on the needs of the oceanographic community. As we obtain more and more oceanographic data, I am sure we will require more and more computer time to process these data. As the analysts and researchers require more and more statistical service, we will require additional time to process the data in the manner requested. It depends on the survey requirements of the next ten years as well as the research requirements.

MR. HORACE E. R. JONES (Electro-Chemical Corporation): Have inertial navigational systems been used in oceanographic survey work?

MR. J. M. SNODGRASS (SIO): To my knowledge, they have not.

REAR ADMIRAL D. McG. MORRISON (USCG): Not to my knowledge.

MR. J. M. SNODGRASS (SIO): There is one other point I would like to mention in connection with this. I think Admiral Morrison implied, though he did not exactly emphasize, that the shipboard navigational systems, as we know them today, have some serious problems in the small ships that are presently used for oceanographic survey work.

MR. ROBERT LAKARI (Sylvania Electric Products, Inc.): In any specific case, where can Industry obtain detailed information on the most optimum format for data recorded by the instrument?

MR. H. W. DUBACH (NODC): We do have a format for physical and chemical data. We are mostly interested in units of measurements and compatibility here. In the meteorological area, we use the WMO Code as our standard. In other areas, standards have not been established. We encourage the instrument people and the researchers to develop standard dimensions. By and large, we adhere to the metric system, insofar as possible. We may deviate from it, however.

Geological and biological data for units of measurement are under study at this moment.

In data on ice and icing, we have an appreciable unknown, because here again, we plan to code or record picture-type data reported from aircraft and satellites, as well as coded data obtained from ship and coastal stations.

MR. ROBERT LAKARI (Sylvania Electric Products, Inc.): Is there a Government publication that describes details of the input facilities of the National Oceanographic Data Center?

CAPTAIN R. D. FUSSELMAN (HO): Yes. We have a whole series of manuals. May I suggest that you write to the Data Center and ask for it. We will send you a copy. We have a provisional one for the Physical and Chemical Data. You can receive these routinely as they are issued.

MR. ROBERT LAKARI (Sylvania Electric Products, Inc.): Correlation of all various data must be important. What methods are presently used in various recording instruments to provide a time sequence? In other words, how is time cranked into our recording methods?

MR. J. M. SNODGRASS (SIO): If you are recording the data that goes into the Data Center, of course, this is primarily hand-annotated. In talking about some of the newer instrumentation that is available, there are a number of techniques, such as real time generators and markers. And of course, still, some hand-annotations go along with script type recorders, but generally speaking, these are the main ways in which we annotate our information.

THE CHAIRMAN: A question from an unknown party: "What is the normal attrition rate due to loss of instruments from line parting, winch failures, and so on. And what is the tolerable cost loss of overboard equipment? This data has a significant impact on cost of sensor vs. reliability of recovery vs. tolerable loss rates."

MR. J. M. SNODGRASS (SIO): I think a variety of us would like to talk on this. This is a rather difficult one to answer. Even so-called primitive instruments, such as a string of Nansen bottles used for taking so-called deep casts, are lost too frequently, unfortunately. The loss, cost-wise, on these, I suspect, gets up to just under $10,000, but since this instrument is very simple, you would not consider the loss very great. There is an item on the book (appendix E, item I-d) fairly high in the priority list, namely, a constant tension winch. This is desired just to help avoid this problem that you are talking about, because most of the existing winches do not give us any real degree of safety in this connection, and the oceanographer is habitually working his cables up to six-tenths of the ultimate. The standard commercial practice in elevators is, I think, something like one-twentieth. The oceanographer uses less of a safety factor to work very deep with materials available. With the kind of winches we have, as a consequence, we sometimes loose a string and this we have to accept. These accidents should become less and less frequent, and, with proper winches, should approach a fairly tolerable level.

PROFESSOR BRUCE B. BENSON, Ph. D. (Amherst College):

Is anyone now working on the development of gas chromatography for quantitative analysis of gases dissolved in sea water -- especially oxygen and nitrogen?

MR. J. M. SNODGRASS (SIO): I cannot give you any really satisfactory answer on this. I know some of the marine biologists at Scripps are looking into this, and have gotten so far as to discussing it with some of the commercial manufacturers. Unfortunately, I did not anticipate this question would be asked, and I do not know the current status. I think it is alive, but I do not know how far it has gone.

MR. HARVEY L. HOWELL (Avien, Inc.): What are Government and private oceanographic organizations doing to make Industry aware of specific needs?

THE CHAIRMAN: This Symposium, and the material included in the report of the Symposium, are the first steps that Government is doing, in a concerted manner, to inform Industry of its needs in this area of oceanography.

If this works out well, we may wish to communicate on this particular matter further with industry as a group, in the hope, of course, of stimulating interest in the industry, and providing communication both ways.

MR. ROBERT S. BOWDITCH (Northrop Corporation): What is the present status and relationship of the various proposed Oceanographic Programs; i.e., NASCO, TENOC, ICO, Magnuson Bill, Miller Bill?

THE CHAIRMAN: These things are somewhat related to one another. The NASCO is the National Academy of Sciences Committee on Oceanography. This Committee of the National Academy of Sciences was formed at the request of a number of Government Agencies, and it has been financed by those agencies. The Navy, Department of Interior, Department of Commerce, the Atomic Energy Commission, the National Science Foundation -- and there may be one or two others -- asked the National Academy of Sciences about four or five years ago to study the needs of the nation in the field of oceanography.

As a result of this study by leading oceanographers from various universities and institutions eleven chapters of the National Academy's report on oceanography have been published. To coordinate the Government activity necessary to execute this program, the ICO, or the Interagency Committee on Oceanography, was developed. This Committee has reviewed the reports of the National Academy of Science and has incorporated in a sense, input from Government programs, and our ability to produce these particular programs. The ICO still uses the National Academy's Committee in an advisory capacity. In fact, these non-Government oceanographers attend and participate in meetings of both the ICO itself and of its panels. For example, Mr. J. M. Snodgrass and others who will follow are here today. These are non-Government scientists who are working in various fields of oceanography. That, then, ties together these two things, the ICO and NASCO.

TENOC (of the Navy) was developed to be incorporated into the National Oceanographic Program of the ICO. The Navy hopes that TENOC will become a part of the National Oceanographic Program of the Federal Government.

The Magnuson Bill of the Senate was an outgrowth of a feeling that some impetus was needed to get this program started. After NASCO had made its recommendations and the Government agencies had come through and reviewed them and in a sense, adopted the Magnuson reports -- with some slight modifications -- then, Senator Magnuson and other very able staff members on the Senate Committee dealing with these affairs came out with the Magnuson Bill which would give Congressional sanction and authorization to proceed in this particular matter.

The Miller Bill is named after Congressman George Miller of California, the Chairman of the Subcommittee of Oceanography of the Merchant Marine Fishery Committee of the House. This subcommittee is set up on a permanent basis within the legislative branch of the Government, a committee similar to the ICO in the executive branch.

The ICO is of a less permanent nature than the one the Miller Bill would establish, composed of senior officers of the various departments interested in the field of oceanography.

The two Congressional Bills, then, reflect the interest of Congress in this field. This Congressional interest stems, of course, from the National Academy of Science's report and the various reports that have been produced by Government Departments interested in oceanography.

DR. A. E. MAXWELL (ONR): I would like to emphasize that this whole program of expansion in oceanography is in its infancy. Just as this meeting is really a first attempt to get Industry into the instrumentation part, the same is true for the organization of the whole program of oceanography throughout the Federal Government.

The TENOC program of the Navy which was originally signed about two years ago was only a program for basic research. It proved to be inadequate to meet the total Navy needs in this area. It has since been reviewed and a new TENOC program covering all of the oceanographic efforts of the Navy has been put out and signed by Admiral Burke.

As a result of these efforts, Assistant-Secretary Wakelin has asked all of the other Federal Agencies interested in oceanography to prepare similar long-range programs in oceanography.

Once these programs are available, they can be put together through the mechanism of this Interagency Committee. We can begin to have some good overall planning in the Oceanographic Program. But the main thing I wanted to emphasize is that the whole program is really just getting started.

MR. LEE HELSER (Fairchild Camera and Instrument Company): It was mentioned by Mr. Snodgrass that optical windows "fouled." What is the nature of window degradation suffered and are any particular glasses -- for example, fused, quartz, crown, flint, etc., better for undersea work?

MR. J. M. SNODGRASS (SIO): No. Extensive studies have been made with various glasses from this standpoint. The problem is due to marine organisms which attach themselves to practically any surface you want to create. It is a physical attachment of the organism, slimy excretions and things of that sort, that cause the failure in the window. Sometimes, there may be structural damage but this is minor.

THE CHAIRMAN: In connection with this, we have been doing some work on specific toxins for oyster culture in some parts of the country and have found that certain chemicals reduce fouling on oyster cultch, the old oyster shell that is put out to collect the spat. Some of these chemicals seem to hang on to this old cultch for many months and keep away the fouling organisms very satisfactorily. Some research in this area might show the same thing for optical windows.

MR. J. M. SNODGRASS (SIO): In fact, there are some very simple brute force methods. One of the simplest is to use a mixture of white vaseline and solid aerosol. It is ground up very finely and put on in a thin coat. It will discourage organisms for a period, depending on exposure and environment, from three weeks to six weeks.

MR. C. E. BRADY (General Electric): Is there presently or in the future, any change in the Navy's apparent philosophy to fund educational institutions to a greater degree than Industry for research and development and yield new instruments or systems?

DR. A. E. MAXWELL (ONR): I think there is no change of philosophy here. The philosophy is, as it has been in the past and probably will remain, that the majority of the basic research will probably be funded at the universities and research institutions.

On the other hand, the Navy is already supporting an extensive applied research program, both at universities and within Industry. I see no trend to show any change in this, with perhaps the exception that if some applied program becomes of an urgent nature, and if this can be funded more logically through Industry rather than through universities, you might have a rapid expansion in this field. Of course, this could go either way.

MR. JOHN A. ACS (Product Development Engineering Company): If a private research laboratory presents a radically new and different type of survey ship, would it be given ample consideration by the ICO?

THE CHAIRMAN: The answer is yes. They are looking for some radically new ideas and a number of us have been thinking in terms of research submarines of various radical designs. In fact, some of us connected with the use of the resources of the sea have been thinking in terms of programs on underwater fishing devices, both manned and unmanned, which would in a sense search out the fish and take them electronically or even mechanically, rather than by use of traditional surface ships.

So I believe I speak for all of us that have served the Interagency Committee on Oceanography for a number of years. This is one of the reasons we brought in you people to provide some new ideas on this particular project. If we could get new ideas for platforms or for data collecting at sea, we would welcome them, no matter how radical they might be. I believe we would even be intrigued by anything that was different from our standard means.

MR. E. J. HITT (Vought Range Systems): Will copies of the Encyclopedia of Oceanographic Instruments be made available to Industry?

THE CHAIRMAN: This is a general question. I think the answer to this is yes. It will be a large job to edit and compile it. What you see in the back of the room is only a sample. Whether it is published or not, of course, will depend to some extent on your interest.

DR. A. E. MAXWELL (ONR): I think you should be warned that this encyclopedia is about two feet thick already.

MR. RAYMOND CANTWELL (The Gems Company): Where is the point of contact for new ideas or products that could solve the various problems as presented at this meeting?

THE CHAIRMAN: The point of contact, I believe, should be the ICO Panel on Facilities, Equipment, and Instrumentation; if you would care to write to me or any member who has spoken to you concerning a particular problem, it would get to the proper group in the Interagency Committee on Oceanography and be considered by us.

We are intending to set up a standing group who will consider proposals from Industry in this regard.

MR. WILLARD H. BRANCH (Consolidated Net and Twine Company, Inc.): If nylon and stainless steel corrode at point of joining, would the use of a plastic or metal link be of advantage?

MR. J. M. SNODGRASS (SIO): Yes. This is routine. One of the materials that has been quite successful is the Westinghouse micarta.

MR. E. G. ANDREWS (Sanders Associates, Inc.): Is data published on the behavior of electronic equipment under environmental conditions as discussed by you this morning? If so, where will we have access to that data?

MR. J. M. SNODGRASS (SIO): Some very small amount, rather sketchy, has been reported in some of the progress reports in the Scripps Institution of Oceanography.

There is also some, I think, in the November and December (1960) issues of the progress reports of the Naval Research Laboratory in Anacostia.

Two papers, I believe on this same subject, by the same authors that wrote the articles appearing in the Naval Research reports will be given at Woods Hole Oceanographic Institution, I think, on September 14 at the ISA meeting. (ISA Journal, November 1961, Buchman and Flato.)

DR. ALFRED A. WOLF (Emertron, Inc.): Would the measurement of attenuation and phase characteristics of large volumes of sea water automatically be of any value?

CAPTAIN C. N. G. HENDRIX (HO): Yes, it would be very applicable to and necessary to the propagation of sound particularly in this oceanographic area, as it applies to the various sonar problems.

CAPTAIN R. D. FUSSELMAN (HO): In the general evaluation of some of our sonar equipments, it is now generally accepted, through all our Navy agencies, we will have some pretty good oceanographic teams to try to determine how some of these performance factors of new equipments correlate with general oceanographic conditions.

We think that there is a tremendous appreciation of this whole problem. We hope we are going to be able to tell why this thing is doing as it is.

MR. HARVEY WEISS (Grumman Aircraft Engineering Corporation): Concerning instrumentation component deviations as a result of pressure increases, do you know of any work going on concerning the variation of mass movement of inertia of uniform shapes as a function of pressure?

MR. J. M. SNODGRASS (SIO): I do not know of any but I can make some estimates for some materials. In some plastics in which you have different strength ratios depending on the axis, I would expect variations, but I do not know of any.

MR. LEE HELSER (Fairchild Camera and Instrument Corporation): What are the bandwidth limitations for: Data transmission via hard wire in instrumentation tow cables for cables that have been proven suitable for undersea oceanographic work?

MR. J. M. SNODGRASS (SIO): I do not know precisely. This question was a little confusing as stated. I will answer, assuming he is thinking of either acoustical transmission of the signal along the cable or electrical transmission. In this case, I am assuming the cable has no electrical insulation on it. I know relatively little about acoustical transmission. There are some background noise problems that enter into this one because simply the motion of cable through the water generates a wide noise spectrum. The other, the matter of transmission of electrical energy along uninsulated cable, can be done to a certain extent but is not very economical of power.

MR. LEE HELSER (Fairchild Camera and Instrument Corporation): Is there a "Sonar Telemetry System" and if so, what are its practical bandwidth limits?

MR. J. M. SNODGRASS (SIO): There are some very good ones. Some of you may have read the reports of the bathyscaphe, Trieste, in the Mindinao Trench which had voice communications with the surface at all times. This was an acoustical channel that could well be used for telemetry, a single sideband-suppressed carrier transmission.

MAJOR GENERAL K. P. McNAUGHTON (Fairchild Camera and Instrument Corporation): To what accuracy will shipboard gravity meters measure the force of gravity?

DR. A. E. MAXWELL (ONR): I am not quite sure of the accuracy that can be measured now. This depends, of course, a great deal upon the ship. If the gravity meter is on a large ship, and a stable platform, it could measure as accurately as plus or minus one or two milligals. If, on the other hand, you are on a very small ship, without a stable platform, the error could be an order of magnitude larger. Navigational accuracy also plays an important role in the measurement of gravity. This accuracy is good enough. We are very happy to have anything we can get from a surface ship at sea, now, with this accuracy. We would appreciate more accuracy because then we could get more information out of the measurements.

MAJOR GENERAL K. P. McNAUGHTON (Fairchild Camera and Instrument Corporation): What accuracy is required for Polaris launchings? Is this classified?

CAPTAIN R. D. FUSSELMAN (HO): I think this information is classified.

MR. ENDEL PEEDO (Electro-Chemical Corporation): Do you anticipate an early need for underwater transmission of broadband radio frequency signals, where a transmission cable with waveguide electrical characteristics may be required?

MR. J. M. SNODGRASS (SIO): There are some places, for instance, the University of Florida's Marine Laboratory, in which it is impossible to telemeter the data. They had to resort to a high quality co-axial cable. I do not think this really answers the question. This is cable I do not know too much about. It is obvious there are many places in which broad-bandwidth co-axial cables will be a distinct advantage.

MR. F. I. OWEN (Texaco, Inc.): When vessels of the Merchant Marine participate in this program, will the ship officers be able to handle the instrumentation and data recording, or will special technicians be aboard?

CAPTAIN R. D. FUSSELMAN (HO): We have had some experience in the Merchant fleet, recording data on the military sea transport ships; we trained young technicians on board, or young sailors if you will. They turned in very good information, using the standard equipments like bathythermographs, and so forth.

Here again, though, we feel that if instruments are not too complicated and too complex, we can get the young men on board to handle them and probably not even go to the officer level.

MR. HERBERT W. BOMZER (Autometric Corporation): Research and survey were discussed by Admiral Coates and Admiral Pierce, respectively. What agencies have the funds and authority to contract with Industry to do the jobs? Much of the work appears to be Government "in house" effort. How much of the task is Industry expected to undertake? For example, in surveys, in building equipment, in installing and testing equipment, in gathering experimental data, and in analyzing the data and bringing it up to date.

REAR ADMIRAL C. PIERCE (USC&GS): From the present plans, most of the data which were discussed today are going to be handled by the Government. We have a National Oceanographic Data Center in Washington, D. C. They are going to process this data. Ocean survey ships are very expensive to build. I cannot see where the average company would make much of a profit out of running a survey ship, particularly at the rate of pay you would have to pay your men today. The actual construction of winches and the installation of equipment, and so forth, will be done in shipyards or by private industry, wherever you can get it done. I do not believe there is any way you can estimate what proportion of this work is going to be done by private enterprise.

MR. H. W. DUBACH (NODC): We have just completed the second revision of the oceanwide survey report for ICO. That report roughly says, in line with the National Academy's report on nationwide surveys, that many ship dealers will be required to conduct comprehensively and systematically the oceanwide survey.

The National Academy has to make 280 to 300 ship units, total. We came up with a figure of a total of 230 shipping units. This means then, with the few oceanographic survey ships available right now, I say if we assume the four we could put on station now, it would take 60 years to do the job. One of the basic items in the National Oceanographic Program is ocean knowledge, or, gross survey of the ocean. We have to get adequate numbers of ships surveying -- more than four. Naturally, you have to improve the instrumentation.

So any way you look at the problem, if we are going to get the job done in a reasonable length of time, keeping in mind the national requirements in which national security or national defense has priority, you have to increase the numbers of survey ships and research ships or you have to get something else out there that will get this data rapidly -- not in 60 years -- in order for us to be able to do with it what we need. Whether Government does it or whether Industry does it, there has to be a solution. It is for our national welfare.

DR. JAMES W. FORD (Cornell Aeronautical Laboratory, Inc.): In Captain Fusselman's discussions there was only passing mention of wave height measurement. Will someone touch on the reason for the absence of concern in this particular problem?

CAPTAIN R. D. FUSSELMAN (HO): Mr. John Schule, Jr., will cover this item in his presentation tomorrow.

MR. HUGH PRUSS (Telemetering Corporation of America): Will your schedules make allowances for interdevelopmental phases of oceanographic instrumentation and along with this, will workable standards be developed?

MR. G. JAFFE (HO): Those are two questions. For the first, we are using interim measures at the moment. We will have to continue to use these measures until the standardized instrumentation is available.

With regard to the standards, the calibration, testing, and standards for testing are being considered, and statements will be made on that either through professional societies, such as the Instrument Society of America, or through a Governmental Center which will handle this for us.

MR. W. J. GREER (Welex Electronics Corporation): Is there any consideration being given to the Decca navigational system for oceanographic fixes?

REAR ADMIRAL C. PIERCE (USC&GS): There are numerous systems that exist today, all employing substantially the same principle. As far as Decca is concerned, it has not proved itself superior to Loran. The United States has a big investment in Loran. What is the point of using Decca? We would not expect England to switch to Loran. That is about as simple as you can make it.

MR. CLIFF BORDEN (Curtiss-Wright Corporation): May we have a registration list mailed later?

THE CHAIRMAN: Yes. It will be mailed later to all attendees, and in addition, it will be included in the proceedings of the Symposium (appendix D).

DR. F. E. ELLIOTT (General Electric): Who are the cognizant people in the Bureau of Ships and the Bureau of Naval Weapons on oceanographic instruments?

THE CHAIRMAN: I believe that if inquiries are simply sent to these particular bureaus, they will get to the proper people.

If, on the other hand, Dr. Elliott would like specific names, he can, I am sure, contact Navy representatives here; we will be glad to give him specific names in this regard and answers to any general questions concerning the oceanographic instrumentation program. I repeat, it might be well to address letters of inquiry to either Assistant-Secretary Wakelin or to myself. In this way, it will be incorporated into the ICO's Panel on Facilities, Equipment, and Instrumentation and will be considered by a member of different Government departments.

THE CHAIRMAN: There are several more questions to be answered that were not reached. They will be incorporated in the proceedings (appendix A).

11. OPENING REMARKS ON THE SECOND DAY OF THE GOVERNMENT-INDUSTRY OCEANOGRAPHIC INSTRUMENTATION SYMPOSIUM

Donald L. McKernan
Chairman of the Symposium

Yesterday we heard from a number of Government and non-Government scientists and science administrators who drew for us a broad picture of the plans of the Government to expand the Nation's effort in the field of oceanography. I believe it is fair to conclude from the papers presented yesterday that (1) there will be a great increase in the demand for the development and manufacture of almost all observational and measuring devices used on oceanographic survey and research vessels; (2) there is a desire on the part of all oceanographers to improve the accuracy, reliability, and durability of instruments on the new vessels now under construction and on the drawing board; (3) Government and non-Government oceanographers believe that Industry can contribute substantially to more effective oceanographic instrumentation; (4) from the questions submitted to our panel in the afternoon and discussions aside with individual representatives of Industry, I conclude that the Industry representatives here have a deep interest in this problem and believe they can contribute substantially to better instruments.

Thinking about the presentations yesterday in a general sense, I believe it is fair to say that the major ship operators in Government badly feel the need of pinpoint navigational equipment in order to locate precisely where the observations are being made, and perhaps of equal importance, they are seeking "packages" of instruments which will allow the greatest automation possible aboard ship and the greatest ease in assembling the observations and data later for use by scientists.

It was also obvious that the Industry representatives had reservations about the part they could play in this development and manufacturing program.

You also wish to know about Government support.

Yesterday, general. Today, more specific.

12. APPLIED RESEARCH INSTRUMENTATION REQUIREMENTS INCLUDING ASWEPS

PART I. FOR THE HYDROGRAPHIC OFFICE (ASWEPS)

John J. Schule, Jr.

Navy Department
Washington, D. C.

I have been asked to describe briefly the instrumentation requirements of the AntiSubmarine Warfare Environmental Prediction System (ASWEPS). At the outset, I should mention that the ASWEPS program is not new, but is approximately 2 years old. Consequently, a considerable amount of contracting in support of instrumentation requirements has already been accomplished. These contracts have been executed mainly for the development of better and more reliable instruments; no large-scale procurement actions have been undertaken.

ASWEPS may be described briefly as a program for developing the capability for providing ASW operating forces with up-to-the-minute environmental intelligence in the form of recent analyses and predictions on a continuing basis. The approach that has been chosen as most potentially successful is one similar to that used in weather prediction and involves the establishment and operation of a synoptic oceanographic reporting network. It is in connection with this network that most of the instrumentation requirements of ASWEPS arise. Data handling, transmission, and processing equipment are very important, because the observations obtained by the synoptic network will be transmitted to shore-based centers where analyses and predictions will be prepared. It is further planned to make the preparation of end products as automated and as objective as possible; research is being conducted to develop these techniques.

In development of the synoptic network, the ASWEPS program has not envisioned the exclusive utilization of one type of platform; rather, it has been planned to utilize any and all platforms available and suitable to the purpose. Available ships, whether in fixed locations or randomly distributed throughout an area, are preferred at the present time as the most reliable and efficient platforms. In the absence of ships, aircraft and moored telemetering stations can be used.

Figure 12.1 schematically shows the synoptic reporting network for the ASWEPS system. ASWEPS in its present form is confined to the western North Atlantic; a complete service test is planned for this area during 1965. Experiments are already being carried out in other areas; it is highly probable that the ASWEPS program will be extended to other oceans if it is successful. Evaluation of the system is not waiting for a service test; individual end products are being released to the Fleet as soon as they are developed. Therefore, in a very limited sense, ASWEPS is currently operational.

Figure 12.1 illustrates the two synoptic networks in the ASWEPS program. One is the regional net designed to provide a gross picture of the entire ASWEPS area; the other is the mobile net which provides detailed information necessary for ASW tactical decisions in a small, restricted operating area. The various types of potential platforms in each network are indicated in the margins of figure 12.1.

It should be clear that, while ASWEPS instrumentation should be as precise and efficient as possible, heavier emphasis should be placed on certain characteristics than would be the case in the development of ordinary research or survey equipment. Liberal use of ships of opportunity and aircraft, coupled with the requirement to transmit the data ashore for immediate availability, are factors which must be considered.

Figure 12.2 indicates some of the special qualities to be emphasized. The emphasis on ease of operation, simplicity of maintenance, and reliability stem from the fact that few of the observations will be obtained by professional oceanographers. The requirements for speed of operation and rapid data transmission are inherent in the synoptic problem itself; compatibility will be mandatory if data from a variety of platforms are to mean anything when analyzed. To achieve these objectives, it will be necessary in many cases to sacrifice depth, precision, and number of variables sensed -- a procedure that would not be tolerated in research or survey operations.

Based on the above facts, the most logical way to proceed

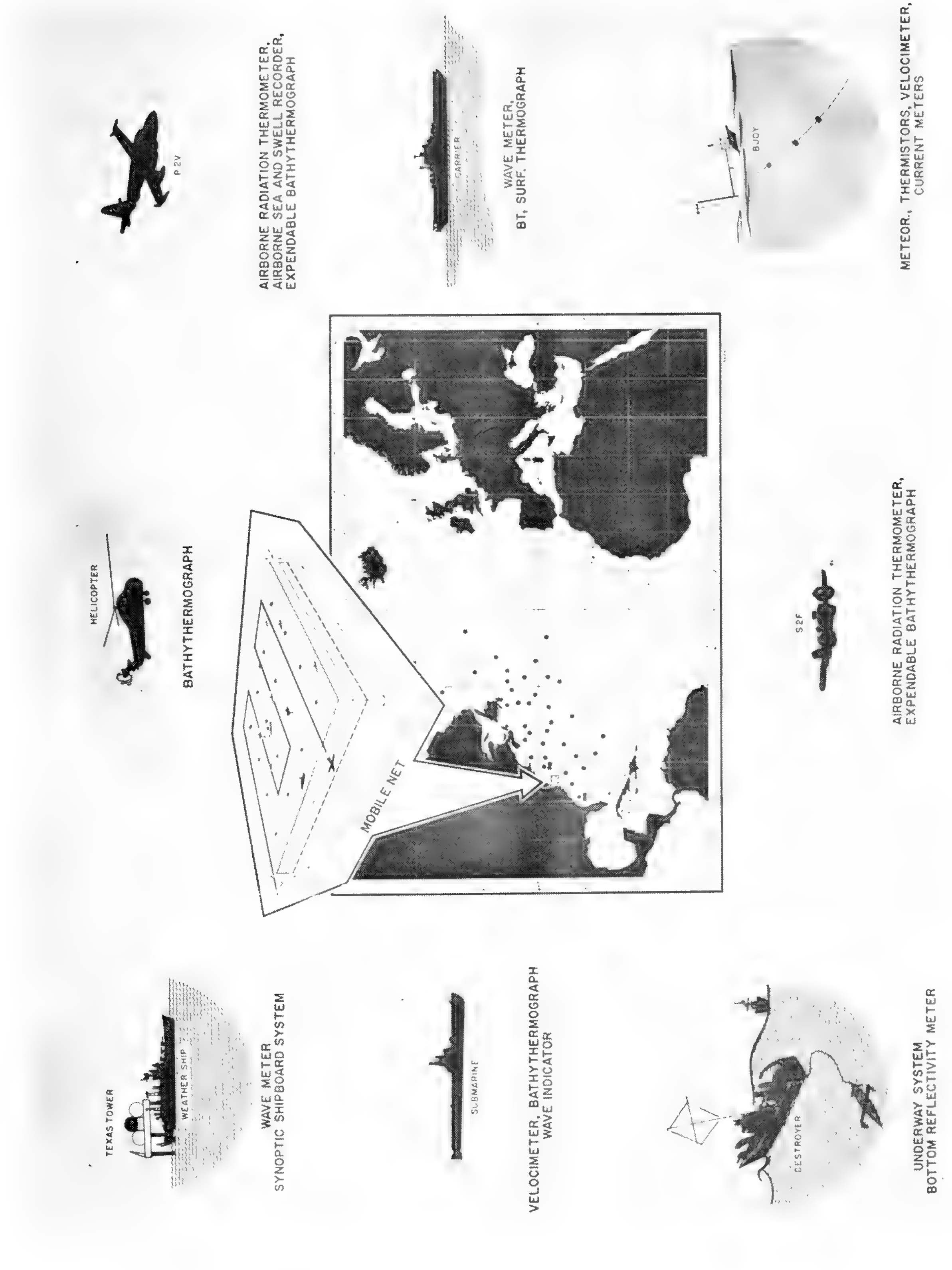

FIGURE 12.1
SYNOPTIC REPORTING NETWORK FOR ASWEPS

probably would be to divide the instrumentation requirements into four categories depending upon the type of platform used and to develop a compatible sensing, recording, and transmitting system for each. These categories include: (1) A basic synoptic system for ships generally positioned continuously in a given area; e.g., ocean station vessels; (2) an underway shipboard system which will essentially be a modified version of the basic synoptic system for ships of opportunity and fleet vessels; (3) an oceanographic aircraft system; and (4) a long-life, long-range, moored, telemetering station. To achieve these requirements, it has been necessary to support the development of individual instruments to fit into the various systems, as has been mentioned earlier. In addition, a certain amount of specialized instrumentation will be required which does not properly fit into these four categories at the present stage, either because they are not truly synoptic instruments or because they have special requirements of their own.

Figure 12.3 attempts to show the requirements of the synoptic survey system. It should be mentioned that this diagram is merely intended to be symbolic and involves no intent to influence the ultimate designer of the system. The basic requirements, as indicated by Captain Fusselman, are also outlined in the figure. Temperature, sound velocity, and conductivity to a depth of 2,500 feet are to be measured and recorded in three modes: Visual, digital for transmission, and magnetic for permanent storage and research use. The system should be completely remote-controlled and simulate an all-weather system as much as possible. About 30 of these systems will ultimately be required for a service test version of ASWEPS; more will probably be necessary as the ASWEPS program expands. Though procurement action of this item has not been initiated, it is planned in the immediate future. A 2-year development contract is visualized with the prototype to be delivered by the end of fiscal 1963.

Figure 12.4 illustrates a modified version of the synoptic system required for fleet vessels and ships of opportunity. Considerable success has been achieved in the ASWEPS program by use of MSTS commercial vessels as bathythermograph platforms. If the synoptic system capability can be extended so that data can be obtained at speeds of 12 to 15 knots, such platforms will be highly efficient contributions to the program. This system is expected to be able to reach depths of 1,500 to 2,000 feet and to measure temperature and sound velocity in a form suitable for transmission

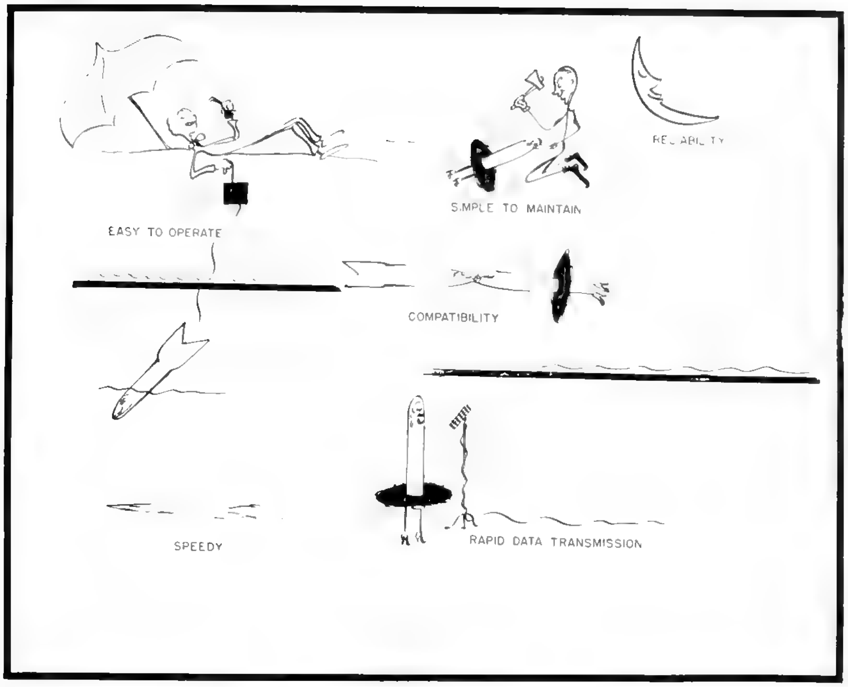

FIGURE 12.2
DESIRABLE QUALITIES OF ASWEPS INSTRUMENTATION

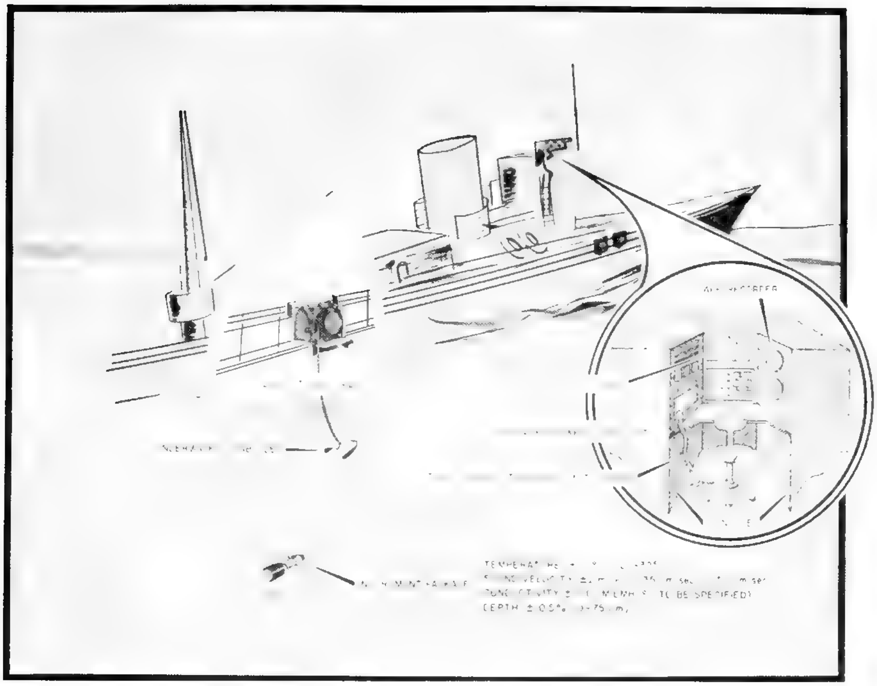

FIGURE 12.3
REQUIREMENTS OF THE SYNOPTIC SURVEY SYSTEM

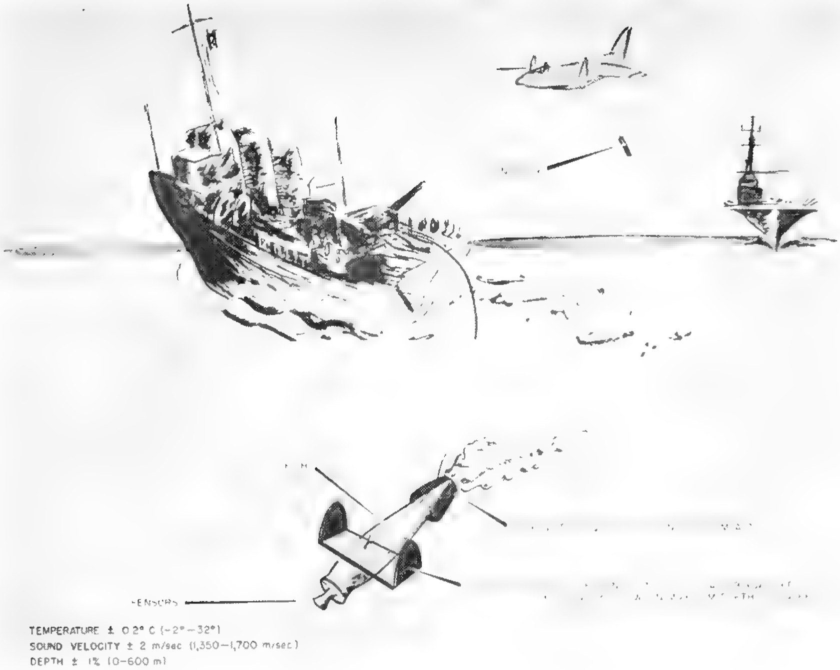

FIGURE **12.4**
MODIFIED VERSION OF THE SYNOPTIC SYSTEM

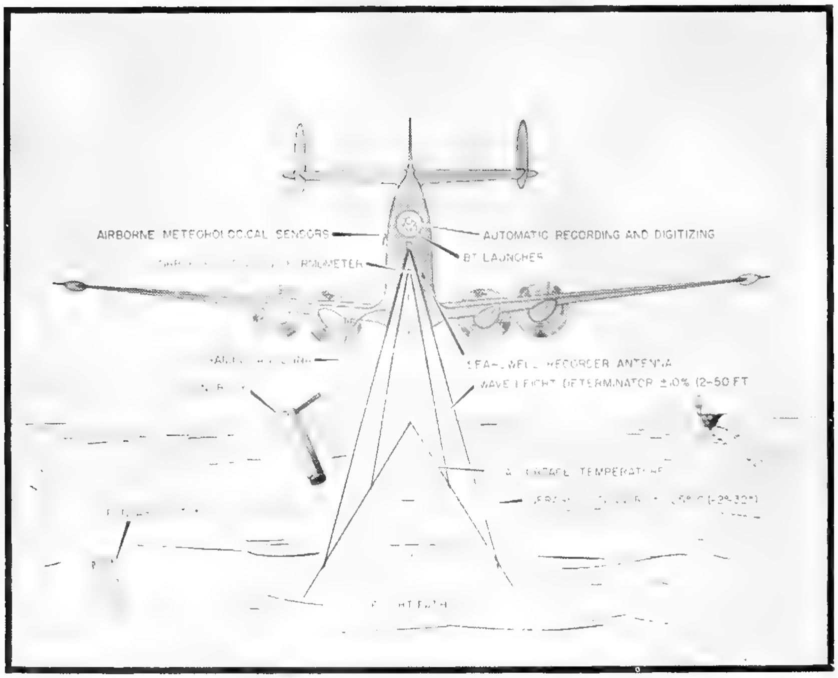

FIGURE **12.5**
AIRBORNE OCEANOGRAPHIC PLATFORM

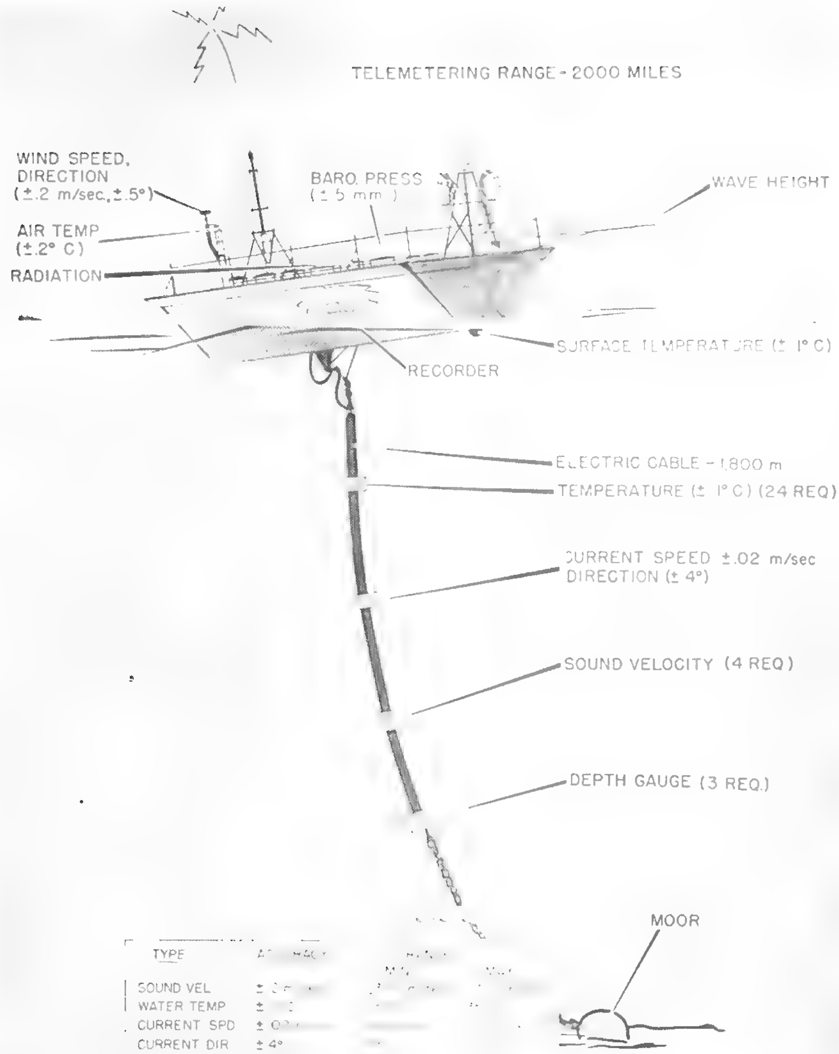

FIGURE 12.6
MOORED
TELEMETERING
BUOY

TYPE	[illegible]	[illegible]	[illegible]
SOUND VEL	± [illegible]	[illegible]	[illegible]
WATER TEMP	± [illegible]	[illegible]	[illegible]
CURRENT SPD	± [illegible]	[illegible]	[illegible]
CURRENT DIR	± 4°	[illegible]	[illegible]
DEPTH	±.5%	0 m	7,000 m
SALINITY	±.004%	3%	4%
AIR TEMP	± 2° C	-5° C	40° C
WIND SPEED	±.2 m/sec.	0 m/sec	40 m/sec
WIND DIR	±.5°	0°	360°
BAROMETER	±.5 mm	700 mm	780 mm
MOOR TILT	± 3°	0°	90°

to shore. Since this system will be operated strictly on a ship of opportunity basis, ease of operation, reliability, and ability to record data at speeds of 12 to 15 knots are overriding requirements. Approximately 36 of these systems, mainly for installation aboard HUK group destroyers and appropriate commercial vessels, will be required for the ASWEPS program. Although experiments in this field will be accelerated, it is not anticipated that this system will be contracted for in its entirety until the synoptic system is well underway.

Figure 12.5 indicates inherent possibilities of an oceanographic aircraft. No attempt has been made to design even a symbolic aircraft system at this stage. Emphasis is being placed on the development of individual aircraft instruments and aircraft observing techniques, although some work in integrated aircraft data recording will be performed. This figure indicates instruments based on the present state of the art that could conceivably be developed to fit into this system. These include: (1) Some type of expendable device almost certain to be required for measuring subsurface conditions, whether it is the version being developed by the Bureau of Naval Weapons or some other instrument such as the BT slug being developed by Canadian laboratories (The Bureau of Naval Weapons has contracted for a number of airdroppable BT's with improved capability for delivery in the fall of 1961.); (2) the airborne radiation thermometer (ART) with which the Hydrographic Office has been experimenting for some time (This instrument was originally developed by Woods Hole and more recently improved and repackaged by commercial contractors.); (3) a device for measurement of wave conditions from fixed-wing aircraft (ASWEPS has procurement action underway for the development of an experimental model based on work performed by the Naval Research Laboratory. This instrument will be evaluated in an aircraft recently assigned to the ASWEPS program.); and (4) possible extension of infrared techniques to include a scanning device for temperature measurement as has been developed for other DOD applications (These instruments and others will be tested and evaluated in the ASWEPS aircraft in the hope that a system can be designed for procurement in late 1963 or early 1964. About 12 such systems will be required for installation on land-based ASW aircraft, as well as on aircraft assigned to operating task groups.).

Figure 12.6 indicates the fourth category of platform, viz., moored telemetering stations. This is an attempt to show the ideal telemetering station as far as ASWEPS requirements are concerned. The Bureau of Naval Weapons has been most active in its development. The Hydrographic Office has recently joined the Bureau of Naval Weapons in the procurement of several stations which will have capabilities somewhat less than those indicated in this figure. Subsequent development can be improved to meet ASWEPS requirements by means of successive procurement actions which will improve the state of the art. For the service test version, about 12 of these stations will be required.

Figure 12.7 indicates a few additional instrumentation requirements; e.g., an instrument to provide an index of bottom reflectivity. This instrument is considered extremely important. One such device is currently being developed by the Bureau of Ships, and the Hydrographic Office is participating in its procurement. Although the proposed instrument is not a true synoptic tool, resulting information will be of extreme importance to prediction of effective performance of new sonar gear. A new type of current meter will be required for synoptic purposes, and will be primarily used in connection with buoys. Several devices which eliminate the mechanical principle of present current meters have been suggested; however, no procurement action has been taken. Support for development of such a meter is planned in the near future.

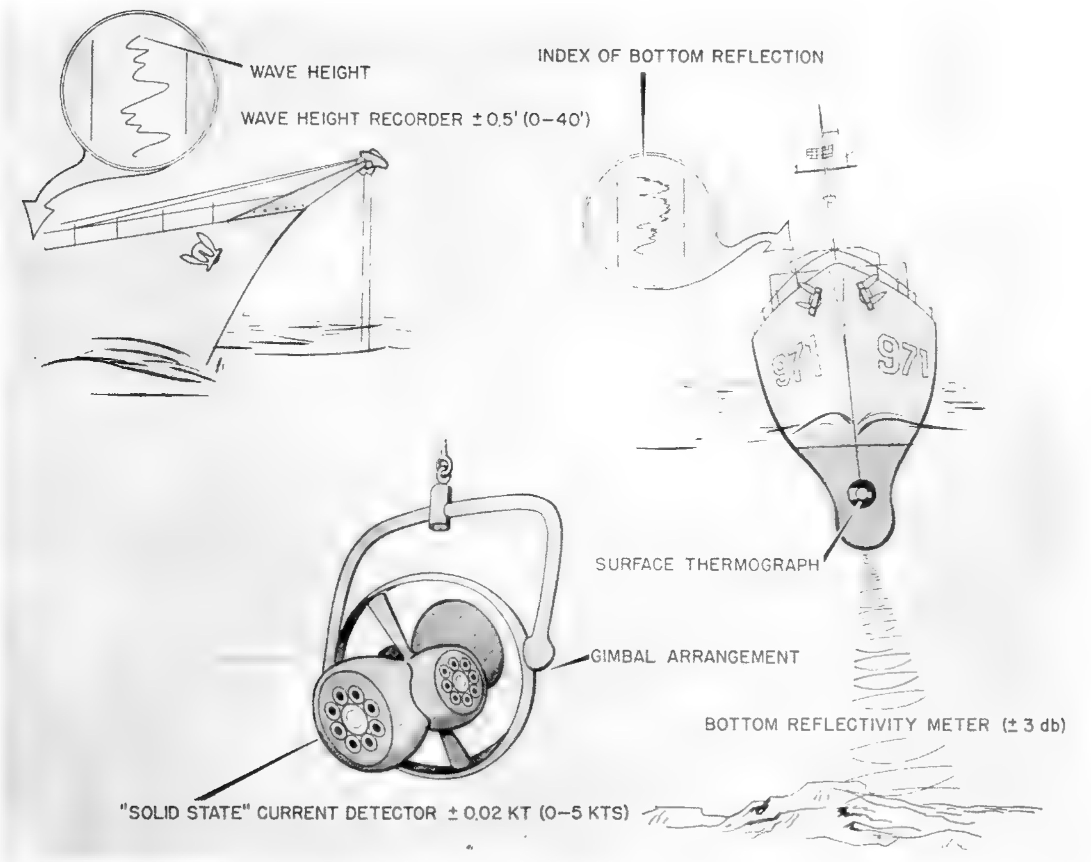

FIGURE 12.7
ADDITIONAL INSTRUMENTATION REQUIREMENTS

The wave-height meter is also being developed but was not included in the synoptic system, because the type of recording required is not really compatible with vertical profile data. A considerable number of synoptic reporting units should include reliable wave meters in view of the importance of sea conditions to all phases of ASWEPS.

It has not been possible to do more than briefly outline some ASWEPS requirements in this paper. With cooperation of Industry, the value of information provided to the Fleet can be considerably upgraded in order to make ASW operations more effective.

12. APPLIED RESEARCH INSTRUMENTATION REQUIREMENTS INCLUDING ASWEPS

PART II. FOR THE BUREAU OF SHIPS

B. King Couper

Navy Department
Washington, D. C.

The position of the Bureau of Ships in regard to oceanographic research has been publicly expressed before Congress at the House Special Subcommittee on Oceanography of the Committee on Merchant Marine and Fisheries as follows:

> "The Bureau provides modest support to oceanographic research . . . as its primary concern is in the application of such research.
>
> "The Bureau is a USER-CONSUMER of oceanographic research.
>
> "However, the Bureau does contribute to the oceanographer and oceanographic research in three ways:
>
> (1) By building equipment which is useful in delineating the ocean,
>
> (2) by assisting in the development of instruments which give us the limiting factors controlling design of military equipment and weapons which we must build, and
>
> (3) by providing direct research support in the case of certain priority items, such as in ASW . . . . . . "

I would like to emphasize the second item above again: "By assisting in the development of instruments which give us the limiting factors controlling the design of military equipment and weapons." This is our main justification for participation in this Symposium.

As an example of controlling limiting factors in determining what goes into a new military equipment, the range of temperature which one will encounter in different parts of the sea is one piece of necessary information. I want to point up the remarks of Mr. James M. Snodgrass a little more specifically. It is obvious that the operational requirements of a ship in the tropics are different from those in the arctic. Such requirements can be important. Take the case of some outboard submarine equipment. If it is mounted outside on the hull below water level, the measuring "readout" will probably not have to be greater than from 28° - 90° F. for just under the ice and for shallow lagoons and the Red Sea. But what about instrument protection during drydocking at Pearl Harbor? The sun beats down there and the steel plates in a local spot may become hot enough to fry an egg; so, in the standby condition, temperature will far exceed the 90° F. for water. For its protection, the equipment might have to stand a temperature spread of 28 to 168, or 140° F. On the other hand, what if the same equipment is mounted on the "sail" of a nuclear submarine? You are cruising along under the ice and the temperature is close to freezing, say 28° F. Suddenly, you decide to come up, and, like the Skate, break through the ice. The air temperature may be minus 50° F., so you get an almost immediate drop of 78° F. Now you need to design for protection from minus 50° to plus 168°, a spread of 218° F. Also, effects of the rapid cycling of temperature on the materials used are important. So environmental limitations must be furnished for equipment design. In addition to the cycling effects and temperature, the factors of wave motion, vibration, radioactivity, corrosion, fouling, shock, and stresses of all kinds are of interest.

Let me emphasize again that the Bureau of Ships is a user-consumer, relying heavily on the Office of Naval Research, the Hydrographic Office, and the private laboratories for environmental information. With regard to instrumentation in the specific areas sponsored by the Bureau of Ships, the bulk of oceanographic instrumentation development is carried out and funded as a part of the approved programs at our Bureau-managed laboratories.

The remainder of this paper briefly covers some of the specific areas of interest to the Bureau of Ships and its laboratories. Of particular interest are the following: (1) Acoustic Measurements, (2) Wave Motion, (3) Antifouling and Corrosion Effects, (4) Deep Current Velocities, and (5) Deep Sea Floor Characteristics.

The Bureau of Ships' interest in ACOUSTIC MEASUREMENTS is understandable both from the point of view of offensive and defensive capabilities of the fleet. Other speakers have mentioned to you direct sound-velocity measurement. A good and partially satisfactory instrument (The National Bureau of Standards Sound-Velocity Meter) has only recently become available in small quantities. Here is a case where a problem of measuring a property of sea water has been partly licked. You will note that -- because it is available -- the instrument has rapidly created additional sound-velocity programs. There is still room for improvement.

For instance: There is need for a rugged, streamlined, sound-velocity meter with a standardized scale which is the same for all instruments and which can be handled very much like a modern bathythermograph (BT) by quartermasters and sonarmen aboard ships which are making speeds of about 10 knots. The absolute "accuracy" of such an instrument is no more critical for velocity than the absolute accuracy of temperature in the present BT. But the precision with which the instrument can record a slope, that is, the velocity gradient with depth, is very important. If such an instrument were available as a replacement for the BT (and good for greater depths) at anything like a reasonable and comparable cost, I am sure it would get most serious consideration. In addition to this simplified, rugged, sound-velocity meter, the survey-type instruments are needed.

I would like to add one more point on acoustics. Navy laboratories, Woods Hole Oceanographic Institution, Scripps Institution of Oceanography, and others, have been studying the effects on sound velocity of pressure at great depths. Several measurements of the coefficient of sound velocity with pressure were made off Guam from the bathyscaphe, Trieste. These have been reported by Mackenzie[3/]. But a lot more needs to be done. The proposed single-packaged means of obtaining direct sound-velocity measurements at the exact spot while water samples are collected will be helpful in several respects: The tables of sound velocity with depth can be corrected, and the computations for long echo sounding and other deep-water sonic paths can be corrected to usable values.

In addition, the horizontal changes in sound velocity, as well as the vertical changes are important. I leave to your own ingenuity the questions of proper readouts and the data processing of such information.

3/ Mackenzie, Kenneth V. 1961. "Bottom Reverberations for 530- and 1030-c.p.s. Sound in Deep Water." Journal of the American Acoustical Society, vol. 31, no. 11, November, p. 1498. (ED.)

Another serious instrumentation problem in acoustics is the determination of the acoustical properties of the ocean bottom from a ship underway. There is a foreseeable need for a blackbox which can be attached to a common echo sounder and which will give us even a rough indication of the type of bottom (physically and acoustically speaking), the special characteristics of acoustic absorption and reflection over a broad band of frequencies.

Turning now to ocean WAVE MEASUREMENTS discussed by Mr. John Schule, Jr., I will just remind you that the Bureau builds ships and submarines. In most ships the structural stresses, the seakeeping qualities, and the combinations of the ship's inertia and the processes of energy transfer, all, involve a somewhat limited wave spectrum compared to the overall frequency spectrum of the sea. Surface wave information and internal wave information from the region of the thermocline would be of interest. Far outside the spectrum of interest in ordinary ship design, the high frequency spectrum affecting sea clutter is important. Right now we do not really know fully how a wave is born and grows in the sea as a measured sequence of events. It is probable that a whole series of "wave meters" will be required in the future. Considerable attention to a better description of sea state for use by engineers is a recognized problem on which professional societies (such as the Society of Naval Architects and Marine Engineers) are now working.

As to ANTIFOULING AND CORROSION EFFECTS, a great deal has been learned from the studies of antifouling paints and the moth-balling of ships. However, the deep waters of the ocean are practically unexplored in this respect. Yet the commercial cables and deep anchoring systems show evidence of considerable activity at all depths. Improved pH meters, conductivity meters, techniques for rate-of-growth measurement, and techniques for the study of fouling organisms as they apply to particular materials are all fruitful fields. The comprehensive report, "Marine Fouling and Its Prevention," prepared for the Bureau of Ships by the Woods Hole Oceanographic Institution, and printed by the U. S. Naval Institute in 1952, has now been pretty well digested and we should be moving on.

DEEP OCEAN CURRENT VELOCITIES are extremely important in deep-water navigation and to deep-ocean structures.

The navigational needs are fairly obvious. A deep-running submarine in an underwater jet stream (and there may be such), or a submarine in the region of shear between a current and the counter current can be set off course unexpectedly and perhaps tossed about. We do not know. We do not have a good method of measuring deep currents.

We need to know about DEEP SEA FLOOR CHARACTERISTICS; people in our sister Bureau of Yards and Docks ask questions similar to those a builder on land would ask, such as: What is the bearing strength of the sediments at this spot? How far down from the bottom is bed rock? What is the expected "windage" (horizontal pressure due to currents) on future structures?

I would like to include a few generalities as to materials at this point. The first rule in choosing materials for underwater work is: "take nothing for granted." You are working in a strange environment -- both salt water and salt atmosphere. During the war, when the radio industry began to manufacture fleet units of sonar equipment, I recall beautiful receivers which had undoubtedly stood up perfectly under hours of the bench testing your home radio would require. But the first time a little spray came through the porthole, some of the condensers turned green, perhaps from sea sickness, and the receiver went dead. Whole systems were knocked out. Just to emphasize the proper choice of materials, here is a verbatim comment regarding a material which most of us sort of "gravitate to," as you might say "naturally." It seems so reasonable to use stainless steel in connection with water -- perhaps because of those lovely knives and forks of which your wife is so proud! "Care should be taken with the use of stainless steels in seawater atmospheres. Class 304L or 316 are recommended for moving and stagnant water conditions, respectively, to avoid chromium carbide formation which leads to pitting."

Each instrument developer must carefully consider the marine environment and the effects of corrosion and antifouling. Sometimes a less exotic material with a good paint may be the better and more economical way to do it. In particular, little is known about the effects of the so-called "trace elements" in sea water. Yet they are becoming important in antifouling and corrosion prevention.

I hope you will carry home with you two final thoughts. The first is that considerable understanding of environmental problems which apply to a modern navy has developed throughout the Bureaus in the past twenty years. This is because we, too, just like Mr. Gilbert Jaffe, have watched a parade of instrument problems go by. Even in those problems where the final solution is not yet clear, much is known about what will not work -- and usually something is known about what may work. I do not believe the Bureau will again be so naive as to favor a manufacturer like the one who developed a beautiful black box and a slick report many years ago for a device dependent on wave motion at sea. The report contained a "safety clause" somewhat like this: "This device will perform properly provided that the ocean surface acts like a pure sine wave!"

I think that we can expect from Industry today a higher estimate of the Bureau than that, and a more realistic solution of problems in the marine environment.

The second and closing thought I have is to beg you to consider and reconsider the effects of pressure wherever they may apply. Please do not be lulled into a sense of slide-rule security by the low compressibility of water and its almost straight-line relationship with depth. There is no more terrible demon hidden anywhere in the sea than pressure. Conditions with which we "land animals" are familiar (under one atmosphere) may not be controlling in the ocean depths. The recognition of pressure hazards and effects takes a conscious effort, a deliberate cold-blooded appraisal to be checked and rechecked throughout all stages of your instrument design work. There are ways of conquering or allowing for pressure effects. But you must think of them to use them. For it is well to remember that into every crevice of the bathyscaphe, Trieste, on its deep dive, and into your cable connections, seals, and coverplates of instruments at the deepest depths, a devil is seeking to deliver a wallop of over 8 tons per square inch.

12. APPLIED RESEARCH INSTRUMENTATION REQUIREMENTS INCLUDING ASWEPS

PART III. FOR THE BUREAU OF NAVAL WEAPONS

Murray H. Schefer

Navy Department
Washington, D. C.

The requirements of the Bureau of Naval Weapons for oceanographic instrumentation are based on the programs which support the mission of the Bureau. This mission reads, in part, as follows: "The Bureau of Naval Weapons is responsible for the research, development, design, test, operating standards, and evaluation of all naval weapons, Navy and Marine Corps aircraft, target drones, naval photographic and meteorological equipment, and supporting equipment. Every effort of the Bureau is oriented to the concept: 'The better to serve and support the Fleet.'" All weapons and detection systems which operate in whole, or in part, in the ocean, or in the atmosphere immediately above it, are affected and/or limited by the marine environment. Intelligent design, improvement, test, and evaluation of weapons and related systems demands that these effects and limitations be well understood. This understanding will only come from the careful analysis and study of data gathered to determine the relationships between the environmental conditions and the instruments. Our first problem, therefore, is to measure accurately those properties of the marine environment which are considered significant.

The oceanographic work pursued by the Bureau, in large part, can be aptly termed Applied Military Oceanographic Research. In addition, a certain amount of basic research is performed because of gaps in our knowledge, because nobody else is doing the work which needs doing to keep the applied program going.

The objectives and requirements of instrumentation for survey and research have already been described to you. Although our mission and objectives differ from those of survey and basic research, it is believed that if their requirements are met many of the Bureau's requirements will be satisfied simultaneously. Certain of our problems, on the other hand, are peculiar to our work and will require special attention.

A brief review of the oceanographic programs of the Bureau of Naval Weapons is in order:

Radar Surveillance: Work in this area generally relates to studies of surface waves as they affect radar signals in an attempt to learn more about the detection of surfaced or snorkeling submarines in various sea conditions.

Sonar Surveillance: This work relates to two areas. One is the development of towed and dipped helicopter sonars. The other relates to bearing accuracy of sonars at long ranges. Much of this is concerned with acoustic transmission in the medium.

Magnetic-Electro Surveillance: Work in this area relates to the detection of submarines using MAD (Magnetic Anomaly Detection) equipment. The type of information required is basic geomagnetic background measurements as an input to the development program.

Sonobuoy Surveillance: The work here is twofold. With regard to acoustic sonobuoys the interest is in obtaining acoustic data relating to sonobuoy use. Second, we are interested in the use of explosive echo ranging for submarine detection. This latter problem requires tests in the ocean on propagation, reverberation, etc., of explosive waves.

Fire Control Sonar: This concerns hull-mounted fire control sonar. The work conducted here in the oceanographic area is basically sound coherency measurements.

Torpedo Guidance and Control: This area represents the largest portion of our oceanographic effort, and relates to the development of acoustic homing torpedoes. Fairly extensive programs are carried on in (1) acoustics of the medium, which includes scattering, reverberation, propagation, etc., in the particular frequency ranges of interest, and (2) acoustics of the target which include active and passive acoustics of a submarine in the operating medium.

Torpedo Hydrodynamics: In this field, a relatively small amount of oceanographic work is done principally in the area of drag reduction.

Mine Development: In the mine development program the basic problem is to obtain environmental measurements to enable the development of better influence mines and determine mine utilization and behavior in varied environmental conditions.

Aircraft Carrier Motion: In the development of automatic carrier-landing systems a knowledge of the surface waves in different ocean areas is required. The same information is needed for sea-plane hull design and performance prediction.

Interaction of Sea and Atmosphere: The Bureau provides meteorological services to the Navy. It is, therefore, very much interested in the interaction of the sea and atmosphere and instrumentation to study this interaction.

These brief descriptions hardly do justice to the significant oceanographic projects underway at such field activities of the Bureau of Naval Weapons as the Naval Ordnance Test Station, China Lake, the Naval Ordnance Test Station, Pasadena, the Naval Ordnance Laboratory, White Oak, the Naval Underwater Ordnance Station, Newport, and the Naval Air Development Center, Johnsville. In addition, the Applied Physics Laboratory, University of Washington, and the Ordnance Research Laboratory, Pennsylvania State University, conduct for the Bureau considerable oceanographic research and instrumentation development, particularly in the area of underwater acoustics. The Applied Physics Laboratory has played a dominant role in the development of underwater range acoustic tracking equipment, of which we will have more to say.

The oceanographic work conducted in connection with the programs previously mentioned calls for a wide variety of oceanographic and marine geophysical instrumentation. Permit me to describe briefly a few typical examples of instruments that have been developed at BUWEPS activities.

Naval Ordnance Test Station, China Lake, has developed the underwater SVTP, a self-contained unit with which sound velocity, temperature, and pressure are measured simultaneously. The present accuracy of the measurements is: sound velocity, about 0.25 meters per second; temperature, one hundredth of a degree centigrade; and pressure, 1 percent of full range. The signals from the sensors are telemetered along a single-conductor polyethylene covered steel cable in the form of different frequencies. The information from the sensors is recorded on magnetic tape for future analysis in the laboratory and also displayed on other recording equipment for examination aboard ship. The equipment has been successfully used to depths of slightly more than 1,000 meters. However, the basic design of the equipment will permit its use to all depths.

This is a development from equipment on which Mr. James M. Snodgrass worked several years ago.

Naval Ordnance Laboratory, White Oak, has developed DEEP DIP, an unmanned, unattached vehicle used to provide an instrument platform capable of descending to the greatest ocean depths and returning to the surface after a predetermined interval of time. The instrument platform is a sphere having an inside diameter of 27 inches. This holds the sensing devices, recorders, and batteries. Under the sphere is an anchor release mechanism and a concrete anchor. Above the sphere is a rubber, gasoline-filled flotation bag, equipped with a small radio transmitter. When the complete system is launched over the side of a vessel, the anchor carries it to the bottom. At a preset time, a clock-actuated mechanism severs the anchor from the rest of the system, allowing the flotation bag to raise the sensor sphere to the surface. Once at the surface, the radio begins to send out signals, permitting the recovery vessel to home on the device. DEEP DIP is designed to withstand pressures at depths of 8 miles. DEEP DIP has been used extensively to make geomagnetic measurements for mine development purposes.

Applied Physics Laboratory, University of Washington, has developed the DEEP SEA RESEARCH VEHICLE. This is an unmanned instrument carrier capable of 50-mile horizontal trajectories at depths to 10,000 feet. This vehicle was tested successfully last year. Now this, I believe, answers one of the questions that was asked yesterday about the artist's conception of miniature submarines. During the period of this Symposium the vehicle is at sea on its first data-gathering expedition. I would have been with it except for this Symposium. It is torpedo-like in shape, 120 inches long and 20 inches in diameter, and has a displacement of 1,000 pounds. The pressure hull is designed to carry sensors and other components to a maximum depth of 12,000 feet. High-performance batteries propel the vehicle for 8 to 10 hours at six knots. It can carry an instrument payload of up to 200 pounds. A radio beacon having a range of 5 to 10 miles has been installed to facilitate location and recovery. The tracking and command link is a simplified version of the three-dimensional underwater range tracker, mounted on a ship. The instrumentation to be used in this vehicle remains in large measure to be developed. Initial instrumentation includes a thermistor probe mounted forward and a high frequency, narrow beam echo sounder to pick up the details of bottom topography. Work will soon begin on a recording system suitable for general application and data recording consistent with the space, power, and weight capabilities of the vehicle.

Ordnance Research Laboratory, Pennsylvania State University, has developed the MICROTHERMAL MEASUREMENT SYSTEM which permits the measurement and recording of horizontal or vertical temperature differentials as small as one thousandth degree centigrade by use of thermistor probes spaced on a bar which can be lowered to any desired depth down to 1,000 feet.

And now in the time remaining, I will describe a requirement in an area which I believe is specific to the Bureau:

UNDERWATER WEAPONS RANGES: The performance of weapons cannot be adequately tested and evaluated in the laboratory. This work has to be done on a range. For underwater weapons, such as torpedoes, this must be an underwater range. The rapid development since World War II of sophisticated underwater weapons has called for a parallel development of underwater ranges to test and evaluate these weapons. Several of these ranges already exist and are constantly being improved, and others are in the planning stage. One of the better known ranges is in Dabob Bay and is operated by the Naval Torpedo Station, Keyport, Washington. The Applied Physics Laboratory, University of Washington, developed the three-dimensional acoustic underwater tracking facility for this range. The range at San Clemente Island, off the California coast, is described by H. R. Talkington in the U. S. Naval Institute Proceedings of June 1960[4]. The ranges in existence, and planned, vary in size from 1 to 10 miles wide, 3 to 70 miles in length, and 150 to 5,000 feet deep.

In order to analyze and evaluate weapon and equipment performance intelligently in an underwater range, it is necessary to know

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those properties of the marine environment which either affect weapon performance or affect the instrumentation employed to measure weapon performance.

Oceanographic surveys of range sites are conducted during planning and early construction stages. These surveys employ conventional available equipment. Once the ranges are in operation, periodic surveys are conducted to gather information on the degree of variability that occurs in the range. However, these surveys do not reveal the day-to-day conditions of the range.

The ranges are instrumented to provide an accurate and instantaneous presentation of the movements of a submerged weapon, or a weapon and its target on the same run. From the data obtained, accurate determinations of weapon trajectory, velocity, acceleration, turning radius, advance transfer, and other parameters are made. This information is invaluable from the standpoint of design and tactical considerations. The ranges present a unique facility as an underwater "laboratory" and many new uses and requirements for them are constantly being generated. Amongst them are calibration of ship-mounted sonar and navigation equipment.

In this underwater "laboratory," however, we cannot control the environmental variables. In this sense, the underwater range cannot be strictly referred to as a laboratory. Therefore, it is important to be able to measure these variables over the entire volume of the range, not periodically, but concurrently with the tests.

A three-dimensional system is required that will accurately measure the properties of interest throughout the volume of the range, communicate the data to a central location where they are recorded, and graphically display the data for immediate inspection. This is the ENVIRONMENTAL SURVEILLANCE SYSTEM for the underwater ranges.

The function of the Environmental Surveillance System is to provide, either according to a programmed schedule, or on demand, environmental data from points throughout the range volume, including the atmosphere immediately above it.

DESIGN CONCEPTS: The system may consist of a number of taut-wire buoys to which sensor clusters are attached at different depth levels. Or, it may consist of sensor buoys which ride up and down on the taut-wire arrays. It is desirable not to obstruct the range; therefore, moored equipment may not be feasible and some other approach will have to be explored. Data collected at the sensors will be relayed to a data center either by radio telemetry or by cable. At the data center, equipment will be provided both to record the data and to display it graphically for immediate inspection.

Now what are the environmental properties of interest? I have lumped these into the water properties and the air properties. The properties of interest with their ranges and accuracies are as follows:

Among properties of the water, we are concerned with: Depth (total ±0.25% full scale); temperature vs. depth (-2° to 35° C. ±0.10° C.); salinity vs. depth (15 - 40‰ ±0.05‰); current velocity vs. depth (0.05 to 5.0 knots ±0.02 knots and 0° - 360° ±10°); surface waves (0 - 20 ft. ±0.5 ft. and 0° - 360° ±10°); pressure (0 - 4,000 p.s.i.); density vs. depth (1.01000-1.07000 ±0.00001); bubbles (to be determined); the optical characteristics of the water, including such things as the ambient light vs. depth (absorption 0 - 100% ±1.0%), and the light transmissivity vs. depth (allowable error to be determined); the acoustical characteristics of the water mass: sound velocity vs. depth (4,500 - 5,500 ft./sec. ±0.1 ft./sec.), ambient noise vs. depth (0 - 100,000 c.p.s.), acoustic scattering coefficients from the surface and from the bottom (to be determined), and acoustic propagation variability (to be determined).

Air properties in which we are interested are: surface temperature (-10° to 120° F. ±0.5° F.); wind velocity (0-125 knots ±3 knots and 0° - 360° ±5°); barometric pressure (880 - 1,050 millibars ±0.1 millibar); incident radiation (0 - 40 Langleys/ min. ±5% range); and reflected radiation (0 - 100 USWB scale ±5% range).

Do not be dismayed by the length of this list or the ranges and accuracies asked for. We are not asking for a trip to the moon. We are aware that redundancy exists in this list, but we want it. We consider it a desirable feature. The system can be built piecemeal, sensor modules being added as the state of the art develops. The design of the recording system, however, should take into account maximum possible utilization.

It should not be construed that the oceanographic instrumentation and data requirements of the Bureau of Naval Weapons are limited to the needs of the underwater ranges. Our oceanographic interests extend beyond the ranges. Indeed, it is oceanwide, particularly as it relates to ASW. The sites of the ranges have been selected with certain considerations in mind which do not make them truly representative of the open ocean or the actual ASW tactical situation. Complete evaluation of ASW weapons and systems must occur under these latter conditions. Meanwhile, the ranges seem to present an excellent opportunity to develop, test, and evaluate oceanographic instrumentation that will be required, not only for our own needs, but also for ocean surveillance as an input to such synoptic programs as ASWEPS, basic oceanographic research, and surveys.

Finally, I add a couple of simple thoughts based on 12 years experience with oceanographic survey instruments.

First, I want to emphasize the point made by Mr. James M. Snodgrass and Mr. B. King Couper regarding the fact that a considerable body of experience in oceanographic instrumentation has been built up during and since the war.

I have considered too many proposals that have completely ignored this background. This experience cannot be ignored even though it exists in no neat package, you have to research and to dig for it.

And secondly, I want to remind you once again that an oceanographic instrument consists of three parts: the sensor, the recorder, and the link between the two. The sensor has to be accurate, reliable, and durable. The link has to be reliable and durable, without degrading the accuracy of the sensor. The recorder has to be reliable and durable, also without degrading the accuracy of the sensor.

The recorder is the area which, I believe, is the least troublesome but the one with which the proposals seem to be most concerned because one can make many beautiful pictures of impressive counters, punches, printouts, and so on. The part most in need of improvement is the sensor.

13. DEVELOPMENT AND MAINTENANCE OF BUOY SYSTEMS

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Yesterday, nine of the speakers mentioned buoys as systems for oceanographic data collection; this morning, two of the preceding speakers mentioned they have an immediate need of buoys. Mr. John J. Schule, Jr.'s picture of ocean buoys is what we look for within the very near future, but I will discuss buoy systems in the light of existing systems. Part of my intention in so doing is to demonstrate that the efforts in this direction have not been very extensive and progress has not been very remarkable.

Anyone who has worked in oceanography and wanted data for his work very soon realizes that there are practically no long time series of measurements in existence, neither physical measurements nor biological measurements. About the only exceptions are some of the light vessel measurements and the Coast Guard Ocean Station measurements, and these, in general, are not in deep water nor are they, properly speaking, continuous. The other thing that is missing in oceanographic data is synoptic data over large areas. The reason for this lack is perfectly obvious. Oceanographers work primarily with the ships and ships are not well suited to taking long-term, time-series measurements at sea nor are they capable of covering large areas synoptically.

I will restrict my discussion of buoy systems to anchored buoys. This is not to imply there are not good uses for drifting buoys (in current measurements, etc.), but I do not think that the full potential of buoy systems is realized until reliable -- there is that word again -- anchoring systems exist. I will also restrict my attention to deep moored stations. By this, I (arbitrarily) mean anchored in water greater than 500 meters deep. There is, of course, much interest in shallow water areas, but the buoys for shallow water can be handled by brute force techniques. I will also restrict my attention to buoys which are to be worked for long periods of time. By this, I mean 1 or 2 months or longer; long enough so a ship cannot be kept alongside to watch them. Such buoys are, of course, all-weather systems. In the case of experiments where a ship can be kept in the vicinity of the buoy or where the weather can be selected, lighter gear can be used in the mooring.

Within this framework of anchored, deep-water, long-term, all-weather buoys, I would guess that perhaps 50 or 75 successful moorings have been made. I am sure I do not know about all of them but I think this is probably a conservative maximum number. Based on the importance which the speakers, both yesterday and today, placed on such systems, it seems like a remarkably small effort, particularly since the buoy can accumulate a type of data which ships cannot.

Existing buoy experiments, or buoy types, may be divided into four classes:

In the first, the buoy records only data from surface observations and these are stored in the buoy. Surface observations are made from a few feet underwater up to and including meteorological observations. This buoy must be visited and the records recovered. This is perhaps the most prevalent type of buoy. It is characterized by the effort of Scripps Institution of Oceanography in fall-out and atomic-blast areas, where they use taut-wire moorings with skiffs as surface floats. There are many other examples.

The next more complicated class is the one in which only surface observations are obtained, but the data is telemetered. This is characteristic of the meteorological buoy which has been moored in the center of the Gulf of Mexico. That mooring is a slack-rope mooring, and I believe the buoy has been in place for about 2 years.

The third extension of the buoy system is that in which measurements are made in the deep water, but no information is transferred to the surface. This might be characterized by the present line of 15 buoys which the Woods Hole Oceanographic Institution has installed between Cape Cod and Bermuda. In this case the mooring is semi-taut plastic rope, and internally recording instruments (primarily current meters) are installed in the mooring at various depths down to the bottom. It is, of course, necessary to pull the whole mooring up to retrieve the records. The instruments are then refurbished and the mooring reset.

This is obviously a somewhat dark-age system; we have no communication to the surface and no telemetry. It leads to the final desired system involving conducting cable moorings, data storage, and radio telemetry from the surface. This is the goal toward which we are working and may be considered an ultimate system. As far as I know, only the work of Dr. Charles S. Cox at Scripps Institution of Oceanography approaches this requirement. There have been very few buoys moored on a conducting cable with information sensed at depth and transferred to the surface. I understand that I. T. and T. will set some deep hydrophone buoys shortly, and we at Woods Hole will be setting some current stations, probably later this winter, but really very little has been accomplished. There may well be efforts in the Department of Defense about which I do not know and there is also some foreign effort.

The title of my talk implied I was going to discuss the maintenance of such a system. Nobody knows very much about this. Our own line has been in place for only about 3 or 4 months. We are just beginning to see what the maintenance picture will be. The first thing one encounters on setting a line of buoys out in the ocean and driving away from them is they look very fragile, lonely, and small. If you are normal, you worry! This is perhaps one of the worst features of this type of experiment. We have lost 4 out of 31 of the deep stations which we have set. In two of these, the cause has been diagnosed as the mechanical failure of a part of the instrument, not really a failure of the mooring proper. For the other two the causes are unknown, since notthing was recovered.

We encounter marine fouling on these moorings at all depths, although the species, of course, change. We do see some evidence on our current meters (where we rely on rotating parts) of difficulty with this facet of the environment. We have had considerable corrosion on some parts of our instruments and presently have installed corrosion test panels in these moorings. This data will be analyzed and available fairly soon. The rates of corrosion in the deep water are appreciable as they are in the shallow water, as you might expect; but for some materials they appear to be different in deep water than in the shallow water.

I would like to finish by trying to convey some idea of the economics of buoy operations as opposed to ship operations. This is rather difficult to do because buoys and ships in general do not do the same job. I feel that perhaps one could make a valid comparison by assuming that there are two operations, such as the buoy-line operation and a ship operation, which occupied about the same length of time and in which all of the data which are collected are important. That is, no excess data was collected. Then we might compare the economics on the basis of the cost per measurement.

What I have compared is an IGY cruise of the R/V Crawford of the Woods Hole Oceanographic Institution and the buoy line between Cape Cod and Bermuda.

Crawford Cruise 10 involved four crossings in the Atlantic Ocean. It was a long cruise, 3-1/2 to 4 months, and an economical cruise. (The Crawford is a small but very efficient vessel.) The work done was hydrographic stations and the primary reason they were done was to take temperature and salinity sections. We may logically put the entire cost of the trip on the temperature and salinity measurements, since the trip would have gone for this purpose alone. If one does this and takes the cost of the trip (pay for the scientists, ship time, etc.), but does not charge for the instrumentation (because Mr. Nansen developed this back in 1900) -- we find that each temperature and each salinity measurement costs $21.75. These measurements are three or four digit numbers so the price is about $5 to $7 a digit. The sea water which was captured in the Nansen bottles and brought up for the salinity measurements costs $16.30 per liter. If you are not facile in the metric system, that is $11.50 a fifth.

In comparing these costs with the buoy line, I use all the costs of the instrument development, procurement, ship time, and salaries. If I then total the number of current measurements which we have available at the present time (3 to 4 months operation), each measurement costs about 50 cents. The line is out there at the present time so it is running the cost downward. Analyses of this type makes buoys look very attractive from an economic point of view.

In conclusion, we can look forward to many buoys at sea. Many of these will have conducting cable moorings and will utilize storage and telemetry. Such systems have not been developed and are not in operation at the present time; only these much less sophisticated, more dark-age systems which I have mentioned have been used and this use has been limited.

We need moorings with conducting cables; we need reliable (that word again) electrical and mechanical connections to the instruments in the moorings and to the surface floats, cables, and ground tackle. We need well-engineered parts for these systems, and I think this is a place where Industry, with its excellent engineering experience, can make a really significant contribution to oceanography.

14. FIXED PLATFORMS IN OCEANOGRAPHIC RESEARCH

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Until about a decade ago, nearly all oceanographic studies were conducted from piers, moving vessels, or from the shore. The choice of locations depended upon the particular specialty or interest of the oceanographer. If such investigations included studies of ocean currents, the sea floor, or midocean meteorology, the oceanographic measurements were made from an oceangoing ship. When near-shore phenomena such as sand transport, shoreline circulation, and intertidal biology were to be investigated, the studies were conducted from the beaches, platforms, or piers.

The U. S. oil industry first demonstrated the value and practicability of constructing offshore fixed platforms or towers. Such structures have been used to pursue oceanographic research. Although these fixed platforms entail certain disadvantages, they are superior in vital respects to all other types of facilities.

The principal advantage in the use of oceanographic towers over vessels anchored in the same location is their stability. A fixed platform virtually eliminates the motions caused by waves, winds, and currents, and the recording, processing, and analyzing of data are, therefore, more precise. In most cases, it is possible to stabilize instruments in depth. The lowered efficiency on oceangoing vessels caused by the absence of seasick personnel is a factor not experienced. The absence of adequate electrical power is no longer a problem. With a fixed platform, or tower, continuous measurements can be made over long periods of time at the same geographical location.

An outstanding advantage of the fixed platform at sea is its economy of operation. Oceangoing vessels are well known to be extremely expensive to maintain and operate. The smaller towers may be, by comparison, adequately manned by two or three personnel or can be left unattended for considerable periods of time. Computed comparisons of maintenance costs between ships and fixed platforms are not available at this time, but it is obvious that a well-designed structure of the smaller class of tower requires much less expensive maintenance than the usual oceanographic vessel, although this may depend in certain instances upon the size of both tower and vessel.

A final advantage is that fixed platforms are quieter, acoustically and electrically, than ships.

The main disadvantage in fixed platforms is a limitation in geographical coverage. The movement from one area to another, as with an oceangoing vessel, is not possible. Range, however, can be increased somewhat through the use of booms or floats, although the latter cannot qualify as a stable platform.

Another disadvantage with the fixed platform is the limited depth at which they can be safely constructed. This is generally considered to be about 200 feet. Such a depth restricts the usefulness of towers to what is sometimes called "shallow-water" oceanography. A somewhat lesser disadvantage is the creation of an unnatural environment, particularly at the bottom. However, reflection and refraction of the waves in the substructure, and their effects on biological population, may be minimized by proper structural design.

Towers and other fixed platforms cannot run for shelter when a storm arises, and, consequently, they are subject to damage by high winds and waves. A hurricane destroyed the first fixed platform at Caplan, Texas, as well as the first Panama City oceanographic tower. Fire devastated the Magnolia Petroleum Company platform off Louisiana, a hazard of interest to oceanographers since some towers are used jointly by oil companies and oceanographic research groups. At Woods Hole, the windmill structure in Buzzards Bay was toppled during a hurricane. The recent loss of a Texas Tower in a hurricane was widely publicized. Fixed, open-sea platforms frequently present boarding and debarking hazards in bad weather.

The most common type of fixed platforms employed in oceanography are piers. These are especially useful for investigating sea boundaries that extend across the surf, and the resulting wave action and beach erosion.

Piers are accessible from land and convenient to electrical supply, but are restricted to even shallower water than towers. Most piers have been constructed primarily for ship moorings, outfalls, and so forth, and oceanographic research is a by-product. A notable exception to the general situation is the pier of the Scripps Institution of Oceanography at La Jolla, California, which was designed and built expressly for research. This pier, unique in oceanographic research, extends 1,000 feet out in the open sea to water about 20 feet deep, and provides for the sampling of water and the recording of tides, waves, and other sea properties.

The other principal form of fixed platform, the tower, as exemplified by the Oceanographic Research Tower, U. S. Navy Electronics Laboratory, promises to be an invaluable tool in extending knowledge of shallow ocean environment, including the sea floor, the surface, and the water in between as well as the meteorological conditions immediately above the ocean (fig. 14.1).

With the NEL Oceanographic Research Tower, the legs are hollow and through them are driven pins, 120 feet long, which penetrate the ocean bottom about 60 feet. This affords a uniquely stable, fixed platform.

A cargo boom is used to load and unload equipment from the NEL tower. A boat is swung on davits from the tower and can be launched to collect samples of surface foam. A cathodic protection system has been in use for the past year. Its purpose is to keep corrosion damage down to a negligible level.

The knowledge provided by the NEL Oceanographic Research Tower will be applied to better ways of detecting and neutralizing enemy mines, sneak craft, and submarines, and to development of improved communications and navigational systems for the Navy.

The U. S. Coast Guard is replacing certain of its light ships with fixed structures, which are intended for additional use as platforms from which to study the ocean by the Beach Erosion Board and the Hydrographic Office. The first of these fixed platforms will be located in Buzzards Bay, 3 miles southwest of Cuttyhunk, Massachusetts, in 70 feet of water. Similar structures will be built at the rate of two per year for the next 9 years, and are

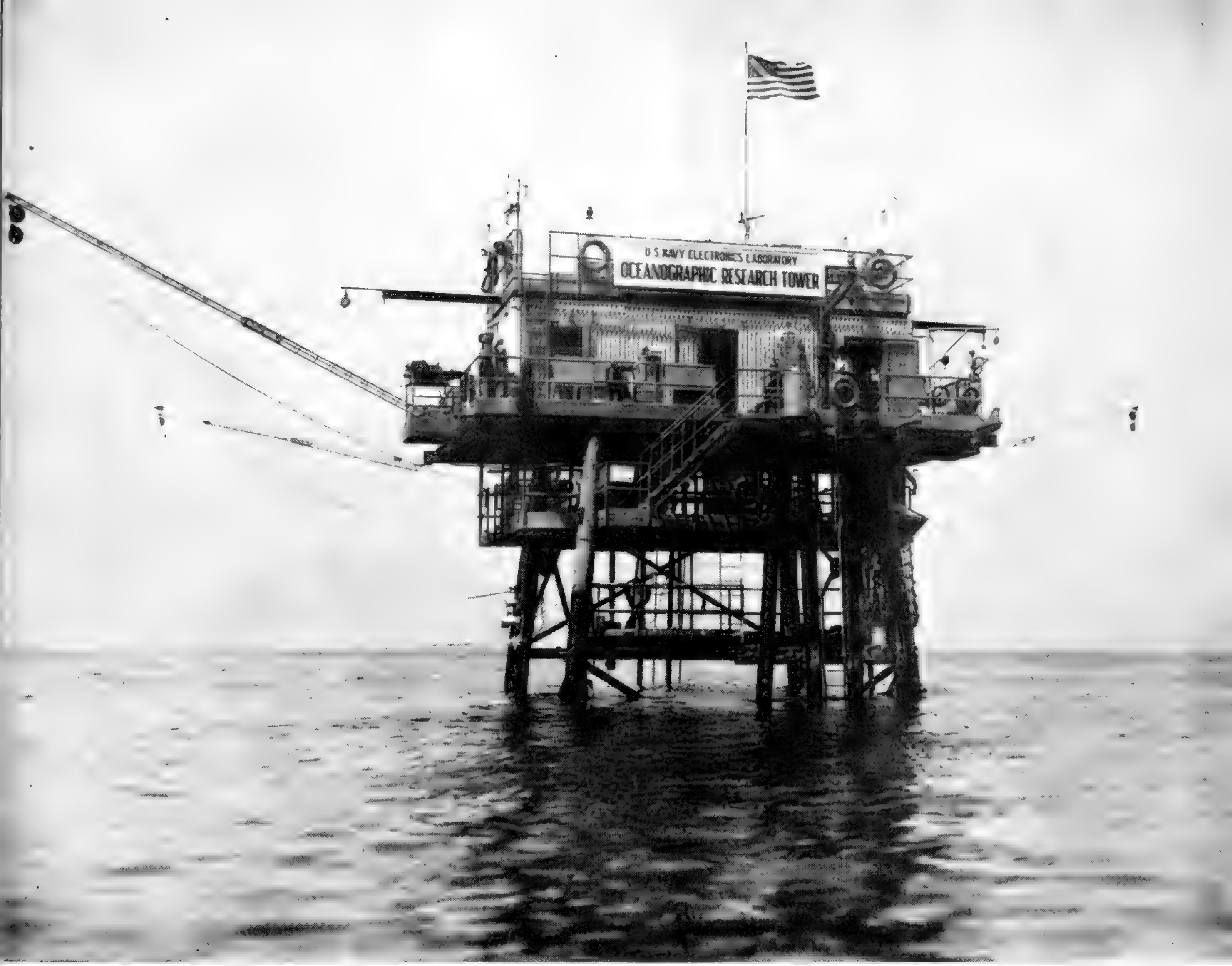

FIGURE 14.1
OCEANOGRAPHIC RESEARCH TOWER

expected to provide splendid oceanographic research facilities.

The oceanographic research program that started out so promisingly on Texas Tower 4 is being transferred this fall to Argus Island (fig. 3.2), located southwest of Bermuda. Installation of cables for the raising and lowering of instruments was finished recently, and a Hydrographic Office ship completed an oceanographic survey of the surrounding areas. The program's prime objective is to study the heat budget of the water column, not only the energy exchange due to radiation, but also that due to the size of the column and the wave action.

The experience with Texas Tower 4 proved the practicability of such a fixed platform, and even greater results are expected from Argus Island.

An offshore structure, located 11 miles off Panama City, Florida, in 100 feet of water, is being readied for an ambitious oceanographic research program by the Agricultural and Mechanical College of Texas, under contract with the Office of Naval Research. This facility for the most part will be unattended. The data will be telemetered back to a shore station over a radio link.

A typical anchored platform is Monob I, the David Taylor Model Basin's underwater sound barge. This ship is a converted water barge, modified by the addition of extensive laboratory facilities. It can be anchored wherever facilities are needed and for as long as required.

Another type of platform being studied by the Naval Research Laboratory is a large, floating structure approximately 300 feet in height and constructed of hollow structural members. According to the particular requirement, it can be made to float high in the water or nearly submerged. The huge lower floats will contain many scientific laboratories. This structure will have less than 1-foot vertical excursion when the surface waves are 40 feet high, but will be responsive to low-frequency waves such as those produced by underwater volcanic eruptions called tsunamis.

The Marine Physical Laboratory of the Scripps Institution of Oceanography is constructing FLIP, a floating stable platform, to do essentially the same work, but along somewhat different lines.

15. SUBMERSIBLES AND AIRCRAFT PLATFORMS

Allyn C. Vine

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

Throughout a great deal of this meeting there has been discussion on the similarities and differences between survey and research. It has been said, "Research is what I am doing and development is what you are doing." In this vein it can also be said, "Survey is something we both believe worth doing."

To many a seagoing research worker the ocean seems alive. Things are happening in it which he wants to further investigate while he is there. To do this he needs to have sufficient incoming data and sufficient operational control to exploit this opportune time to improve his data-gathering procedure. This is in contrast to the generally understood survey concept where the measuring program is laid out well in advance and is to be closely followed. However, any good survey program will allow the chief scientist on the ship enough operational control to take advantage of unexpected events. The Coast and Geodetic Survey has recently done this and they are to be commended for it.

We probably talk about research and survey in terms that are too absolute as though any trip is either all survey or all research. The most rabid research worker with his pet project likes to retain his data in order to make it available to others; likewise, the most dyed-in-the-wool survey man wants to learn more about interesting, transient phenomena while they are occurring.

The question for us to consider here is what method of recording best achieves these goals. We hear too much discussion about the relative merits of magnetic tapes that play data back in the laboratory versus graphical recorders with convenient readouts for meaningful on-the-spot observations. There seems to be every reason to have both types of recording. By having both visual recording and tape recording available, the on-the-spot observer can make the best immediate judgements affecting the operation and a detailed permanent record can be brought back for later examination by all.

Individual discussions at this two-day meeting are so brief that they may be misleading as well as frustrating. Whereas our presentations may appear to be too general and not definite enough with a specific list of budgeted instruments with formal specifications, please remember you have been invited to this general discussion before all the decisions have been made. This conference may be premature, but it is not too late.

At special meetings at a later date a whole day can be devoted to a particular instrument, such as a new echo-sounder or a biological sampler. At this time when the number of actively interested companies is perhaps twenty instead of five hundred, discussions can be held on specifications and design concepts in lengthy and meaningful detail. The list of oceanographic instruments (appendices E, F, G, and H) which you have all received will help you decide the kind of instrument in which your company is seriously interested.

The use of AIRCRAFT FOR RESEARCH has been mentioned by several previous speakers and there are several important aspects of aircraft in research. Airplanes are cheaper per mile than ships. A large airplane might cost $1 per mile and a large ship might cost $10 per mile. Therefore, continuous measurements which can be made from an airplane are much cheaper to do from a plane than from a ship which is making only the same measurements. As indicated earlier, such measurements might be of surface waves using a vertical radar system, surface temperatures of the water, air turbulence, or color of the water as an indicator of biological activity or different water masses.

If one considers making discrete oceanographic observations 50 miles apart, it costs $500 to move a ship between stations and only $50 to move an airplane. However, if one is using an expendable instrument which costs more than $450 at each 50-mile interval, the total cost for the plane plus the instrument would be greater than for a ship using non-expendable instruments. In considering future problems in oceanography, it may be that you manufacturers can make such expendable instruments considerably cheaper than $450, or perhaps the equipment can be recovered later by ships or aircraft. It may also be that a special scientific or military requirement justifies the extra cost of expendable equipment.

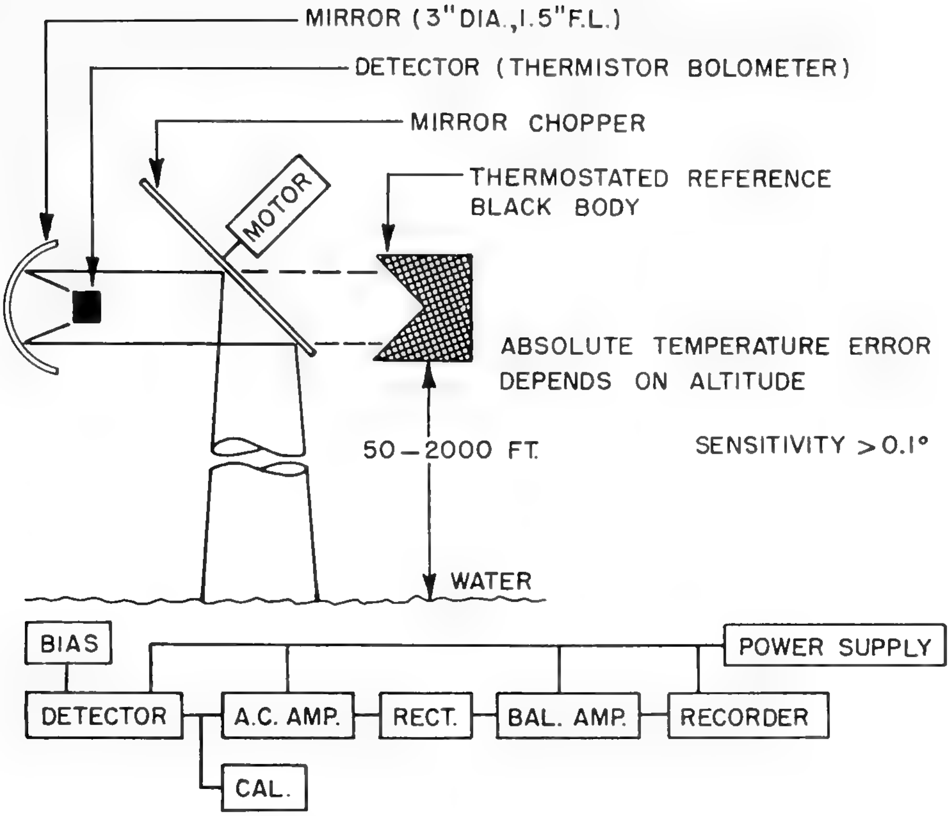

FIGURE **15.1**
AIRBORNE RADIATION THERMOMETER

Airplanes have great speed and transport type airplanes have ample space for equipment, but unfortunately there just are not many types of oceanographic instruments available today for use in aircraft. An excellent example of one of the instruments that does exist is the airborne radiation thermometer for measuring surface temperatures (fig. 15.1). The radiation thermometer compares the difference in temperature between a self-contained standard temperature reference and the ocean surface. By using the new thermo-electric heating and cooling devices, the radiation thermometer might be made much simpler and more usable than earlier models that depended on thermos bottles with ice cubes in them which had to be renewed at awkward intervals. Simplifications of this type might result in much wider use of airborne thermometers.

Concerning UNDERSEA VEHICLES, let us start with the deep-running torpedo which has already been mentioned. One of the assuring things about torpedoes is that we have considerable knowledge and experience with their hydrodynamics, propulsion, noise, and control. Recently a deep-running torpedo for scientific purposes has been made and used by scientists at the University of Washington.

A torpedo can make almost any simple measurement that can be made on wires or cables, or from submarines. The fact that it is remote from the mother ship is an advantage that deserves more exploitation. Properly programmed torpedoes can make observations along lines radiating away from a stationary ship. There is also a possibility that echo-sounders could be mounted on slave torpedoes that run parallel to the mother ship. With such a combination a single survey ship accompanied by a system of slave torpedoes could echo-sound a broad path across the ocean. Something like these echo-sounding slave torpedoes that navigate acoustically from the mother ship and return to one mother ship for battery charging might turn out to be a more economical way to do bathymetric survey work than to use two conventional ships.

We usually think of an echo-sounder as looking down at the bottom from a surface ship. The detailed depth and slope of a rough bottom might be found more accurately if an inverted echo-sounder is run close to the bottom on a torpedo so it can look up at the relatively flat surface. An echo-sounder of this type would permit more detailed bottom measurements because a point on the bottom would be much smaller and more discrete than averaging the central Fresnel Zones from a surface-mounted sounder.

The above are thoughts on special torpedo-like devices that you might consider. Some of these devices might only be needed in quantities of five or ten a year. However, if they really make a magnitude of difference in oceanographic capabilities, the quantity required might increase to proportions that would frighten the user and please the supplier.

In using conventional military submarines, availability and operational control have been limiting factors. Submarines have normally been used as specialized ships of opportunity on which one could measure such variables as temperature, salinity, or sound velocity. The special capabilities of great stability have made the submarine an eminent platform for gravity measurements. Their quiet mechanical and acoustical background have also made them ideal for certain kinds of acoustical measurements. A portable set of special instruments and attachments for a Navy submarine might make them much more useful and generally available for research work.

The polar, under-ice trips have provided an excellent opportunity for good science and good instrumentation. For example, on her recent trip under the polar ice, the Sea Dragon was equipped with television, high resolution sonar, inverted echo-sounders, and an automatic-multiple-plankton sampler. This trip produced the pleasant and anomalous situation of knowing for the first time how deep the plankton samples were being taken, what the plankton swarms looked like on TV and on sonar, while simultaneously measuring temperature and salinity. The fact that this ideal combination occurred first under the polar ice was simply because scientists, instrument designers, and the Navy seriously faced the problem of under-ice work. That so much has been done so quickly augers well for further advances.

There is obviously a great deal of under-ice work yet to be done. We have all heard about the under-ice work in the Arctic, but some of the scientists interested in the Antarctic would like to see submarines used to study oceanographic features under the Ross Ice Shelf. The much greater thickness of ice involved and the greater distances represent a serious problem, but there is every reason to think that a second generation of nuclear submarines and instruments will see it done.

A submarine can travel in three dimensions. Where the ocean is streaky, the streaks can be explored in depth as well as in latitude and longitude providing the submarine is properly instrumented. Such investigations require that gradiometers be installed on two axes.

The Bureau of Commercial Fisheries has done some exploratory work in the Pacific using submarines for studying fish. They hope to do a great deal more in studying the schooling habits of fish and are seriously discussing the requirements of a submersible for this purpose.

In the NASCO report (Oceanography 1960 - 1970) much attention was given to deep, manned submersibles. The general concept was of a small submarine that could carry three or more people and could dive several miles to expedite the studies of the biologist, the physical oceanographer, and the geologist.

Although two European-built bathyscaphes have been used for research, to date none of the U.S.-designed craft has been constructed. Many deep submersibles have proceeded through early design stages and some designs are becoming practical, nearly final, and I hope saleable.[5] If small submersibles are successful, it may well turn out that most of the large research ships will routinely carry a small submarine in just the way that they now carry an ordinary work boat in order to investigate interesting biological or geological features found on the echo-sounder.

The scientific justification for these submarines is that by having a trained person in a deep, on-the-spot laboratory more purposeful and fruitful experiments can be made than could be made with an instrument. For example, a rock-hunting geologist can select the rock he chooses, turn it over with a manipulator, and, if it still looks interesting, he can bring that particular rock back. He will also know something about the local environment and whether that rock is typical or not. If ripples are found on the bottom, the area can be surveyed to see if they are present over a wide area or a small area.

Certainly, submarines with usuable windows in them are going to encourage more interest in optical methods in research and should increase our emphasis on the optical properties of the water, including the optical scattering characteristics of marine life and of the particles in the water. It will emphasize the color aspects of the ocean and its inhabitants.

It is often heard that one cannot see much under the water. Perhaps the real reason we have not seen much to date is because we have refused to look underwater. Conventional submarines took their windows out in 1941 and periscopes cannot be used very far below the surface. The bathyscaphes did not have very powerful lights and few of our surface craft have windows in them. Happily some of the research ships and submarines on the drawing boards have corrected this optical deficiency.

A few more comments about the techniques associated with working at great depths are in order. Mr. B. King Couper was certainly correct when he said that that "old devil pressure" and that "old devil corrosive salt water" are working against us at all times. On the other hand, there is also the point of view inferred by Mr. Bridgeman in his book on high pressures that at such low pressures as a few hundred atmospheres, almost any

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5/ Since the August meeting, a construction contract has been let for Aluminaut.

logically designed device will work. Somewhere between these two points of view lies the practical answer. The important thing to remember is that there are well established physical principles, and there are good materials and components, which, if properly used, will permit simple instrument cases to be tight, strong, and economical. In fact, oceanographers are as apt to have trouble with low pressures and shallow-water equipment as with deep equipment in deep water. With shallow-water equipment they may get sloppy in design; deep cases are rugged and their design is usually based on fundamentally sound principles. Pressure compensation techniques often solve high pressure problems exactly as easily as they solve low pressure problems. There are reasonable descriptions of these techniques scattered through the literature.

Most of the instruments that are good for small submarines might work equally well if mounted on deep fish towed by a surface craft. If an instrument is well designed, the chances are it will work at great depths as well as at shallow depths. A very practical point for you manufacturers to remember is that the more universal you can make your instruments, the more potential buyers you will have for any one model. The balance between a multi-purpose instrument and a simpler, single-purpose instrument is an important one, both to the user and the manufacturer.

With respect to the desirable recording equipment on a small submarine, there should definitely be provision for instantaneous viewing of data and there should also be provision for recording it for further analysis at a later date. It would appear that six to eight recording channels should be available for routine measurements such as temperature, salinity, and depths, and a few more of the recording channels should be reserved for recording variables of particular interest to a particular dive or program.

It is likely that a deep research vessel would be used much like other research ships. As such, a biologist might use it for three or four trips on his problems and then when his work is finished, or his instruments quit, or his time runs out, he would turn the submarine over to a geologist or someone else with a new set of equipment and interests.

A research submarine looking for biological specimens or geological features has about the same problems as a military submarine; it must detect, classify, and capture its prey. By using an acoustic echo ranging system out to perhaps 1,000 meters to provide search and to help avoid obstructions, both good search and high safety should be achieved. Classification of objects will be accomplished at short ranges by visual methods. There is every reason to believe that the water is clear enough to see at distances of from 30 to 100 feet. Capture can be either photographic with a camera, or be physical with nets, or with remotely-controlled mechanical arms and storage bins.

The camera equipment should be very complete, taking not only time lapse movies, but also high quality stills and movies on demand. Fortunately, some of the second generation deep submarines now being designed have the electrical power to provide sufficient illumination so water clarity may be the only limiting factor in vision, photography, and TV.

There has been little done either with research submarines or good towing equipment from surface craft. The thermal tow chains now used on Woods Hole and NEL ships that permit continuous underway observations down to several hundred feet are merely indicative of future possibilities.

In summary, I would like to say that although aircraft have been very useful in oceanography, their overall general utility is low compared to surface craft, so it is doubtful if there will be more than one aircraft per ten surface ships. If the number and capability of instruments for aircraft could be increased, the overall efficiency of aircraft in oceanography might become high enough to compete seriously with surface craft on more than just a speciality basis.

The Navy has obtained a good many complex sonar and recording equipments for use on such submarine projects as under-ice work, equipment test, and survey. There will probably be more demand for equipment of this type and there may be more varied instrument requirements after a few civilian submarines start doing oceanographic research.

As you have noticed throughout this meeting, the surface ship has done most of the work and will remain the standard of comparison for the foreseeable future. Carefully selected and generally useful instruments or devices will become generally adopted. The frequent loss of instruments at sea is a decided factor in favor of manufacturers. The design of survey type instruments will be frozen from time to time and prototypes and production units will be obtained. The much wider use of electrical cables and telemetering will have a profound influence on the kind of equipment used by oceanographers.

These are some of the directions oceanography may take in developing and using instruments. The potential instrument market will be built up as new instruments and techniques prove that better and more measurements can provide a much better picture of what is going on in the ocean.

A typical example of this progress is that just in the last two years since the initial oceanwide survey recommendations made by NASCO in 1959, instrument development has progressed sufficiently to enable oceanographers to plan seriously for much better surveys than initially suggested.

16. PHYSICAL AND CHEMICAL REQUIREMENTS

Dr. Hugh J. McLellan

Agricultural and Mechanical College of Texas
College Station, Texas

Occasionally I read in the Houston Post a syndicated column by someone, whose name escapes me, who very often lists things that people get tired of hearing. One week it might be things that a policeman gets tired of hearing, the next, the things a psychiatrist gets tired of hearing, etc. These columns contain a careful analysis of essential misunderstandings that make relations with the public a trial for the men who are engaged in a selected method of earning a livelihood.

Recently, I have been thinking of what a column would look like if it were "things that an oceanographer gets tired of hearing." At the top of the list would probably be: "Our company is eminently situated to take care of all your instrumentation needs in oceanography, both present and future. Mr. Blank of our engineering staff will call on you early next month, and we hope you will be free to discuss some of your current problems."

To the perhaps 15 percent of all U. S. oceanographers who spend anywhere from 10 to 15 percent of their time talking to Mr. Blank these days, this is one of the few tangible results of the spate of publicity which has been given to oceanography during recent years. Few among us had heard this gallant offer more than 2 years ago. We did hear its equivalent, however, usually from young physicists and engineers who were interested in ocean studies.

They usually put it this way: "Gee, what a crude way to measure temperature. There are modern techniques by which it can be done much better and much easier."

In those days it was not very hard to hire some of these people and to give them a few odds and ends to work with. Some of the more stubborn among them are still, fortunately, with us.

Yet, the reversing thermometer of 1880 vintage is still the one way to measure deep sea temperatures accurately. Why have we progressed so slowly? Why have only two or three oceanographic instruments come into general use since 1900? Why do we sometimes have doubts about the ability of these "well-qualified companies" to answer all our problems?

The answers lie in the ocean itself, its nature, the behavior of small ships on the surface, and the physiological reaction of man to this behavior. Quite a number of young fellows started out and decided the resistance thermometer could give precise temperature measurements, for example, and only stopped when they ran up against problems introduced by several miles of cable dangling in an ocean of nonuniform temperature, with perhaps part of the cable still sitting on deck, either warmed by a tropical sun or cooled by frozen spray.

Quite a number of electronic gadgets that work perfectly well in the laboratory turn out to be allergic to high humidity, fluctuating line voltage, vibration, and seasick operators.

The interest of U. S. Industry in our problems is really very heartening to all of us in the laboratories. We hope that some of the companies in instrumentation will learn of our problems and will come forward with solutions. We hope they will send their people out to sea to measure something from small, uncomfortable ships like the ones that are going to have to keep our program going for several years at least. This is about the only way to grasp the problem fully. Again, I repeat what other people have said: "There has to be an effort to keep things simple." Even those lucky ones among us who never get seasick operate at fractional efficiency after a few days of tossing in a ship.

The maintenance of electronic equipment, which might be dead simple ashore, can become absolutely impossible when the chassis refuse to stand still.

The man who studies the ocean proceeds very much like any other scientist. He takes the best reliable instruments that he can get his hands on, and he goes out and makes observations. When he begins to suspect that he knows what his subject is like, he makes the kinds of observations necessary to check his suspicions. Soon he finds he is working to the limit of the available instruments and he may be trying to modify them and get a little better performance. He begins to suspect that the measurement of something else may teach him more about the oceans. He devises some gadgets to do this. Perhaps the results fail to interest him at all and he abandons this tack completely. Perhaps it leads him into something more exciting than he ever imagined. Each new measurement is a speculation, and if one could be sure which measurements would pay off, the game would not really be worth playing.

Captain Hendrix's group prepared a document which has been circulated at this meeting laying out the requirements for a set of instruments for survey ships (appendix E). Captain Fusselman and Mr. Jaffe have both discussed parts of this set of instruments. These instruments are being asked to do the reasonably possible in light of what oceanographers know about the oceans and about instruments, and to measure the sort of things we are fairly sure we would like to measure.

If these instruments come into being, they would represent a marked advance over present capabilities; and if they should become available tomorrow, it would be perhaps several years before the researchers had caught up with them and learned anywhere close to all that they can get with these instruments.

We hope that American technology can do these things for us. If we sometimes appear pessimistic, it is because we have not yet seen a real try. We are still hoping to get the first-class, reliable, reversing thermometers, which were available some years back. We hoped for a long time that the bathythermograph would be improved to the point where we could get an instrument with a uniform rectilinear calibration. Right now, we would even be happy if we could get bathythermographs as good as the ones we had in 1945. We have been disappointed, but we still have faith that better days are ahead.

Many of you have had, or will have, dealings with the people in the research laboratories. Representatives of at least 20 percent of the companies here today have visited my own obscure and rather unprofitable office. In case you interpret this otherwise, I have enjoyed meeting you. But I wonder if you understand the people in the laboratories?

Most of us got into oceanography for the fun of it. Up until very recently there was little chance of any more concrete rewards. We in the laboratories either do not have funds to finance new developments, or, if we do, we are not used to doing it and do not know how to proceed.

We value freedom in our work, including freedom to try things that may not turn out well at all. Hence, we like to do a lot of our own instrumentation. Not all of the laboratories have good instrumentation sections; those that do, do not have all the good people that they should. This is improving, and, from where I sit, it looks as though we are learning to compete with Industry for talent.

Because you have become interested in us, we are beginning to learn a lot more than we did about available instrument components and more and more we are exploring the possibilities of meeting our instrumentation needs by assembling existing parts. You will have to excuse us, though, if we like to assemble our own prototypes. We often do not know enough about what we want to measure in order to write specifications. Often, we cannot wait out delivery delays in order to try out ideas that we suspect may turn out to be worthless.

One of the things that we like about oceanography is that there is surprisingly little jealousy in the oceanographic community. We in the laboratories compete with one another for the sponsor's dollars all right, but we exchange data, we exchange equipment, and we exchange ideas rather freely.

If you in Industry have good ideas, you will find the laboratories ready to help you check them out. If you have gadgets to test, we will take them to sea. All you will usually be asked for is a chance to see the data and the opportunity to buy your successful instruments.

I think it would probably be useless to try to outline the most pressing instrumentation requirements for physical and chemical oceanography from the point of the institutions. There would be no agreement between any two people on this, and our opinions change rather rapidly. Three of the things, though, about which there is rather general excitement in oceanography are: First, the certainty that in the very near future we are going to get synoptic data from reporting buoys; secondly, the apparent feasibility of instrumenting in-shore areas from towers for making microscale observations of the environment; and finally, the developing capability to measure certain variables continuously, both in the vertical and the horizontal dimension.

These are going to require cooperation from Industry. Once we decide exactly what we want to do, there is going to be the job of producing the equipment we require in quantity.

It was interesting to me yesterday to hear in the question and answer session a query about available funds. We at the institutions have been wondering, too, what all this publicity is leading to. We all have research schemes that are not being funded now. We hope this will change.

However, no matter what way we look at it, it is obvious that oceanography in this country has shown more signs of growth in the last 2 years than in the previous 20. I would think that both the oceanographers and the few companies that are going to end up building their tools have a promising future.

17. GEOLOGY AND GEOPHYSICS

Dr. J. Lamar Worzel

Lamont Geological Observatory
Columbia University
Palisades, New York

I would like to point out that, while these instruments I am about to describe are not very sophisticated, they work. We have a very limited space on research vessels for instrumentation, and we run up to 30 programs on one cruise. So, it is not possible to take all the space for any one instrument. Therefore, it is essential that the instruments be kept within reasonable sizes.

We have at least partially solved the question of reliability by having two of each instrument. This way we can usually keep one working. Navigation is one of our most difficult tasks. We are always on the last ships at sea to receive new navigational tools.

Figure 17.1 shows a DEEP SEA TRAWL WINCH (rather fundamental to the studies of geology and geophysics, at least of the more remote types near the bottom). This winch is not packaged very well. It had to be built piece by piece. We could not get money enough to build a whole winch at once. It started out as Dr. Piggot's winch in 1928, and has rather remarkable capabilities: It can pay out 3,000 fathoms of cable in 30 minutes; it measures the tension in the cable; and it is somewhat responsive to constant tension, but not completely. We had one winch which was completely responsive to constant tension. Before we could find out how to unhook the device, we lost three sets of instruments. Our present winch will recover 3,000 fathoms of cable in 90 minutes with a ton on the end of the line, and, of course, the weight of the wire as well. This particular one is capable of operating in 5,000 fathoms of water, which covers any of the trenches in this part of the world. Only those near Asia are deeper.

The PISTON CORING DEVICE (fig. 17.2) is of great use in geology. With it, samples up to 70 feet long of the sediment on the bottom of the ocean have been taken. We have now about 4,000 such samples in our laboratory taken with the winch shown in

FIGURE 17.1
DEEP SEA TRAWL WINCH

figure 17.1. Incidentally, the winch is rather reliable. It is just returning from a full year's cruise without a single breakdown. The thermoprobes on the side of this coring device are an innovation to measure the thermal gradient at the time of coring. Useful information can be obtained from this data and the thermal conductivity of a piece of this sediment can be measured later.

We need to extend to deeper layers to see what is under the 70-foot depth in the sediments. It is rather important. On the other hand, a rig as complicated and as expensive as that used in the Mohole Project will never give us much information about areal distribution. So we need something on the order of a drill that is capable of being carried on an oceanographic vessel, along with the equipment of the other 29 programs that must be carried out as well.

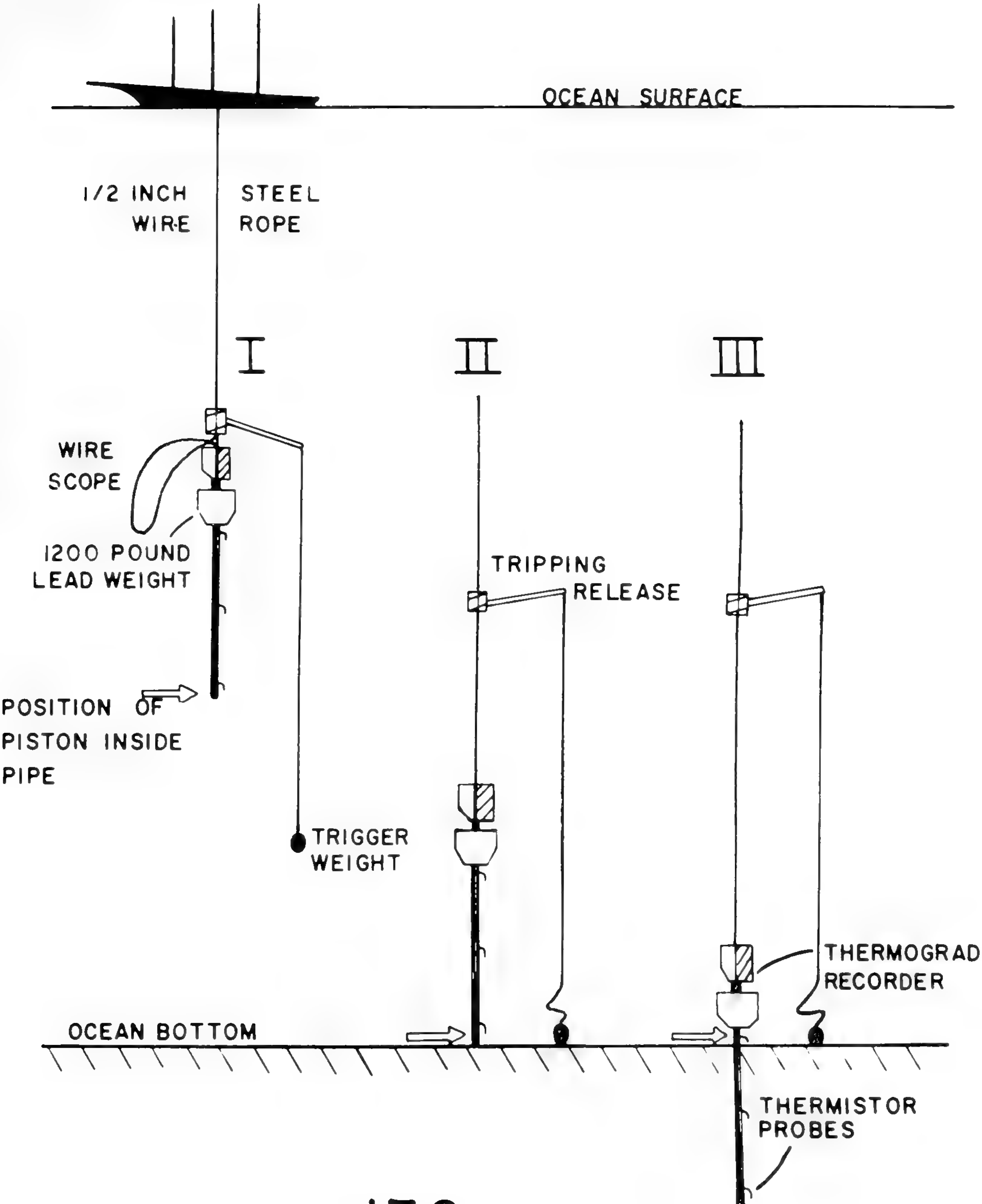


FIGURE 17.2
PISTON CORING DEVICE

FIGURE 17.3
UNDERWATER
CAMERA

The UNDERWATER CAMERA (fig. 17.3) has been extremely useful for guiding the use of dredges and similar instrumentation for recovering rocks. Rocks are not very readily available on the bottom of the ocean. A lot of sediment pours down from the rain of death in the ocean and covers everything pretty well, so it is necessary to search pretty hard to find some rocks. You do not just go around dredging at random. The underwater camera is very useful for this purpose. In the bottom is an electronic flash unit; near the top is the camera itself looking out a porthole; at the very top is a transducer which sends out a ping about every ten seconds as long as the camera is water-borne, and squeals continuously when the camera hits bottom to indicate that it is doing its job.

There are many forms of the OCEAN BOTTOM TRAWL of which figure 17.4 is one. These have to be rather rugged instruments. Many times we have to break the rocks off for they are not just lying around loose for the taking. They must be broken off from the walls. This is hard duty for the wires, winches, and trawls. The trawls have to be ruggedly made and relatively inexpensive so we can afford to lose them fairly often.

FIGURE 17.4
OCEAN BOTTOM
TRAWL

The PRECISION DEPTH RECORDER (fig. 17.5) is a fundamental geophysical tool. The recording and measurement of depths are controlling issues for nearly all of the other programs that go on at sea. With this particular one it is possible to measure to one fathom in 3,000. A narrow-beam vertically-pointing sounder is needed in addition to the broad-beam sounders that are prevalent today. Both are necessary, and each has its own uses.

Figure 17.6 illustrates a rather old MAGNETOMETER. New ones are about a third or a quarter of this size. They are used for measuring the total magnetic field. It would be desirable to be able to include the measurement of declination and variation, although this has not been done yet. Recently our friends in Cambridge have demonstrated that the stationary type of magnetometer is very important in the oceans in that the magnetic field variations with time at sea are not very similar to what they are on the nearby land. The corrections we have been applying are not very reliable.

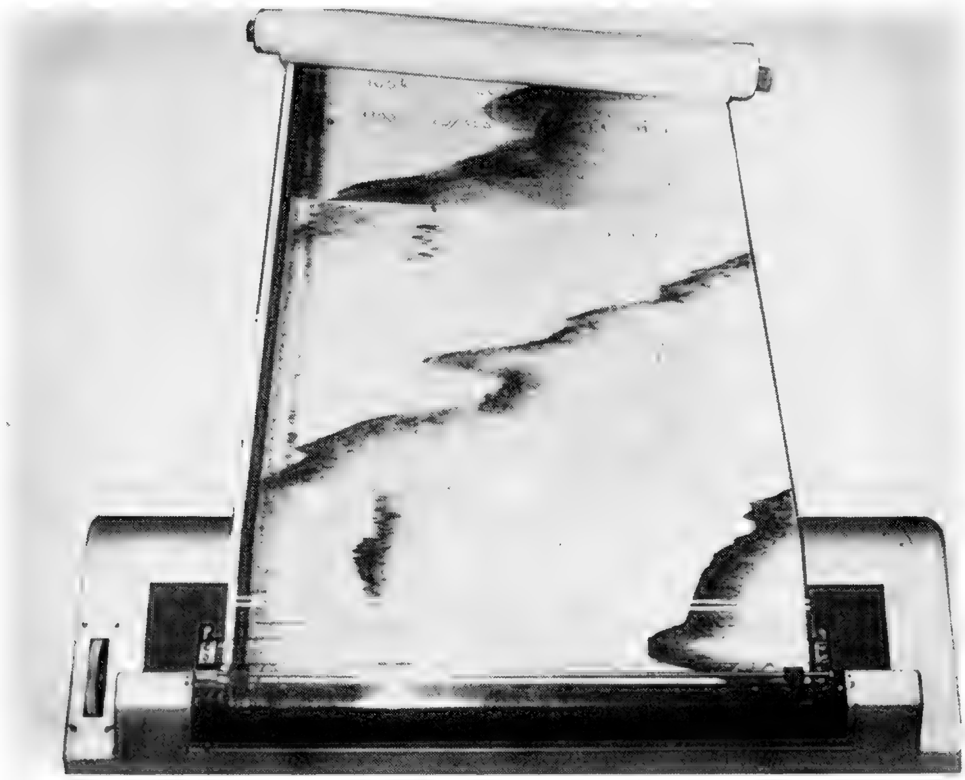


FIGURE 17.5
PRECISION DEPTH RECORDER

FIGURE 17.6
MAGNETOMETER

Some GRAVITY METERS (fig. 17.7) used at sea are mounted on stabilized platforms. The platform is stabilized to within about one minute of the vertical. With it, we are able to measure gravity to about plus or minus 5 milligals. We could do better than this if we had better navigation.

The navigation is the fundamental obstacle to better accuracy. Eötvos' correction is required by the change in centrifugal acceleration due to the east-west component of ship's speed. This amounts to 7-1/2 milligals per knot of ship's speed in east-west directions at the Equator. If the direction and the speed are not known accurately, it is hard to make the correction. The gravity meter is just one of many, many uses for a stable platform on a ship. I am sure when we get the narrow-beam sounders, we will need to stabilize the heads, which may be done by simply telemetering the information from the stable platform of the gravity meter.

It might be much more sensible to do this than to add additional stable platforms, which require considerable space and upkeep.

The DATA GENERATOR (fig. 17.8) is continuously in use on our ship. It puts data on depth, magnetics, gravity, course, mileage, and time on the record simultaneously. This combination makes all the data much more useful and gives the scientist on board a chance to utilize the coordinated information immediately.

One of the most fundamental geophysical measurements made at sea is that for SEISMIC REFRACTION. Figure 17.9 shows the method of marine measurements in less than 600 feet of water. We fire charges of half a pound to 300 pounds, in ranges of zero to 60 miles apart. From the timing of the return of the sound waves through the water and through the sediments, we are able to determine the sound velocity in the sediments and the layer thicknesses. These have rather striking variations in the ocean and are upsetting the geology books, which had all problems pretty well solved until we started finding out what occurs at sea. In general, the frequencies examined in the ground waves are between about 6 and 50 c.p.s. In the water they vary between about

FIGURE 17.7
GRAVITY METER

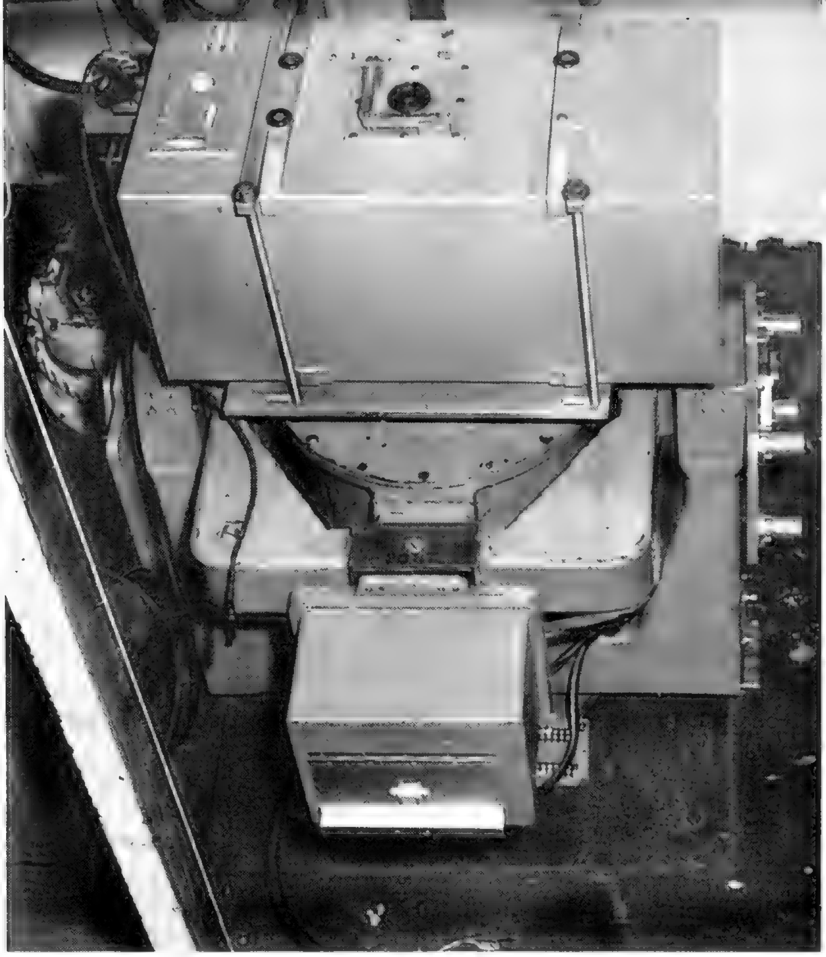
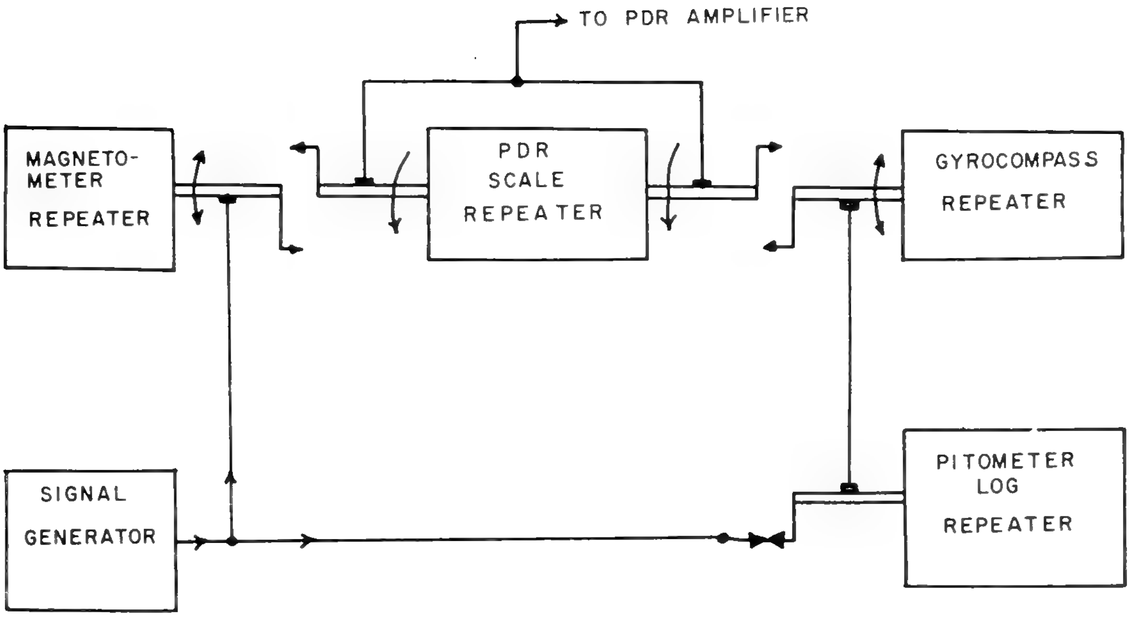


FIGURE 17.8
DATA GENERATOR



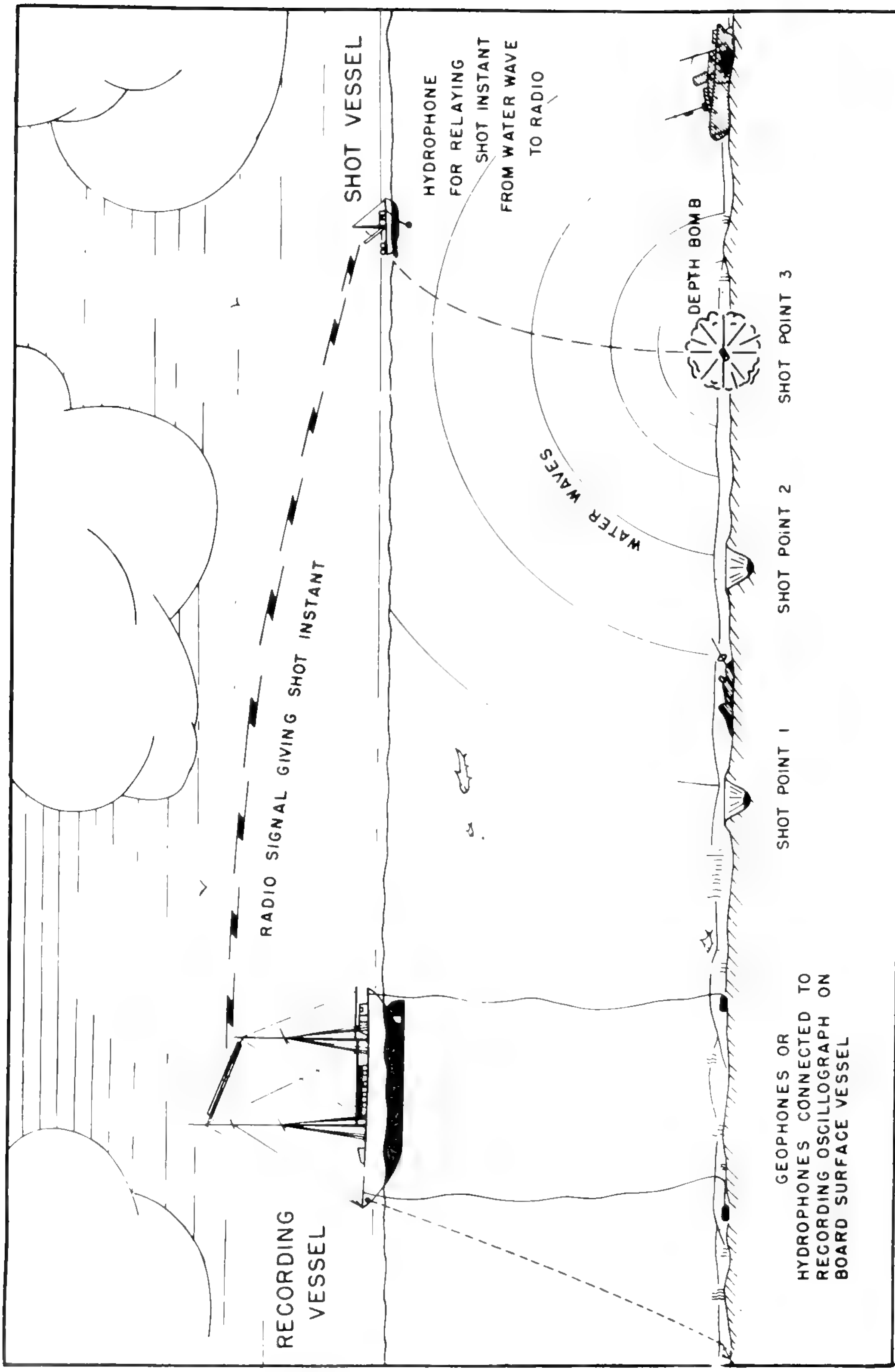


FIGURE 17.9

SEISMIC REFRACTION

Method of making seismic measurements in shallow water (less than 600 ft. deep)

Another seismic method which has become more commonplace is the REFLECTION TECHNIQUE (fig. 17.10). This gives considerably less information than the seismic refraction technique in that it does not indicate the velocity in the sediments. You only learn of the reflection time to the various horizons. This, however, is very useful for some particular cases, as will be shown later.

Figure 17.11 shows a record made with a sparker sound source. This is just the sound of an electrical spark under water, recorded from a hydrophone towed from the ship. Two gains are shown: the top is a low gain; the bottom is a high gain. Several of the layers in the bottom are visible and show some of the complex geology at the continental margin off New York. There are various types of sound sources being used for this, and I expect there will be many more. About every six months a new one comes along that enables us to do much more than the last one.

Figure 17.12 is a vertical reflection profile made with half-pound shots fired at 2-minute intervals across the PUERTO RICO TRENCH. I would particularly like to call your attention to (1) the abyssal plane part, and to (2) the many reflection horizons. The rock surface comes down rather abruptly (3), comes up in a pinnacle in the middle (4), down again (5), and up along the side (6). You see there are about 20 reflection horizons (7). There are about four kilometers of sediments (8), about a half a kilometer (9), and about a kilometer and a half (10), on the different parts of the trench.

These are the types of sections that we have been getting recently. Our vessel the Vema has made about 30,000 miles of such geological sections which are rather startling, even to us who have been startled very often by what the sea tells us.

Besides the explosive sources and the spark sources, a noise source known as the thumper, which is an aluminum plate caused to jump away by the eddy currents in it, an oxyacetylene gas chamber, which is exploded by a spark, and, more recently, a compressed air gun have been used. Each one of these has a little bit more energy than the previous one and allows us to see the ocean sediments in a little more detail.

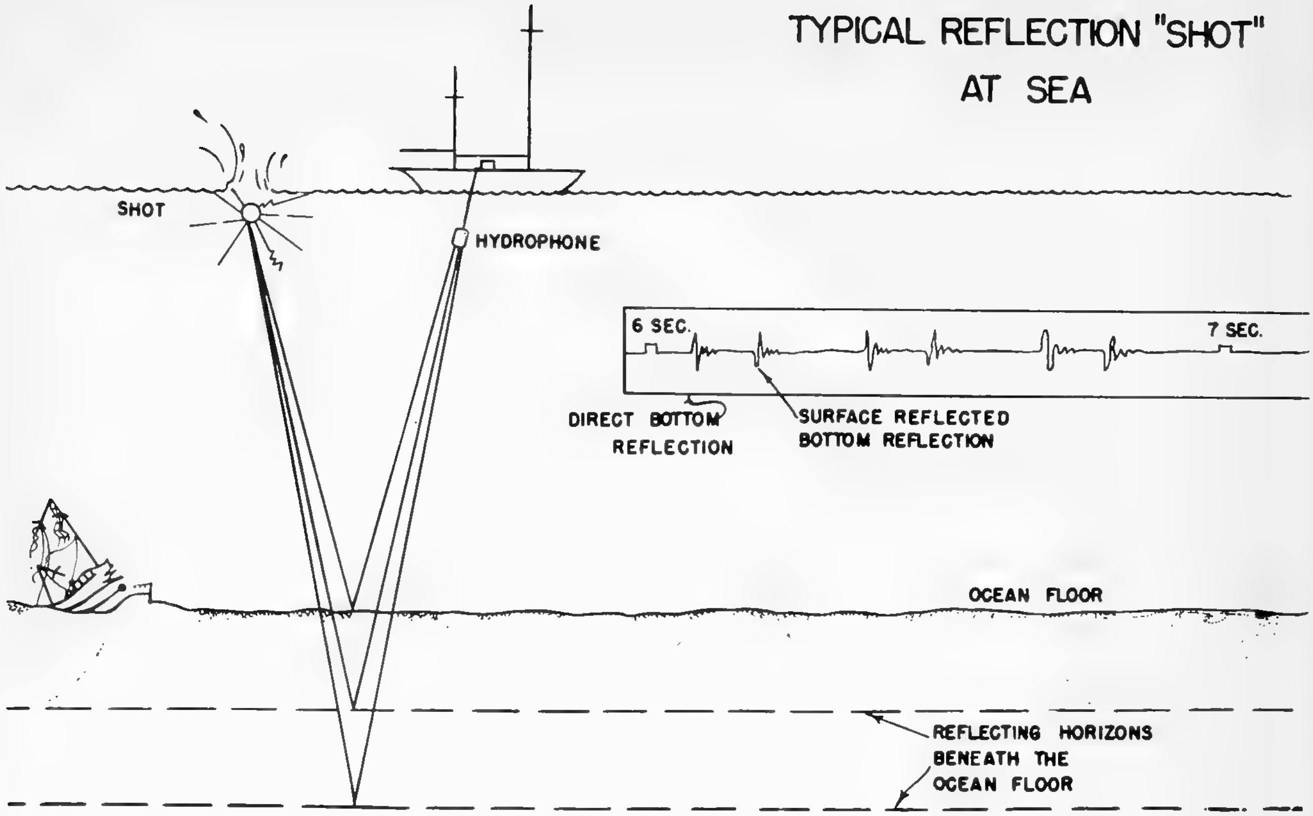
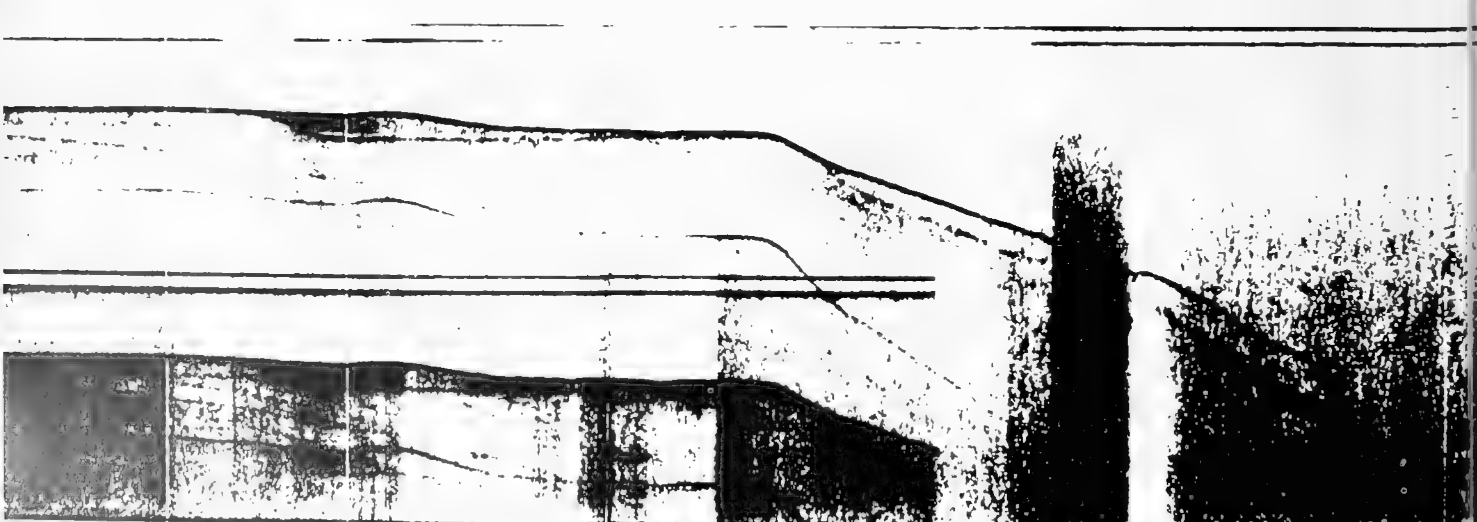


FIGURE 17.10
REFLECTION TECHNIQUE

FIGURE 17.11
SPARKER RECORD



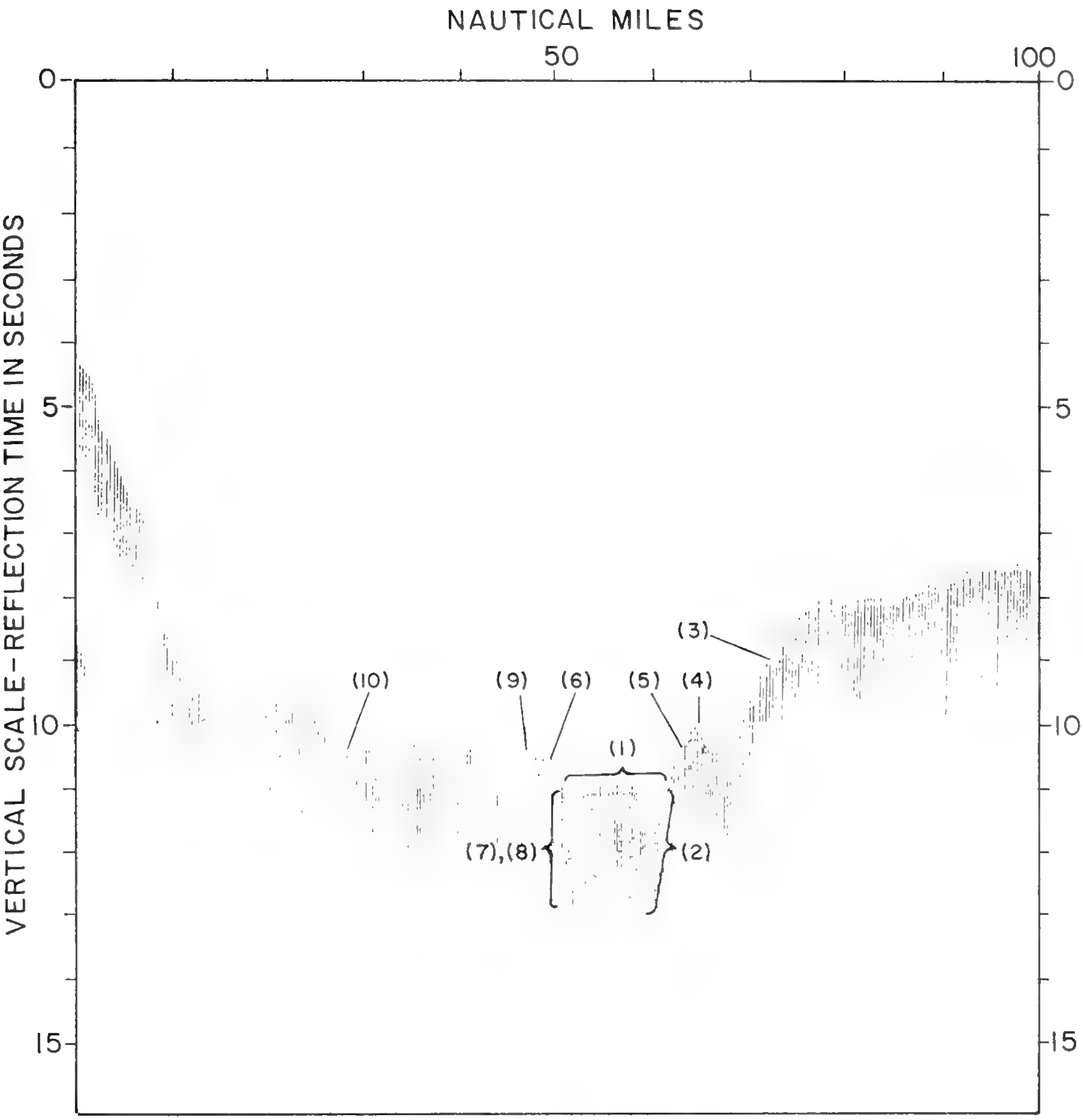


FIGURE 17.12
PUERTO RICO TRENCH

An OCEAN BOTTOM SEISMOGRAPH, one of our latest instruments, is a throw away unit (fig. 17.13). It is quite a largesse to throw away this much equipment. On the bottom there is a detector, some amplifiers, etc. Then the signal is put on the transducer and telemetered to the surface by frequency modulation on a 12 kc. carrier. This is analyzed at the surface and recorded on magnetic tape and also on a pen recorder so we can see what we are getting immediately. These instruments also bring in rather startling results. We have shot refraction profiles out about three times as far as we can for surface refraction measurements. We have seen some things in earthquakes that we have never seen on land. We have not had very many of these working very long, so we expect many other surprises when we get to use them more extensively.

It is necessary that these be extended to other frequency ranges, and it is necessary that some form of recovery technique be devised so that these instruments do not have to be thrown away. As instrumentation gets more complex, it will become harder and harder to tear yourself away from it.

In addition to the gravity measurements (mentioned on p. 184), many others can be made from a stable platform. Three-component accelerometers are kept in position relative to the vertical reference. A great deal is being learned about ship motions from such records. I suspect that we might do quite a lot better for ship's navigation if we just tied the master's sextant to our stable platform and brought it up on deck and let them look at the stars without having to see the horizon; but we at Lamont have not tried this yet. This would be, of course, a stop-gap type of measure.

Figure 17.14 shows the ray diagrams for a sofar shot. This is an explosion made 700 fathoms deep in the Atlantic, and about 400 in the Pacific. The ocean acts like a speaking tube. The sound is relegated to within the body of water in the ocean, and we have heard sounds from a 50-pound explosion as far as 14,000 miles away, half way around the world by this method. It is useful in many ways. It can be used as a navigational scheme. To date, its accuracy has not been adequately tested. It is possible to use it to locate life rafts at sea. It is a quick method of surveying for higher parts of the topography and has been so used,etc.

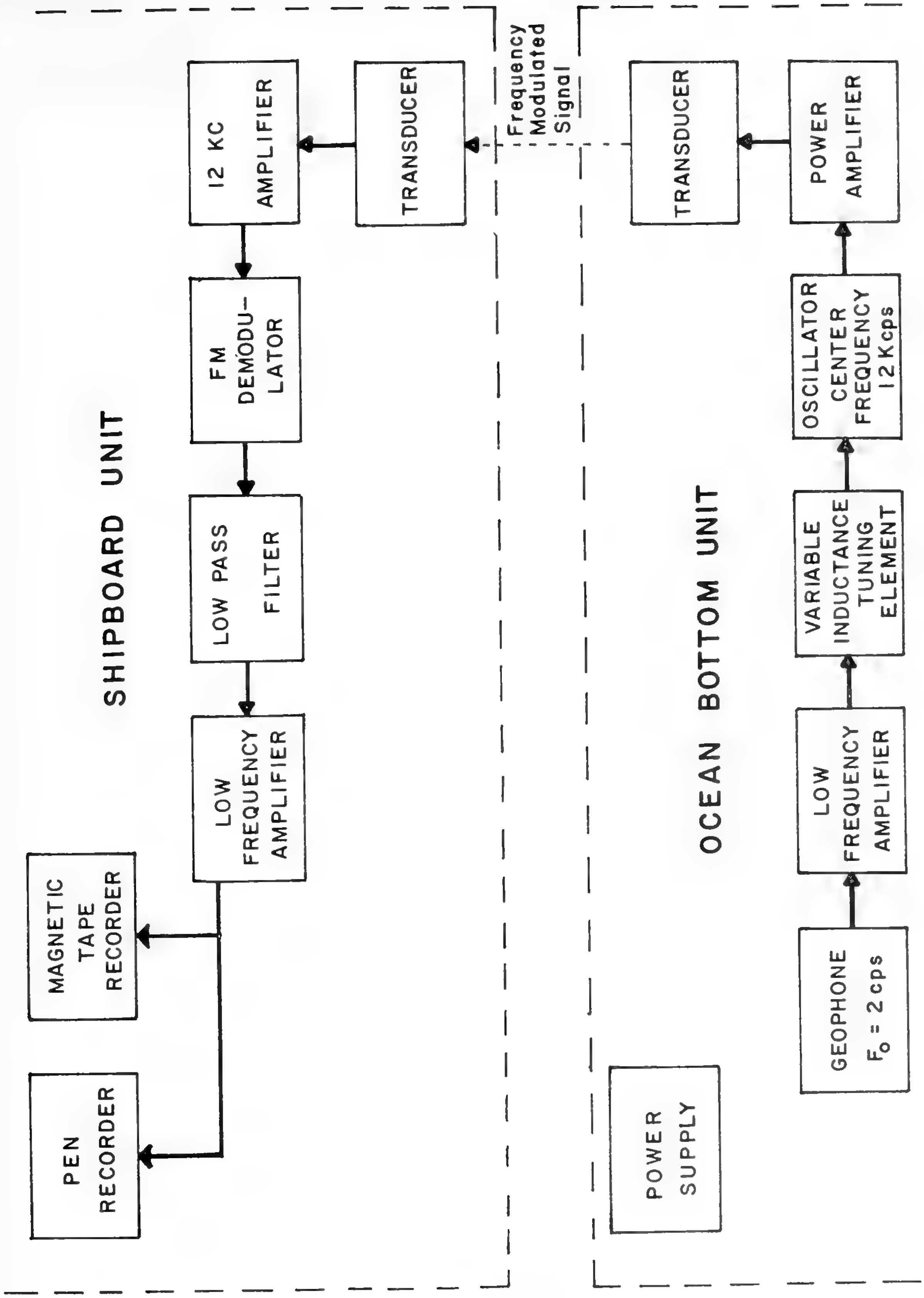


FIGURE 17.13
OCEAN BOTTOM SEISMOGRAPH

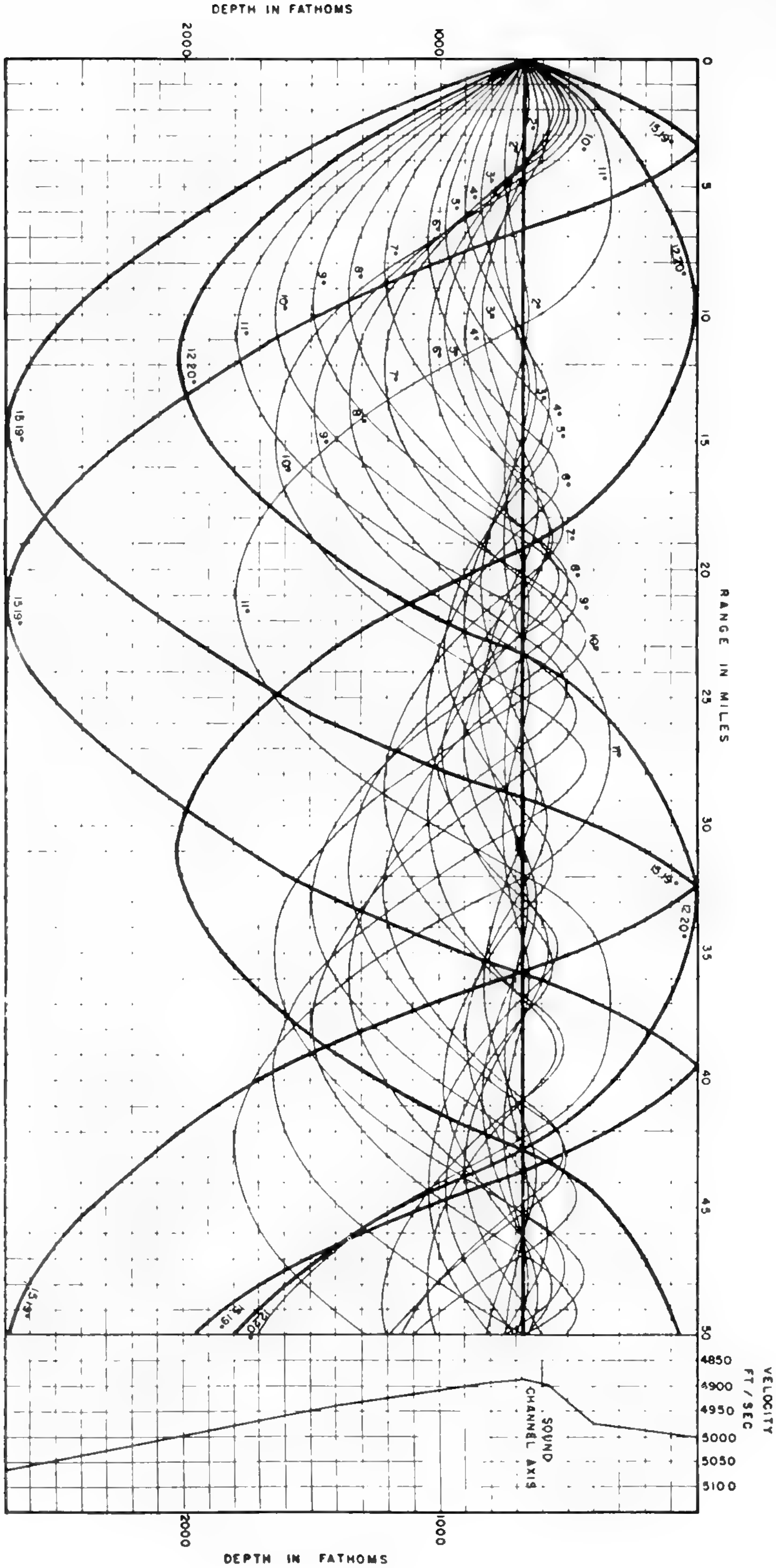


FIGURE **17.14**
RAY PATHS IN DEEP-SEA SOUND CHANNEL

Ray diagram for a source located at the axis of a typical Atlantic Ocean sound channel.

There are several ways of building THE ACOUSTIC POSITION KEEPER (fig. 17.15). One is a unit that squeals intermittently until the batteries run down. Another type answers when queried by the anticipated signal. With a single one of these, it is possible for a ship to maintain its position at sea to within about 1 mile in 3 miles of water. If three of these are used in an appropriate technique, the position can be kept accurately to within several feet. What we need to improve this kind of work are better sources, better transponders, and, above all, longer-lived batteries. The nuclear batteries are, of course, the most promising. Corner reflectors can possibly be used for this purpose with great economy but have not been tried.

The THERMAL PROBE (fig. 17.16) was used for measuring the heat flow out of the bottom sediments. From the cores, of course, we can measure the heat conductivity of the sediment.

A LARGE-VOLUME WATER SAMPLER (fig. 17.17) is needed for some types of radioactivity dating techniques, such as, those using carbon-14 and strontium-90. Other programs could utilize it also.

This is usually done in conjunction with a coring operation so that we take a core, measure thermal gradient, and take a deep water sample simultaneously. This sort of doubling up or tripling up, if you will, is necessary in order to increase the efficiency of operation of the research vessels which are rather expensive.

Another problem is the measurement of the SOUND VELOCITIES IN SEDIMENTS right at the bottom of the ocean from places where core samples have been taken. If we can get longer cores, this will become more and more important. There is good evidence that rather peculiar velocity variations occur in the bottom, or near the bottom (fig. 17.18), and that these may have a much more fundamental concern to underwater sound than anybody has given them credit for to date.

Additional geophysical measurements will obviously be made. It is necessary to make deep ocean tide meters and probably a bottom instrument like the seismograph will be developed for this purpose. Current meters mounted on floats for use in the deep ocean have already approached this principle. There are other methods.

We need deep-water sound sources of all kinds. Noise monitoring at the bottom will be done. A particular need is a cheap sound source that will have considerable energy, such as, an explosive charge, and that will make a sound when it hits bottom. There are very many uses for this kind of a device.

The most urgently required item is a system for making a low frequency sound -- 20 to 400 cycles -- at frequent intervals -- at least each 2 minutes -- of an intensity equivalent to one half pound of TNT, that is safe to operate and does not require too large an energy source.

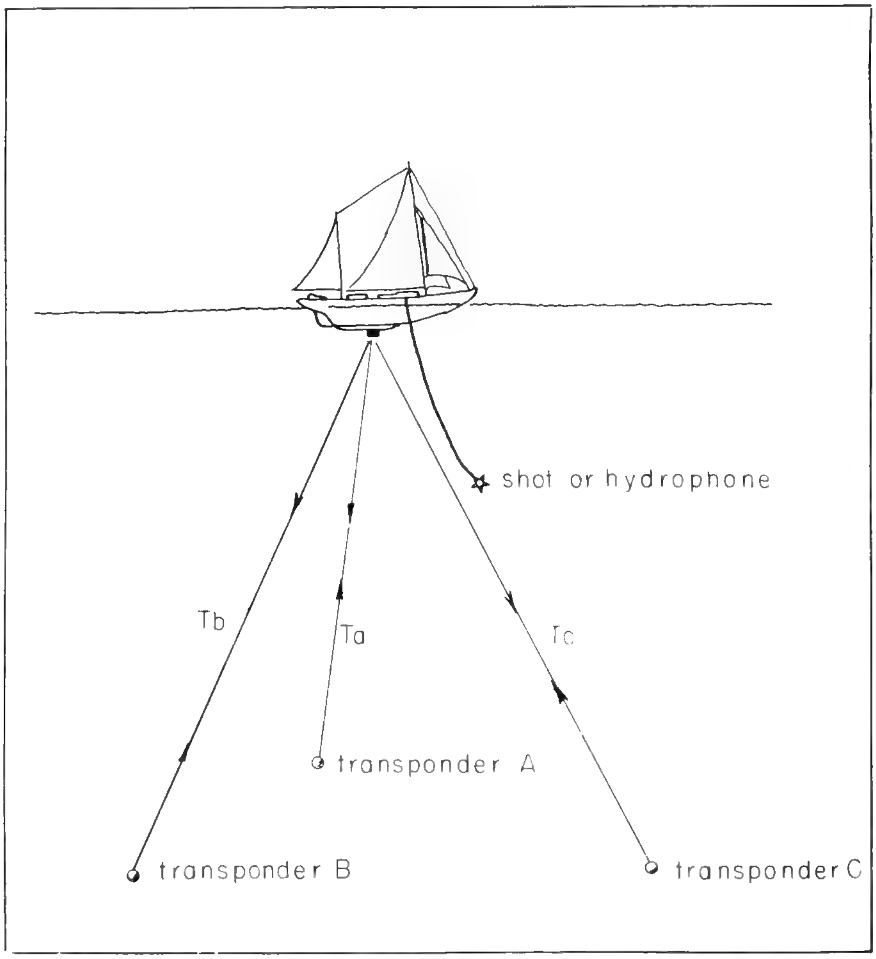


FIGURE 17.15
ACOUSTIC POSITION KEEPER

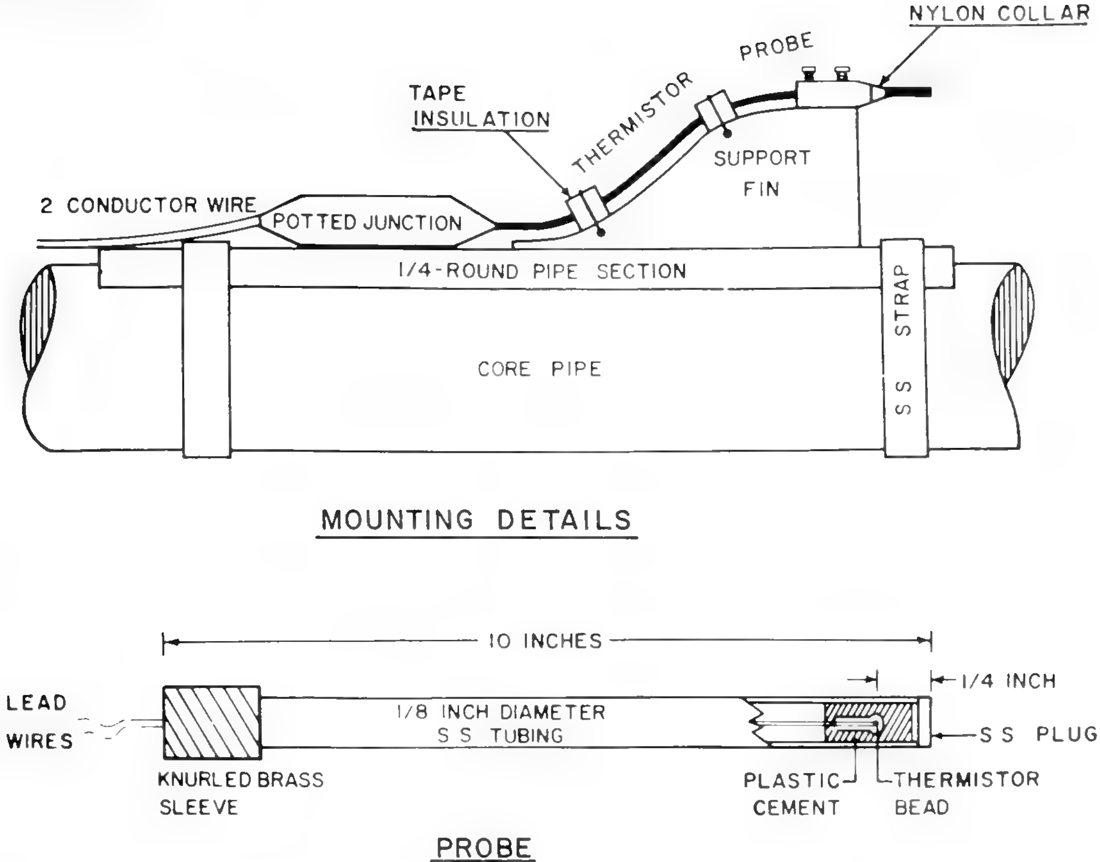


FIGURE 17.16
THERMAL PROBE

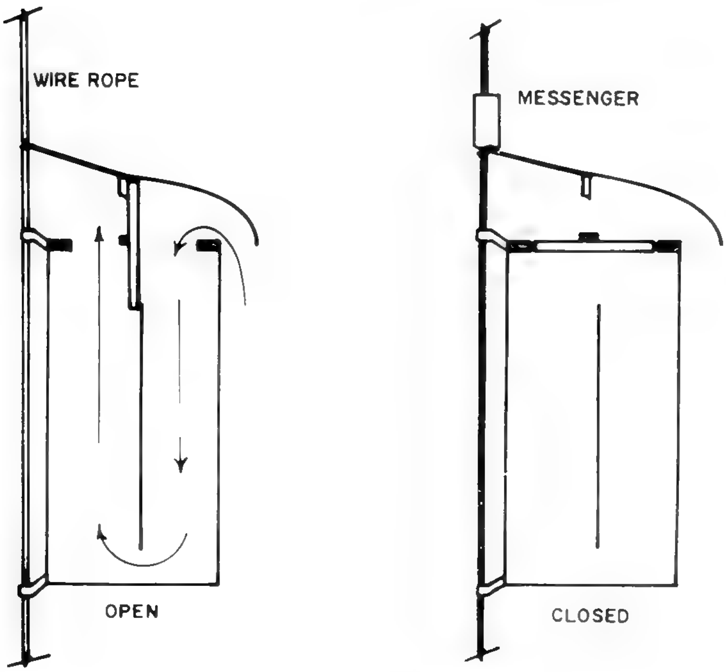


FIGURE 17.17
LARGE-VOLUME
WATER SAMPLER

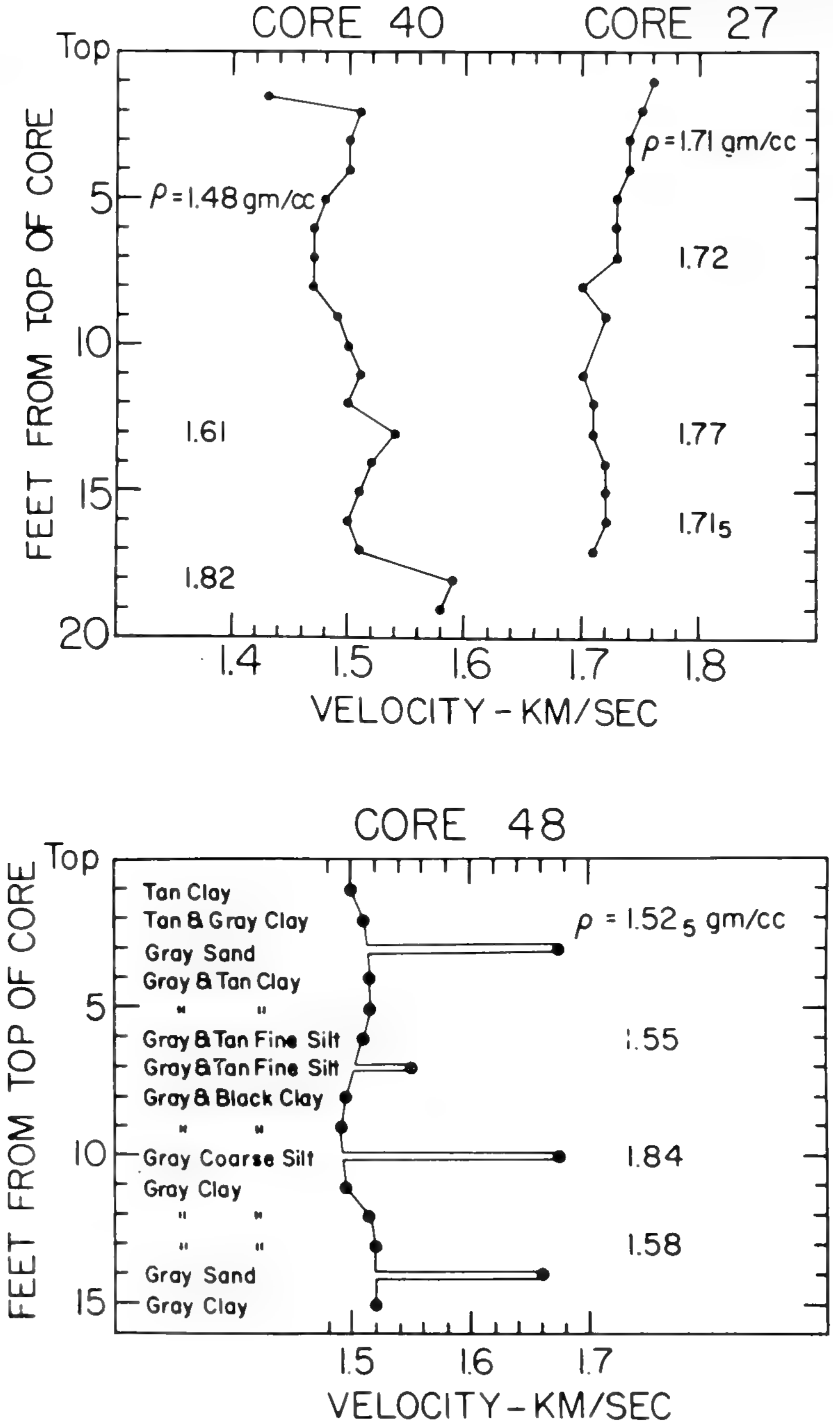


FIGURE **17.18**
SOUND VELOCITIES IN SEDIMENTS

18. BIOLOGICAL INSTRUMENTATION

Charles S. Yentsch

Woods Hole Oceanographic Institution
Woods Hole, Massachusetts

In the short time that I have this afternoon I cannot possibly describe all existing problems of sampling in the field of biological oceanography. Any attempt to do so would only result in worthless overgeneralization. Therefore, I shall confine my discussion to a major field in biological oceanography, the study of plankton, and discuss some of the sampling problems associated with it.

"Plankton" is an aggregation of plant and animal organisms which is moved about by ocean currents. Plant plankton is phytoplankton and the animal, zooplankton. In open oceans these organisms make up the bulk of living matter and are responsible for many of the chemical, physical, and biological changes in the sea.

Figure 18.1 is a microphotograph of a collection of PHYTOPLANKTON. Notice the great diversity in the shapes of these organisms as well as their size. Most of these are diatoms, one-celled plants which contain chloroplastic pigments and are capable of photosynthesis. The cell-wall material in these organisms is silica and the organisms may be found as solitary cells or in long chains as shown. In the open ocean these organisms are responsible for the initial production of organic matter. Through their activities, inorganic matter changes to organic in the presence of light. Figure 18.2 is a microphotograph of ZOOPLANKTON. Notice the bizarre shapes of these organisms and the wide diversity of size. Much zooplankton is made up of "primary herbivores"; these organisms graze on the phytoplankton and thus provide the second step in the transfer of organic matter in the food chain. Not all species of zooplankton remain such for their entire life histories. For instance, the organism with the big eye and spine in the center of the lower photograph (fig. 18.2) is a zoeal stage of a crab. It will eventually develop into an adult similar to the well-known coastal blue crab. Examples of species which remain as plankton throughout life are illustrated by the shrimp-like forms in the

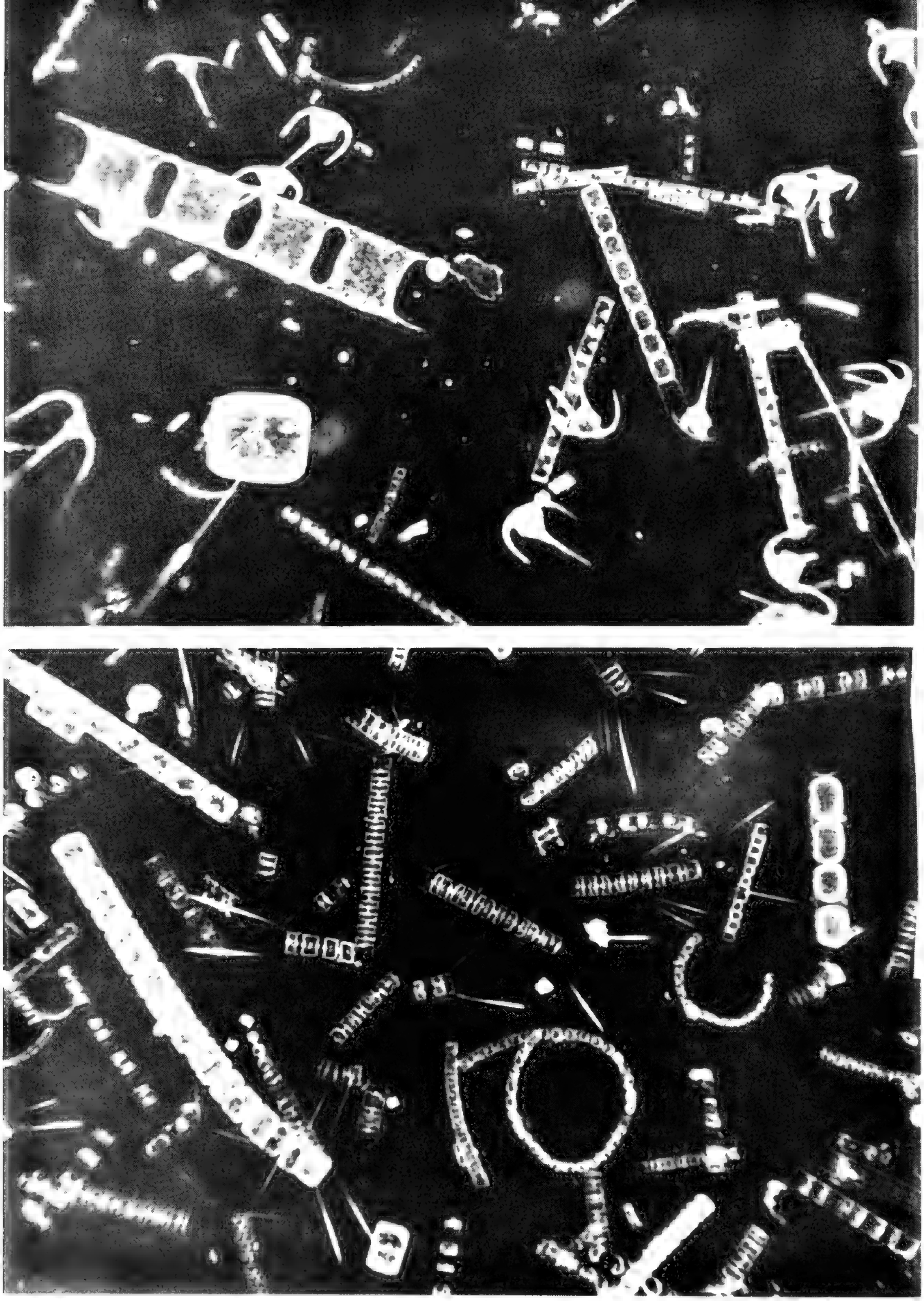


FIGURE 18.1
PHYTOPLANKTON
Magnified 110 times (from Hardy 1956)

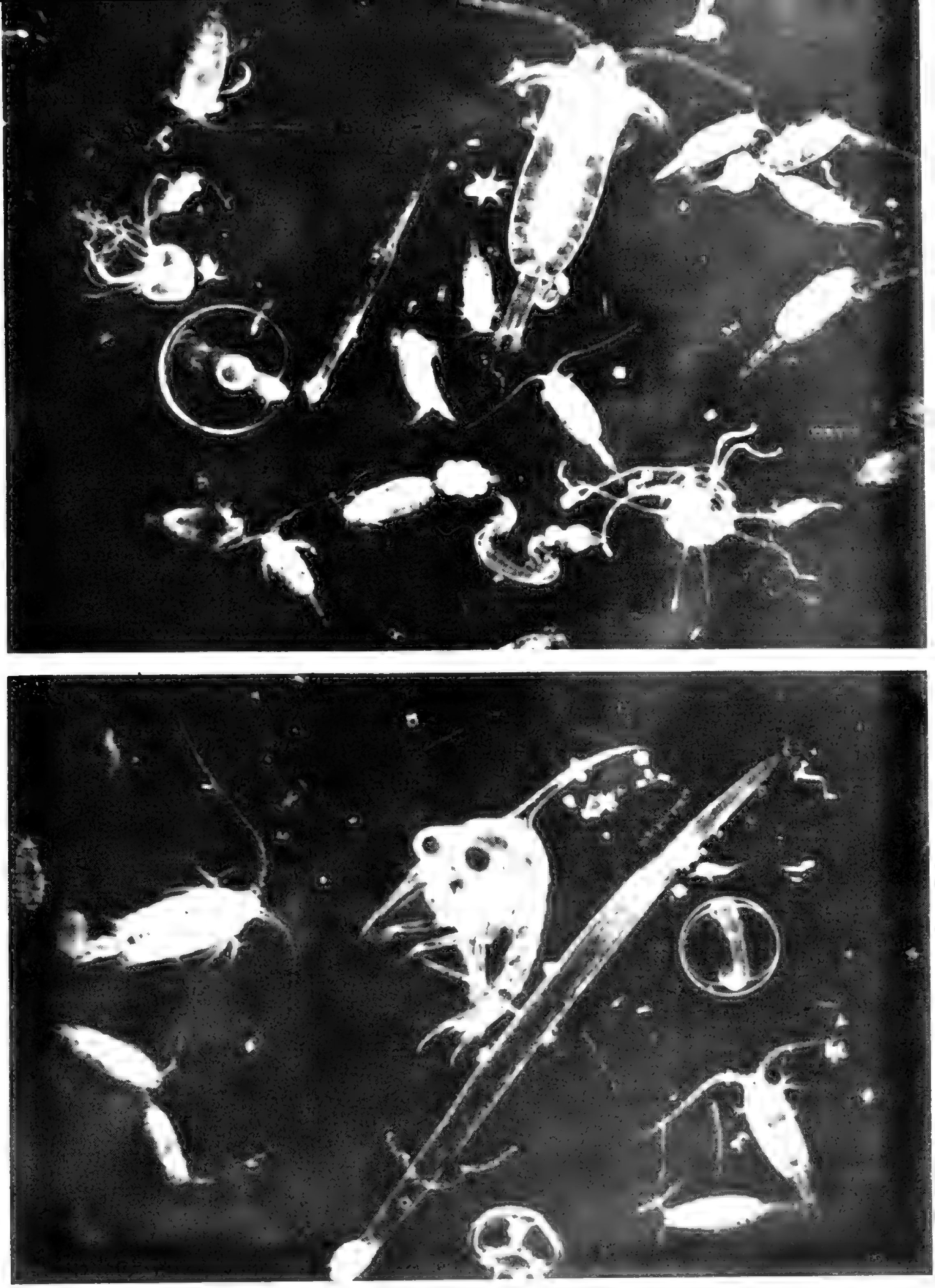


FIGURE 18.2
ZOOPLANKTON
Magnified 16 times (from Hardy 1956)

photograph. These are copepods and are probably the most important group of the zooplankton. Another permanent species is the cylindrical, tube-like worm known as the arrow worm, seen in the lower portion of the photograph.

To be a bit more specific about the sizes of these organisms, the cell diameter of the phytoplankton ranges from approximately 5 μ up to 100 μ. In some cases, the overall length of a colony of chain-forming diatoms may exceed 100 μ. The zooplankton are considerably larger. Their sizes range from approximately 10 μ to 10 mm. Hence, there is considerable overlap in size between the zooplankton and phytoplankton. The maximal size of zooplankton is difficult to ascertain since some individuals grow from forms which are passively moved by ocean currents to those which are freeswimming organisms.

These pictures may give a wrong impression with regard to the abundance of organisms in the oceans. They are photographs of concentrates of organisms and do not represent the natural abundance. The concentration of phytoplankton cells in the open ocean ranges from 1 to 10 per milliliter of water, while individual zooplankton organisms are found in numbers of 1 to 10 per liter of water.

Therefore, whether the initial problem in the study of plankton be taxonomic, chemical, or physiological, the concentration of the organisms is almost always a necessary step in their collection. This step is frequently the most difficult one to overcome in the instrumentation of this field. Principally two methods of concentration have been used. These are centrifugation and filtration. Of these, the latter has found most wide use. For example, phytoplankton biologists frequently measure chlorophyll by filtering 4 to 6 liters of water through a membrane filter with a pore size of approximately 1 μ. Collection of water in this quantity is not easy, and, in practice, it is presently accomplished by using what is now termed a MODIFIED VAN DORN WATER SAMPLER (fig. 18.3). In addition to having a large water capacity, such a sampler must be non-toxic; the sampler shown in the figure contains no metal, being composed entirely of polyvinyl chloride with the exception of the two plumber's-helper valves (pure gum rubber). The tension between the valves is applied by gum-rubber tubing, and the valves are kept in an open position by two connected chains

FIGURE 18.3
MODIFIED
VAN DORN
WATER
SAMPLER

retained in slots slightly below my right hand in the picture. A number of these bottles may be attached to the wire and tripped by messengers. Routinely, 4 to 5 samples are filtered at a time in the shipboard laboratory. After the samples are filtered they may be: (1) used for pigment analysis, (2) measured to determine their dry weight or some other biochemical parameter, (3) examined by special microtechniques, or (4) identified and individually counted on the filter.

In connection with studies of phytoplankton, biological oceanographers are generally interested in light penetration. The SUBMARINE PHOTOMETER (fig. 18.4) is a Weston photoelectric cell enclosed in a watertight housing which is lowered on a two-conductor cable. The amount of light detected by the Weston cell is read on a microammeter. Such a unit has many advantages with regard to simplicity. However, it is becoming increasingly apparent that we need better measurements which may be interpreted directly as energy. We have considered using pyrheliometers with special watertight housings; however, further improvements are desperately needed to give the necessary accuracy and sensitivity required for studies of photosynthesis in the oceans.

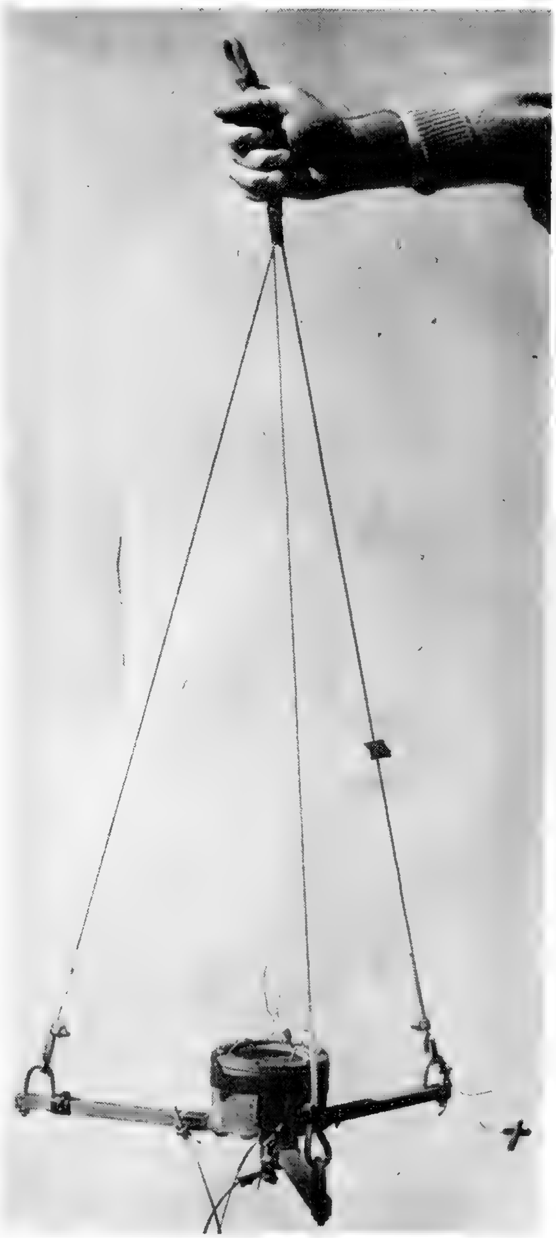


FIGURE 18.4
SUBMARINE
PHOTOMETER

As the mean size of the zooplankter is larger than the phytoplankter, coarser filters may be used. The THREE-QUARTER METER (diameter) QUANTITATIVE PLANKTON NET is essentially a cone of nylon netting with a mesh size of 0.16 mm. (fig. 18.5). It is possible to purchase material with mesh diameter ranging from 1.3 mm. down to 0.064 mm. The net shown is equipped with a flow meter to record the amount of water passing through as it is towed. From the data obtained and the catch, the density of the plankton in the area may be computed in terms of numbers per unit volume of sea water. Such nets are towed at approximately 2 to 4 knots and some 200 to 300 cubic meters of water are filtered. In an open ocean area we get approximately 10 to 20 ml. of packed volume of plankton from such a haul. Nets may be used for towing at higher velocities, but the intake opening must be much smaller than the filtering area (fig. 18.6). The intake of this HIGH SPEED PLANKTON SAMPLER is approximately 1 inch, and the appropriate filtering area is much larger. This net is towed at 7 to 10 knots with a small depressor.

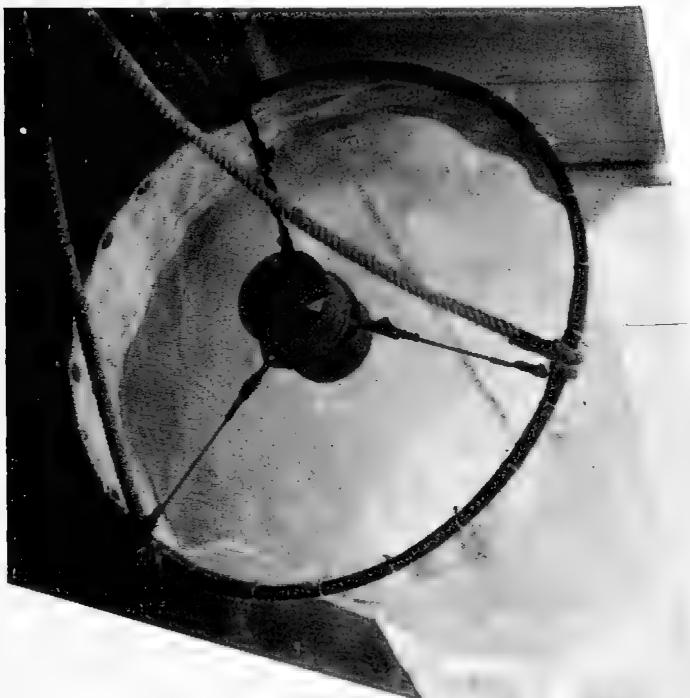


FIGURE 18.5
THREE-QUARTER METER QUANTITATIVE PLANKTON NET

FIGURE 18.6
HIGH SPEED PLANKTON SAMPLER

"Fire nozzle" type

In many cases there is now a need to bring the organisms back to the laboratory alive. This has been done successfully at our laboratory by removing the organisms from the plankton catch and placing them into small plastic containers and into a refrigerated box. Such a procedure is highly satisfactory for surface catches of zooplankton; organisms have been kept for 2- to 3-month periods. There is little chance that the deepwater plankton, however, can survive the ascent of the net from deep, cold water through the warm surface layers of temperate and tropical waters. The severe thermal shock is so great using our present techniques that we are denied access to these animals for careful physiological or biochemical studies.

I have reviewed generally the nature of the collecting techniques used in plankton biology; now I will be more specific with regard to the instrumentation for obtaining the larger zooplankton from various depths throughout the water column. Our present

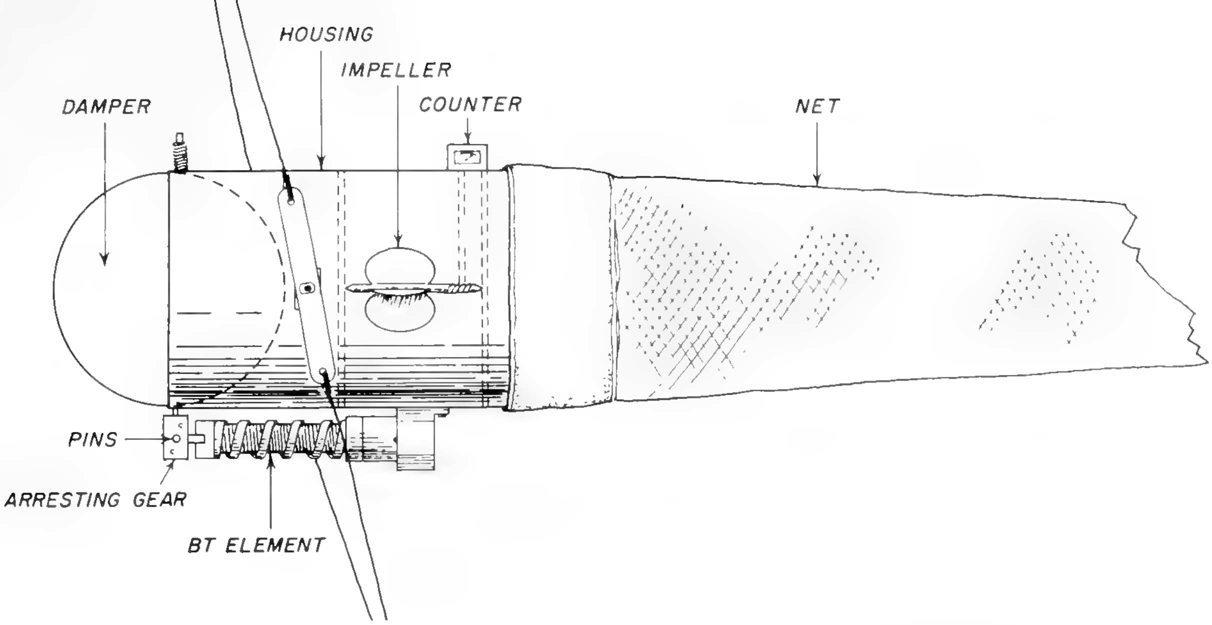


FIGURE 18.7
PRESSURE-OPERATED
PLANKTON NET

understanding of the vertical distribution of plankton is hampered by not being able to sample at specific depths. Various methods of closing the net have been proposed and some of them have been moderately successful. However, in the long run, all of them have been shown to have some basic inadequacy. Pumping water from depths is not entirely satisfactory largely because some planktonic animals can avoid the existing pumps. At our laboratory we have considered designing sampling devices which can be actuated at depth by either pressure, electrical, or mechanical action. An example of a PRESSURE-OPERATED PLANKTON NET (fig. 18.7) has a pressure mechanism for opening and closing a plankton sampler using a spring-loaded damper actuated by the pressure element from a conventional 900-foot bathythermograph. The sampler fishes between depth intervals preselected by inserting pins of different lengths into the arresting gear. The first pin governs the point at which the sampler will open as the BT element is compressed by the water pressure. The sampler remains open until further pressure releases the second and longer pin. Larger plankton nets are not as easily opened and shut, one of the means that we have considered is to use so-called strangle lines which are successive attachments to the net for pursing it off. Pressure pistons can be used to sever the strangle attachments.

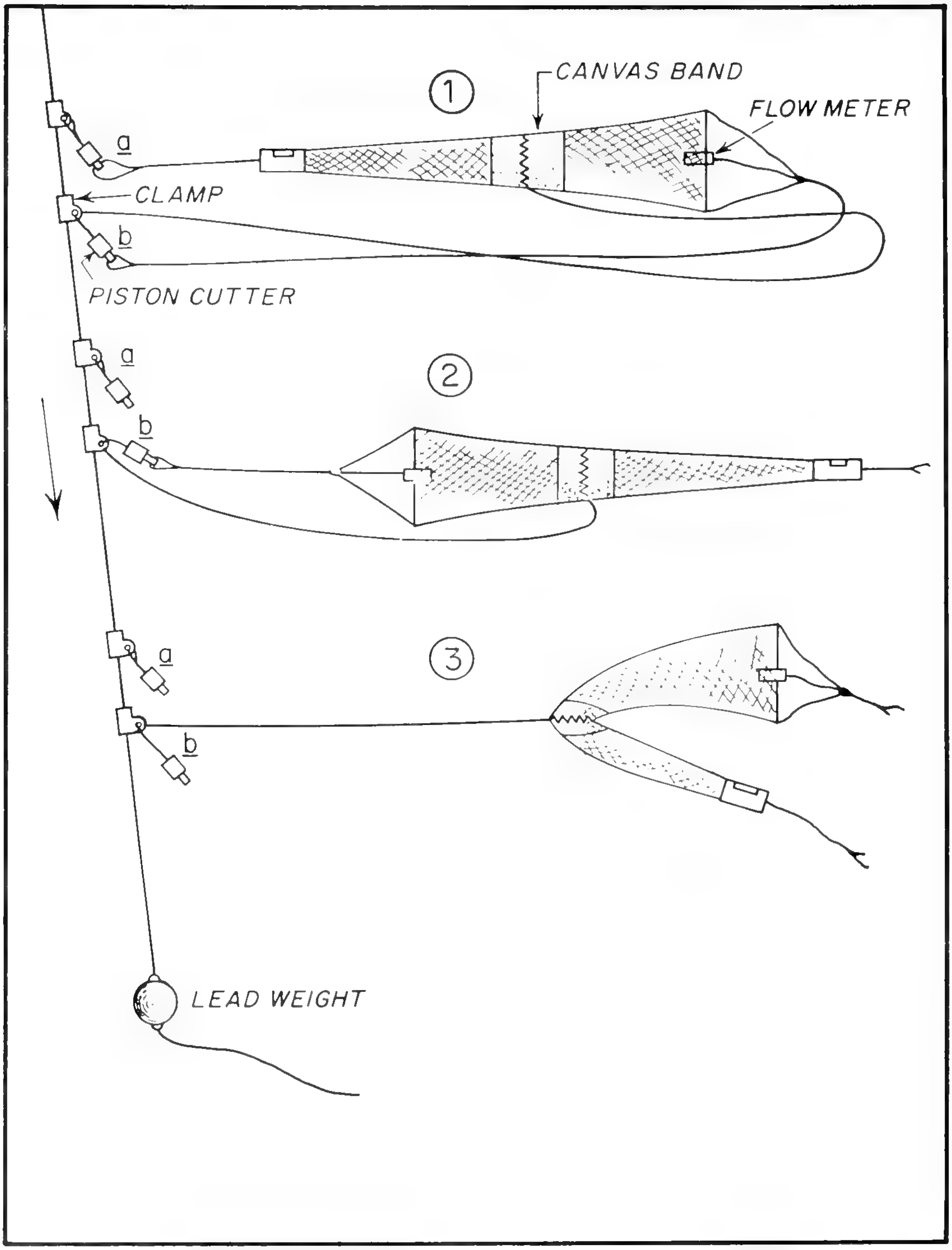


FIGURE 18.8
MIDWATER NET RELEASE SYSTEM

One device, a MIDWATER NET RELEASE SYSTEM, uses two pressure pistons (fig. 18.8). The first (a) compresses and cuts the cod end release which allows the net to filter the water under tow (2); the second piston (b) compresses at a greater depth and severs the frontal towing bridle and the net is pursed off midway (3). The selection of depths is accomplished by inserting rods of various diameters in a secondary hole in the cylinder to arrest the piston.

In looking for devices to aid in our understanding of the distribution of plankton in midwaters let us consider the use of well-logging or conducting cable. Such a cable would provide a means of monitoring depth. This may be easily done by using a PRESSURE POTENTIOMETER (fig. 18.9). Three conductors are used for the operation of the potentiometer, the outer cable armor being the third wire and the ground. The signal from the potentiometer is taken from the wire via the winch-drum axle and a slipring brush contact at the end of the axle. Batteries are maintained topside and depth can be conveniently read in microamperes from a meter. Since the wire has little electrical resistance, pressure is a linear function of current.

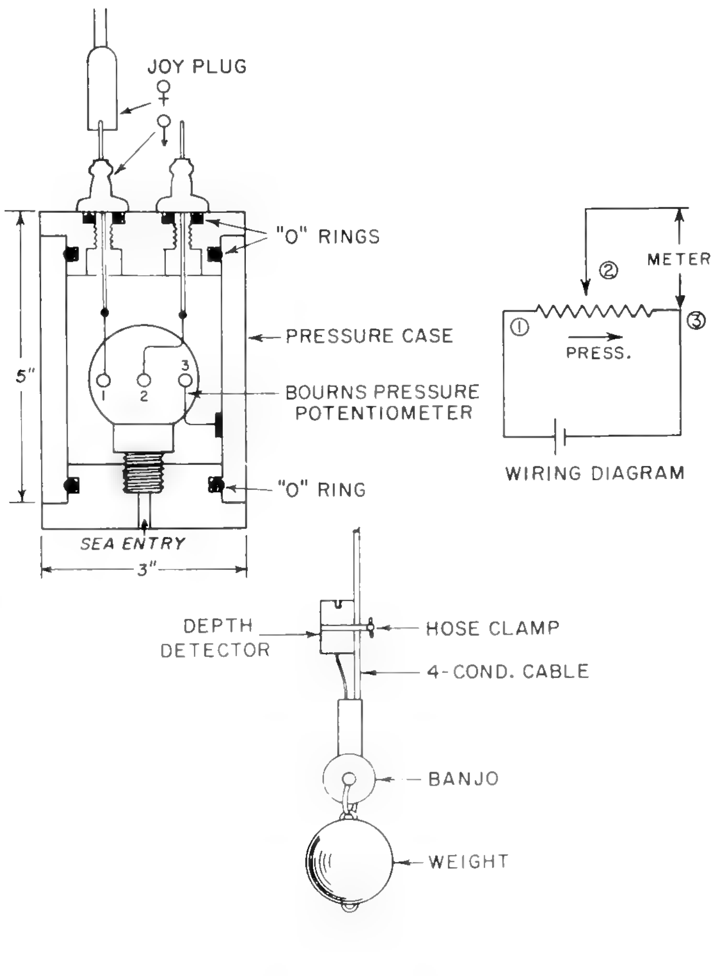


FIGURE 18.9
PRESSURE
POTENTIOMETER

In conjunction with this depth-detecting device it is equally feasible to have some sort of system for opening and closing nets. Initially, we felt a solenoid would be the simplest and most satisfactory device. Later, we abandoned this approach because of the frictional effects and the resulting large power requirements and selected a simpler means of turning the damper. An EXPLOSIVE SQUIB was used as a wedge to hold the damper door in various positions (fig. 18.10). These squibs contain a half grain of black powder which is fired by an internal element energized through two external leads. The outer case of the squib is of sufficient strength to withstand water pressures up to at least 2,000 meters and at the same time to arrest the spring-loaded dampers. Such an arrangement allows the observer on the vessel to lower his net to a desired depth, fire the first squib to start the sampler fishing, and then fire the second squib to close the sampler.

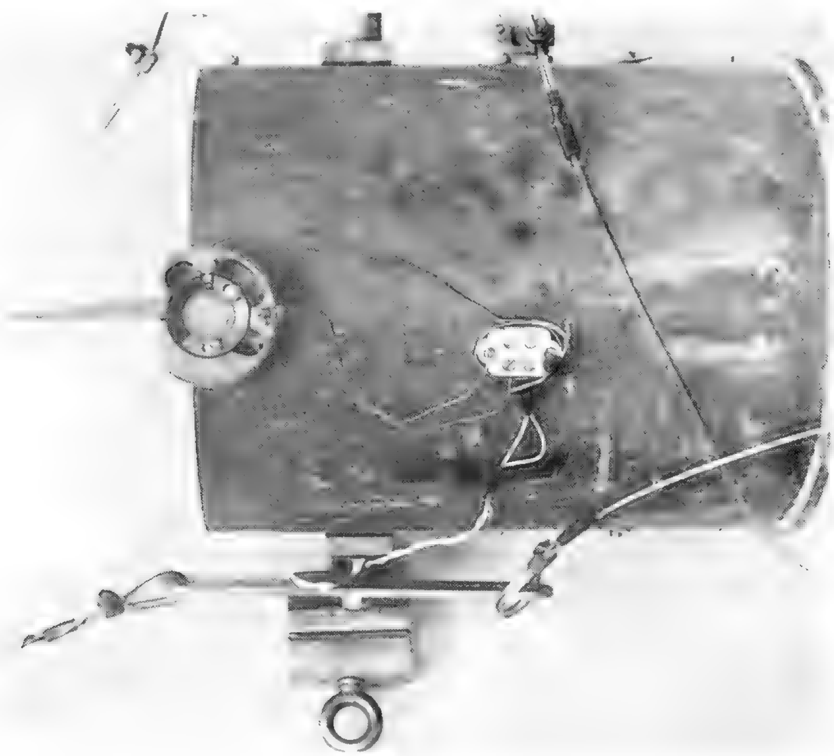


FIGURE 18.10
EXPLOSIVE SQUIB
RELEASE MECHANISM

The damper is in the open (fishing) position, one squib having been fired. When the second squib (which can be seen) is fired, the spring will turn the damper on around, counterclockwise, and effect the closure.

FIGURE 18.11
MECHANICALLY CONTROLLED
DAMPER SYSTEM

We have attempted to adapt this system to larger plankton nets, but, instead of opening and closing the mouth, we tried opening and closing the cod end. This has proved difficult largely because it seems to be impossible, using a fine mesh net, to get all of the plankton to converge in the cod end by the times of opening and closing the net.

Finally, our mechanical devices have esentially included the original design of the Clarke-Bumpus sampler greatly enlarged and vastly improved with regard to opening and closing techniques. Such a sampler with a MECHANICALLY CONTROLLED DAMPER SYSTEM is shown in figure 18.11. It consists of a damper closing unit with a net attachment. The damper is controlled by sliding messengers down the wire which contact the lines at the top of the frame. The inside diameter is approximately 1 foot and the cyclometer housing is made of 3/8-inch thick polyvinyl tubing. Such a sampler has proven highly satisfactory and has an advantage in the fact that several units may be placed on the wire and tripped simultaneously.

My purpose in hurriedly showing you as many sampling apparatuses as possible has been to introduce some of the present thinking with regard to instrumentation of biological samplers. The instruments cited represent only a small percentage of those used in oceanography and are essentially designs and developments from the Woods Hole Oceanographic Institution. The plankton biologist deals with a heterogeneous distribution of organic particles in sea water; his needs for continuous three-dimensional monitoring are great. There is no doubt in my mind that this void will persist until proper instrumentation engineering is applied.

19. FISHERIES

Dr. J. L. McHugh

Bureau of Commercial Fisheries
Washington, D. C.

Fishing is one of the most primitive activities of modern man. Since fishing first began many thousands of years ago, there has been no substantial change in gear or methods. Today we still fish with essentially the same devices that our early ancestors used, the trap, the net, or the hook. Over the years, we have added various modifications, it is true, but these have merely served to increase the efficiency of catching with the same old gears. The major improvements have been power to allow boats to move more quickly and range more widely, power to reduce the labor and increase the speed of hauling nets or lines, and new materials to prolong the life and increase the catching power of nets. The only radical change has been the use of electricity for guiding fish, but even this has not developed into an entirely new method, for it is used in conjunction with net fishing.

The ACT OF FISHING has two distinct phases. First, it is necessary to locate the fish in sufficient quantity; second, to catch them and bring them aboard. Both operations depend on a knowledge of the habits of fish. Fixed gears rely on prior knowledge of migration paths, vertical distribution, or reactions to barriers. Moving nets rely on visual clues, like jumpers, "finners," bird concentrations, or the tell-tale color of a school of fish near the surface as seen from the crow's nest, but prior knowledge and experience play an important part, too. Hook and line fishing depends on the feeding habits of fish, and requires a knowledge of their feeding habits, vertical distribution, and movements. Various types of attractants, such as lights or disturbances of various kinds, may be used in conjunction with conventional types of gear. These depend on a knowledge of reactions to different kinds of stimuli. An interesting method, once used to locate schools of herring for seiners, employed a length of piano wire with a weight at the end, suspended over a man's finger at the bow of a slowly-moving boat. By feeling the vibrations caused by contact of herring with the wire, an experienced man could judge not only the size of the school, but its depth and direction of movement as well.

The ART OF FISH LOCATION has benefited more from modern technology than has the art of catching. Various types of sonic equipment have been used with some success for the past 20 years or more. Even the standard fathometer is useful for this purpose. With the most modern equipment, it is possible to determine the depth and numbers of fish, not only immediately beneath the vessel, but at distances of a mile or more. With experience, it is also possible to recognize the kinds of fish on the record. But much more needs to be done before the art of fish location can become a science. Perhaps waves other than sound waves will prove useful, and these should be investigated. It is interesting also that many fishes and other marine animals produce distinctive sounds. No one has yet put this knowledge to use in fishing.

The ART OF CATCHING FISH, as I have already mentioned, is one of the most primitive activities of man. This situation did not arise entirely by chance, for increased efficiency without regulation places an extra drain on the resource. Many laws limit the efficiency of fishing operations in the name of conservation. This often has been carried to ridiculous extremes, such as, forbidding the use of power in fishing boats. Science can help the fishing industry in two ways: by determining the maximum sustainable yield for each fishery resource, and by reducing the cost of catching fish to a minimum. But the tradition of conservation by inefficiency is so strong that it is difficult to put scientific management measures into effect even when our scientific knowledge justifies them.

Some of the most serious problems of our United States fishing fleet today are economic in origin. As the world's population grows, and the fleets of the major fishing nations range the world's oceans in search of protein food, it will be disastrous to the American fishing industry to operate under inefficient conditions. Indeed, because our living standards and our wages are higher than those of any other nation, our fishermen need to be more efficient in order to compete successfully. This will require the fullest use of instrumentation, both for locating and for catching fish.

Two recent developments show promise as radical new methods of fish catching. One is the air-bubble curtain developed by our New England scientists. The other is electrical fishing. It is known that when fish come within the influence of an electrical field, they orient themselves with respect to the gradient in potential and swim toward the positive pole. The dissolved salts in sea water create problems, and a purely electrical method of fishing has not yet been developed, but electricity is used in the menhaden catching operation, once the fish have been surrounded by the seine. The anode is placed on the end of the hose used for pumping the fish aboard, and the cathode is laid in the bottom of the net. This brings the fish to the hose, relieves the strain on the net, and speeds up the process. Electricity also is used successfully in fresh water for a variety of scientific purposes, such as sampling the fish life of a stream, killing predators like the sea lamprey, or guiding salmon past turbines in dams. Electricity, therefore, offers possibilities for locating, for guiding, and for catching fish. If the two operations could be combined, an important step would be achieved in reducing the cost of fishing. One way to do this might be to design an underwater trawler, a submarine-like vessel, with open mouth, which would attract fish to itself with electricity, then gulp them in. Such a vessel might even process the fish aboard, bringing a finished product back to shore.

The needs for instrumentation in FISHERY SCIENCE are many and time will not allow a complete account. (A special list is included in appendix H.) Better methods to measure abundance in the natural environment would be invaluable, for such information is now obtained quite indirectly by sampling, from tag returns, or from catch statistics. Particularly useful would be practical ways of estimating abundance of young, as a guide for planning future fishing operations, for fluctuations in abundance are sources of difficulty to the fishing industry. They usually are not anticipated, and thus, they add to the cost of fishing.

When migration pathways are restricted, direct counting may be possible. In narrow, clear streams, for example, migrating salmon can be counted by eye, but in broad or muddy streams this is difficult or impossible. Electronic counters have proven successful in restricted channels; but in broader streams, much of the width must be blocked in order to lead the fish to the counter. Barriers interfere with movements of fish in various ways, and may cause serious delays in reaching spawning grounds, to the detriment of reproduction. What is needed is a successful method of scanning the water without using extensive underwater structures.

Our scientists have solved the physical problem of passing adult salmon upriver and young salmon down over low dams, and we think high dams can be conquered in a reasonable length of time. A difficult problem that still has to be solved, however, is to find a sure method to attract adult salmon to the entrance of a fishway. There also remains the problem of guiding fish without undue delay through the unfamiliar environment of the reservoir at a reasonable cost. One method might be to create a turbulent path from end to end, or in some other way to simulate the river that they seek. Some success has been achieved with electrical guiding, but more needs to be done, and other methods perhaps should be tried.

Another important series of problems exists in PLANKTON RESEARCH. These microscopic plants and animals are the basis of all organic production in the sea. Many fishes spend a part of their lives in this drifting world as eggs and tiny larvae. Plankton is also important food for many fishes. In collecting plankton for study and for estimation of abundance, fine-meshed nets usually are employed, but this is a cumbersome and awkward method. Many plankton organisms are so tiny that they can escape through finest mesh; others are sufficiently active so that they can escape the net mouth. Thus, nets of any kind give a biased sample at best. Something close to a complete sample can be obtained by bringing aboard a quantity of water by pump, or in a container, and separating the living organisms from the water by centrifuge. But plankton is relatively sparse, and large amounts of water must be handled to obtain a sufficient sample.

Although plankton samples taken with nets are biased, they still give useful information. One of the most successful ways of studying the distribution of plankton over large areas of ocean has been with the Hardy Continuous Plankton Recorder, which preserves a sample on a moving belt of fine-meshed silk. Later examination of this strip under a microscope permits reconstruction of the numbers and kinds of organisms along the path of the ship. This method is successful only in waters where plankton is relatively abundant, for the amount of water strained per unit area of sea surface is small. Moreover, the net fishes at only one level, and we know that the vertical distribution of plankton varies in time and space. Some automatic method of fishing a sinuous path in a vertical plane, on the order of 300 feet from the ocean surface to the deepest part of the trajectory, is needed. More thought needs to be given also to methods of recording temperature, depth, and amounts of water strained by plankton samplers.

Solution of some of these problems of scientific plankton study may have commercial applications, too. Plankton is much more abundant in total mass of protein than the larger marine organisms. Hence, some people have suggested that plankton is the most effective source of food from the sea. The slow rate of harvesting by conventional methods, caused by the need to handle large quantities of water, has prevented development of a practical method. If this instrumentation problem can be solved, fish factories may become a thing of the past.

20. RADIOBIOLOGICAL REQUIREMENTS

Dr. I. Eugene Wallen

Atomic Energy Commission
Washington, D. C.

The Atomic Energy Commission is not an operating agency; our research and surveys are done on contract. We do not have to decide between in-house and out-of-house research.

However, those who request research support of the Commission, must choose between four AEC divisions which might be involved in any instrumentation program. These Divisions are Reactor Development, Isotope Development, Research, and Biology and Medicine.

Our oceanographic research effort is directed at any kind of a program that might give us information about the ultimate distribution and potential hazard of radioactivity in the ocean. We support research in instrument development but we are primarily concerned with the use of the instruments in research. We prefer that requests to develop instruments come to us via one of our marine science contractors or potential contractors who wish to do research using the instrument; proposals need to be approved by the independent investigators who will use them.

Our primary interests in radioactivity involve three general problems. One of these, of course, is the total problem of biological effects. We would like to know the direct effect of radioactivity on all kinds of organisms. We would like to know the concentration factors, the specific activity, and the length of residence time of various radioisotopes in marine organisms. We would like to know what the effect might be on neutron activation of various materials within the ocean as these neutron products might be concentrated or might have some effect on organisms. We are interested, of course, in long-term effects of direct radiation.

In addition to this major item of biological effects, we are interested in processes that may remove radioactivity from or distribute it in the ocean. That means that we are interested in all aspects of sedimentation and in various kinds of equipment that may be useful in studying sedimentation rates.

A third concern is with water movements and all of the various devices that might be of value in studying oceanic circulation, either vertical or horizontal and either long-term or short-term.

From a differing standpoint, we are interested in instrumentation as it may use nuclear power in the ocean. We are interested in the applications of various Systems for Nuclear Auxiliary Power -- that is, the so-called SNAP devices. Nuclear batteries permit the development of instruments that will do jobs that were impossible before. We feel that these instruments have a great deal to offer to the oceanographer, particularly where needs for electricity independent from a shore-based source may be such as to make these devices practical. As you know, the SNAP devices may be made into battery form, and they may function at a relatively low power, up to about 5 watts; or they may be small reactors, which can produce a kilowatt of electricity or even many megawatts of electricity. We feel confident that these devices will continue to operate in the ocean; however, we are concerned with various potential hazards of the operations.

Thus, part of our instrumentation requirement lies in the development of equipment which could make it possible to judge more accurately the hazards of the devices that may be developed.

SNAP, or at least similar devices, are presently conceived for use in oceanographic buoys and for use in various kinds of instrument stations including oceanic instrument stations where a continuous or intermittent readout is needed to give the information.

As far as our marine operating interest is concerned, the Commission places priority on those oceanic areas adjacent to shore-based nuclear reactors. We are concerned with any possible equipment that might tell us more about the distribution of radioactivity from such sources as the Hanford reactors where radioactive materials may be released into the ocean. We are concerned with the safety and possible hazards of ship operation. If there should be a nuclear war, we realize there is a good chance of a nuclear submarine having an accident, and certainly a very small chance but perhaps a minimum chance that an accident will occur during normal operation of these or other vessels. In such case we would like to know particularly the diffusion rates for radioactivity.

Since the operating devices may be destroyed at the surface, or at some depth in the ocean, they could remain a hazard until the toxic substances have been diluted in the marine environment to an extent that they are no longer harmful, or they may remain as a point source hazard for long periods of time.

We are interested in the rates of diffusion at the surface of the ocean and the rates of diffusion at depths in the ocean. As some of you know, the dye, rhodamine-B, has been developed recently, and other rhodamines as well, to where it is possible to study very minute quantities of these dyes. We plan to do some initial experiments with dyes. Rather soon, we hope to be able to try large-scale experiments with loss of radioactivity in the ocean.

Some people contend that the only practical way to put a man on the moon is to use nuclear-propelled space vehicles. Almost everyone is certain that even if ordinary propulsion is used, various types of nuclear-powered devices will be aboard these vehicles.

All these will have to be tested and various concepts, various instruments, and various techniques will have to be developed in order to insure that their operation meets the very high standards of safety which have been set and accepted by the Commission in past operations.

One other thing, although the economics of ocean disposal of radioactive wastes are such as to preclude any great increase in disposal of radioactivity in the ocean, we are very much concerned with continuing programs that may make it possible to determine the distribution of waste products that may be disposed in the ocean at some future date.

21. GENERAL DISCUSSION AND QUESTION AND ANSWER PERIOD RELATING TO ALL TOPICS

Donald L. McKernan, Chairman, and Panel[6]

DR. GEORGE M. BRYAN (Genisco, Inc.): A great deal has been said about the need for Industry's cooperation in the National Oceanographic Program. Would someone care to comment upon the incentives offered to Industry to develop instruments for a market which is as thin as this Symposium has led us to believe? Even if engineering costs are sustained by a governmental agency, the most precious commodity expended by a company in a developmental program is time, and that is not refundable.

THE CHAIRMAN: This is a serious problem which both Government and Industry are going to have to consider. It may be that some companies, after thoroughly understanding the possibilities, may decide that they cannot afford to go into this particular program. From personal discussions I have had with some of you, however, I feel that your present developmental and manufacturing program is quite similar to what is required, and that perhaps for some of you it will not be quite the problem that it will be for others who are about to enter or are considering entering the field of oceanographic instrumentation.

I can only repeat what I said yesterday -- perhaps a little more clearly -- that I believe the Government is prepared to enter into financing and funding a certain amount of development for oceanographic instrumentation. Part of the Government's problem in deciding to what extent it will contribute is the fact that many of us do not know to what extent governmental funding is required. For example, I understand a great many companies are very close to manufacturing certain oceanographic instruments. In this case, no great extra effort is required to alter their developmental and manufacturing programs.

On the other hand, if great sacrifices and a great deal of time and thought are required to improve other aspects of oceanographic instrumentation, then Government will have to pay for or share a greater proportion of these developmental costs.

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[6] The addresses of panel members and of those asking questions may be found in the List of Attendees. (See appendix D.)

Some of us do not know to what extent we need to share the developmental costs in oceanographic instrumentation. We hope that information which is provided you at this conference and in the Proceedings of the meeting will give you an idea of what we need. Perhaps this will be the beginning of the negotiations between Government and Industry. We hope it will culminate in new oceanographic instruments to benefit the Nation by more efficient utilization of our oceanographic platforms at sea.

One of our speakers this morning -- Dr. William S. Richardson -- pointed out that some of the individual temperature readings which we are taking cost about $21 each. This is pretty expensive. If we can get these cheaper by better equipment, we will. We can indicate better how much of the development Government must pay for after we find out what Industry's contribution is going to cost. If you are already set up to produce certain instruments, then the Government should not be required to pay very much for their development. On the other hand, if no one is set up to produce given instruments, then Government is going to have to pay more. We are going to have to wait and see what your situation is after you have viewed our needs and requirements.

Later, I presume, there will be negotiation between us, between you and Navy Department officials and those of other agencies, such as, the Coast and Geodetic Survey, who are carrying out the survey program and who will fund a great many of the survey instruments required on their ships.

MR. AUGUSTUS N. HILL (U. S. Weather Bureau): Aerological soundings (radiosondes) were not mentioned in regard to meteorological suits. Is this data not important to oceanography, or has the need for a good, portable system already been solved?

MR. J. J. SCHULE, JR. (HO): Data for the lowest levels of the atmosphere are important to oceanography, and we do not feel that a good radiosonde device for providing such data has as yet been developed. Recently there have been requirements for a low level radiosonde expressed not only by the ASWEPS people, but by other organizations in the Navy as well. The Bureau of Naval Weapons has an active program in this area, and preliminary evaluation of the equipment will begin soon. As far as the standard radiosonde is concerned, the Weather Bureau has developed a portable system which is being installed aboard more ships-of-opportunity each year.

MR. ROBERT S. BOWDITCH (Northrop Corporation): Does the ICO contemplate the possibility of establishing an oceanwide network of telemetering buoys for ASWEPS, navigation, and oceanographic research?

MR. J. J. SCHULE, JR. (HO): I do not know of any plan to establish a worldwide network of telemetering buoys. In the ASWEPS program we have planned to take advantage of any available platform, and buoys would mainly be used only in areas where other platforms, such as ships or aircraft, were not available.

MR. A. C. VINE (WHOI): I do not know of any plans for a worldwide field of buoys, but there is a great deal of work going on right now trying to visualize what the future extent of buoys might be. This is strictly crystal-ball gazing. We are trying to get frequency allocations in the radio spectrum for buoy-satellite networks so that it might be possible to operate at least several sets of several hundred buoys each.

MR. ROBERT S. BOWDITCH (Northrop Corporation): Would the hydrofoil, if available, be a useful survey vessel because of its speed, recognizing the present state of hydrofoil art?

MR. A. C. VINE (WHOI): I would think that a hydrofoil would be very much like all these other vehicles, if it is competitive on a general basis. If people have a particular job where a hydrofoil would work extremely well, then, of course, that would be a good thing for them.

There is work going on in several laboratories in which scientists are getting very interested in catamarans. We hope that in a few years there will be several catamarans operated for research work. Several of the people are interested in hydrofoils, but their day-to-day capability is a little uncertain to the oceanographer.

MR. JOHN D. NEELY (Tracerlab, Inc.): Is it possible to obtain some of your ocean core material for analytical studies of the possible presence of micrometeorites?

DR. J. L. WORZEL (LGO): It is indeed possible to get samples of cores for study providing the results of such studies are made available in publications. We have given too many core materials out, not to get any return in published information. This, then, makes it ultimately impossible to give materials to somebody else who would publish later.

MR. RALPH MONAGHAN (Dresser Research): Mr. Allyn Vine indicated in his talk that more specialized and selective conferences on the measurement of a single parameter should follow. Are these conferences anticipated? And, if so, who will be invited, when, etc.?

MR. A. C. VINE (WHOI): That is certainly a good question. I do not see how some of these things can get solved unless such conferences are held. It would seem to me that if, when you people go back, you think about the areas of oceanographic instrumentation in which you are particularly interested and let the people who held this conference know about your particular interest, then we can be sure you are included.

A conference for a particular instrument would probably be called by the individual group or bureau who is the most interested in it, and the one who would forge ahead. This might be either a design group or it might be people who had the money and wanted the instrument in a hurry.

One of the purposes of this conference is to find ways to do this and to find out how many of you might be interested in different aspects of oceanographic instruments.

THE CHAIRMAN: Someone who remains unnamed mentions that many of the past two days' presentations have contained a paradox, namely, the oceanographers are severely limited in their work by rough seas -- there certainly has been mention of getting green around the gills. Yet, the emphasis for future shipbuilding is for smaller surface ships of some 1,500 tons, which will be subject to surface water conditions. Why is not more serious consideration being given to submarine oceanographic ships, for example? This might be a good use for mothballed submarines currently in existence.

MR. A. C. VINE (WHOI): Submarines are very specialized, and then you have to get them. There has not been any submarine over which oceanographers have had full operational control for a long enough time to get it properly equipped and to get everybody really shaken down.

Undoubtedly, submarines will be used in the future, but nobody has yet been quite bold enough to take on a full-fledged, full-time, non-Navy operated submarine; and a full-time, Navy-operated submarine with a small crew is not yet available.

DR. H. J. McLELLAN (T. A. M.): A 1,500-ton ship is not small. Very few of us have had the luxury of going to sea on research vessels of that size. Those are definitely larger ships, and the distinct possibility of having anti-rolling devices on them would make them palatial compared to what we have been used to.

DR. W. S. RICHARDSON (WHOI): I think those of us who have been out on trips in the 1,000- to 1,500-ton range feel that they are very nearly ideal. When the ships get bigger than that, they can become rather cumbersome. There are things that are hard to do. Some of us would rather enjoy the sunshine and be a little seasick than live all the time on a submarine.

THE CHAIRMAN: Interestingly enough, the Russians have developed much larger ships. I recall the one I visited in New York last year, a 6,000-ton vessel. They have gone in for much larger ships than we have. Most of our oceanographers feel that this size is really larger than they would like to have.

DR. J. L. McHUGH (BCF): The Russians have a submarine which is being used for fishery research. I believe it is in full use all around the year.

DR. J. L. WORZEL (LGO): There are many operations in geology and geophysics that would be difficult if not impossible to perform on a submarine. I might point out that a submarine would cost probably twice as much to operate as a ship of the same size.

THE CHAIRMAN: I would like to ask, what kinds of things might be impossible from a submarine? Of course, taking observations of the sun might be a little difficult unless you came to the surface.

DR. J. L. WORZEL (LGO): I think you would find ocean bottom coring from a submarine would be rather difficult. Seismic work has been done on submarines, but it is extremely difficult. The underwater programs are very simple. Most of the water sampling techniques are too deep for most submarines to reach, so they would require essentially the same gear as a surface ship.

THE CHAIRMAN: Of course, many of us like the idea of submarines, which would allow us to escape from wave action and enable us to study concurrently severe storms and their effect on the surface layers. Submarines would also enable us to inspect and visually select and pick up biological and rock samples from the continental shelf.

MR. JEROME ROTHSTEIN (Maser Optics, Inc.): Will the speakers add short bibliographies useful to industrial people?

THE CHAIRMAN: This is an excellent suggestion. Might I speak for our people and suggest that we do add a short bibliography. This is a good suggestion, and I see no reason why we cannot do this. (See appendix I.)

MR. W. THOMAS HUGHES (Farrand Optical Company, Inc.): Are there any organizations studying the use of porpoises for herding less intelligent fish in groups, much as dogs herd cattle? Also, has there been any effort in domesticating food fish by chemical-electrical stimulus or breeding techniques?

DR. J. L. McHUGH (BCF): I have heard this porpoise suggestion before. I think I read it in the funny papers. It is not a bad idea, though. It is worth looking into. They are intelligent animals and perhaps could be used for this purpose.

As far as the control of farming techniques is concerned, we have made the most progress with shellfish, animals such as oysters which are farmed to some degree. Commercial oyster culture is much more highly developed in some foreign countries than it is in the United States, particularly in Japan, Holland, France, Australia, and to some extent in Great Britain.

We have some ideas for the future about breeding oysters in laboratories. Our laboratory at Milford, Connecticut, has oysters that are in their fifth or sixth generation of captivity at least, and have lived their entire life cycle in the laboratory.

They have been produced by artificial inducement of spawning, and we believe that they can be bred selectively for certain desirable characteristics, such as rapid growth and disease resistance.

Not as much has been done with commercial food fishes, with the possible exceptions of salmon, carp, and catfish. There has been some hybridization. Considerable work has been done in other countries. We are also interested in the possibility of using rice ponds in this country for growing fish, too. This provides mutual benefit. It grows better rice if we have fish in there because they keep the roots clean, and the fishes, such as, carp and buffalo-fish, can grow quite rapidly in rice ponds.

We are doing something along these lines, but we have a long way to go.

MR. THEODORE J. SMITH (Packard Bell Computer): Of the 20-odd transducer types mentioned for survey vessels, indicate the number which provide output in the following ranges: 0 to 10 v.d.c., 0 to 1 v.d.c., 0 to 10 mv.d.c., and 1 mv.d.c. or less.

MR. B. K. COUPER (BUSHIPS): The range for most transducers or sensors would be, perhaps, 0 - 5 v.d.c. However, the ranges and accuracies desired are usually expressed in other units, or, in some cases, merely indicated in the hope of improvement in present designs. These 20-odd transducers to which you refer have not yet been ordered -- for the most part. You will notice that the handouts (appendices E, F, G, and H) tend to be performance rather than engineering specifications, and so it is not known what their output will be.

MR. THEODORE J. SMITH (Packard Bell Computer): Are there any digital output transducers yet?

DR. W. S. RICHARDSON (WHOI): Yes, there are several pressure transducers, such as the vibratron, which are essentially digital devices, if you include with the sensor the amplifier service system. Of course, this is the most common type of system in instrumentation.

MR. SCOTT A. MILLS (Ramo-Wooldridge): What technique makes Omega more effective than Loran, and when will Omega be in worldwide operation?

DR. W. S. RICHARDSON (WHOI): Omega's greater range is due to the lower frequencies. I do not have any idea when it will be generally available.

MR. THEODORE J. SMITH (Packard Bell Computer): What sampling rates are typically desirable in oceanographic data gathering?

DR. W. S. RICHARDSON (WHOI): That is a very difficult question. If you are talking about acoustics, of course, we get up into the megacycle range. On the other hand, we normally like to work somewhere near the time constant of perhaps a second for things like temperature, and we might be satisfied with time constants of several minutes for current measurements. It depends very strongly on the particular instrumentation problem and the particular scientific problem to which the data apply.

MR. BENJAMIN H. FONOROW (Philco Corporation): How will Industry or the general public be able to get the output data from the National Oceanographic Data Center? Will this data be in a form useful to the user of the data?

CHAIRMAN: They can buy it at the cost of machine time, the same way that the rest of us do, and it probably can be put in a useful form -- any convenient form -- that they wish. Further information on this, I think, can be supplied by NODC, Washington 25, D. C.

MR. RUSSELL E. HUKEE (Imperial Electronics, Inc): Is there a requirement for an inexpensive disposable bathythermograph?

MR. B. K. COUPER (BUSHIPS): The increase in ship speed would make a disposable bathythermograph quite useful. However, the cost, as far as we have been able to find out from casual discussions with quite a number of people, has not been anywhere down to what we are getting at present by the bathythermograph.

We have had some wonderful ideas, but, if I may mention the horrible word of reliability again, we have had difficulty. The difficulty with the present bathythermograph is that, in general, we must limit the speed to reach the depths we want. An expendable one would be very handy, but again it is a matter of cost.

MR. RUSSELL E. HUKEE (Imperial Electronics, Inc.): Is there a requirement for a temperature to frequency converter?

MR. B. K. COUPER (BUSHIPS): Increased efficiency of information transmission is always of interest, especially if the technique is more economical, reliable, and easily maintained. The value of the technique you mention would depend on how it contributes to any or several of these qualities in the actual system of which it would be a part.

MR. WILLIAM HILDRETH (Lockheed Aircraft Corporation): Is an Encyclopedia on Oceanographic Instrumentation to be published?

THE CHAIRMAN: We have not fully decided whether or not to publish these several volumes of the encyclopedia. If there seems to be enough interest in Industry, in Government, and in non-governmental laboratories, we will publish them. It may be published for the ICO by a staff on contract. These several volumes at the back of the room are too bulky to be included in the Proceedings of this particular meeting. An indication from you concerning an interest in the encyclopedia will help us to make a decision in this regard.

DR. ROBERT S. BRAMAN (Armour Research Foundation): Would you please comment on the use of nuclear techniques in automatic sensing devices?

DR. I. E. WALLEN (AEC): Nuclear energy offers long-term, reliable, lightweight power sources for sensing devices. Because of the limitations of production and the high purity requirements of suitable materials, these power sources are expensive for the usual types of oceanographic observations.

When remote operations or special use requirements demand reliable performance for several years, my opinion is that wide use will be made of these Systems for Nuclear Auxiliary Power (SNAP) units.

MR. R. B. PRIEST (Fairchild Camera and Instrument Corporation): How much use has been made of television in oceanography? What results have been obtained as to range of view and depth of operation with artificial light and with natural ambient light?

DR. J. L. McHUGH (BCF): I can answer with respect to our own work in fisheries. We have used TV primarily for watching the behavior of fishes in trawls with an idea of seeing whether we can improve the efficiency of trawls for catching various species.

DR. I. E. WALLEN (AEC): We have made some use of television in testing the barrels in which packaged wastes might be placed. We have surveyed waste disposal sites. We probably will continue this.

MR. B. K. COUPER (BUSHIPS): One of the interesting experiments going on in the Navy Electronics Laboratory Oceanographic Tower is a closed-circuit TV with which one can see the effects of internal waves. At about 10 feet from the camera, there is a metal grid from which, by means of dials, we can release dye or dye markers, or on which we can tie little strings of wool. By means of televisional photography we are getting some information about the rotational motion of shallow water. It is very interesting to see these pictures. Near the surface the little strips of bunting make almost complete circles; whereas, when you go down near the bottom off the California coast, where everything is controlled by the swell, you see almost a right and left, flip-flop motion.

MR. M. H. SCHEFER (BUWEPS): On the underwater ranges, TV is in frequent use to locate lost ordnance and to assist in the installation and inspection of bottom-mounted devices. Operating depths are from 600 to 2,000 feet, with an existing requirement to 6,000 feet. Artificial light is used. (See also appendix A, page 248.)

MR. SCOTT A. MILLS (Ramo-Wooldridge Company): What does ASWEPS stand for, and will the central data processing equipment and display be aboard ship?

MR. J. J. SCHULE, JR. (HO): ASWEPS stands for "Antisubmarine Warfare Environmental Prediction System."

The master data processing and display system for ASWEPS will not be aboard ship but will be located ashore. Such a unit will provide the daily synoptic analyses for the entire ocean area concerned, as well as long range predictions of a general nature. However, other smaller units will be located at Fleet commands and aboard Task Group Flagships for the purpose of providing environmental displays for the particular area of interest. These displays, intended mainly for local tactical use, would not require as complicated a data processing capability as the master unit.

THE CHAIRMAN: An anonymous person asks: If various radioisotopes are concentrated by plankton and other biological systems, what happens to the radioisotopes in organic compounds after the organisms die?

DR. I. E. WALLEN (AEC): Radioactive isotopes can be expected to behave as stable isotopes. The dead organism decays or is eaten to release the elements for reconstitution by another organism. The actual cycle of reconstitution varies with the element's abundance and the requirements of the species.

Dilution of the radioactive isotope by stable ones tends to reduce the availability and, thus, the concentration in succeeding steps in the cycle. In addition, radioactive decay and diffusion processes reduce the environmental concentration of the radioactive element of concern. (See also appendix A, page 236.)

THE CHAIRMAN: An anonymous person asks: Has any study been made concerning the possibility of obtaining sedimentary samples with a coring device operating from submarines?

MR. A. C. VINE (WHOI): Yes. On a small scale, an external manipulator can operate a drill or hammer a tube into the bottom from a small submarine, or essentially jab a tube or a series of tubes into the bottom to collect small samples near the submarine. A large number of samples could be so taken. They might be very useful, even though no one sample was very long. There has also been some discussion about a small submarine supervising a much larger bottomed device which took much larger and longer cores.

MR. CLIFFORD C. BORDEN (Curtiss-Wright Corporation): Has any work been done on subsea floor strata profiling by means of an electrical resistivity on ships underway with depths of the order of 6,000 fathoms of water, plus 2,500 feet of sediments or bedrock? Would some such device be useful?

DR. J. L. WORZEL (LGO): So far as I know, no work of this type has been done in the ocean anywhere. Such a device would be useful.

THE CHAIRMAN: Gentlemen, there are a few more questions that are of a somewhat technical nature which we will try to answer in the Proceedings of this meeting. (See appendix A.)

DR. W. S. RICHARDSON (WHOI): Mr. Chairman, I wonder if I might make a remark? Yesterday Mr. Snodgrass made some remarks which I would very strongly like to second. He suggested that if there are among you people anyone who is serious about learning what the sea and the environment of these instruments is like and who wants to go to sea, arrangements can be made for you to go to sea on research vessels. I presume he was speaking for his institution, and I think now I can speak for mine. If you want to come as a worker on a trip, we will provide you with a bed and steak lunches and things, and hold your hand if you are seasick. We expect you to work -- not just go along to visit. But arrangements can be made, not always at your convenience, but with some advance planning.

I would like to leave that thought with you. If you want to go and see what the ocean is like, these arrangements can be made.

22. SUMMARY OF OCEANOGRAPHIC INSTRUMENTATION REQUIREMENTS

James M. Snodgrass

Scripps Institution of Oceanography
La Jolla, California

Since the hour is late and since you have been most kind and patient, this will not be a long summary.

Before I get into other comments, I would like to say something about the talk by Dr. Richardson which you heard this morning. Many of you have not had, I am sure, extensive experience in the ocean. The program which he has undertaken, which is installing a string of buoys from Cape Cod to Bermuda, ranks as a first-class project and one that will be an outstanding prototype for future research. This is a substantial accomplishment. It is difficult to do justice to what has really been done. Great credit is due to the insight which went into the program, and I am sure that it will get us the kind of information we need.

With regard to ocean sampling, as recently as about 1956, by using our most intense techniques on a cubic mile of sea water, we could sample one part in 10^{14} at best. With such a miserable sampling, you might ask quite properly: "Do we really, after all, know very much about it?"

I would like to suggest a reference for you to peruse. It has food for thought on the basic problems of instrumental design and the kind of things that we need to keep in mind. It is, "The Crisis We Face; Automation and the Cold War." The authors are George Steele and Paul Kircher. It was published by McGraw-Hill in 1960. I strongly recommend the sections on reliability and on long-range technical problems. This bood is basically written for space problems, but it can be easily translated into the field which we have been discussing.

Next, I would like to point out that the ocean we have been talking about is not, by and large, properly appreciated for what it is. We often ignore its relationship to the atmosphere.

We should remember that the atmosphere and the ocean represent the two largest heat reserviors with which we are associated. In reality, they are vast heat engines. The surface of the ocean to which we have referred both critically and humorously is the region through which energy exchanges occur between these two dynamic systems. We are just beginning to get a glimmering of basic understanding, and we need a great deal more solid instrumentation. New theories, too, are needed. We need to do a great deal more work in this interfacial region because it covers such an important proportion of the earth's surface, where energy may be most easily exchanged.

We should take very much to heart the warnings and comments made yesterday with respect to the problems of the National Oceanographic Data Center. Dr. Jacobs pointed out, it is not difficult to overload almost any data processing system if the data is not in the right form or selected with the proper discretion. Close cooperation between the instrument designer, the oceanographer, and the data custodian is extremely important. I was surprised to hear that the oceanographer of the future might not have any firsthand contact with his medium but would come to depend upon data from data centers. This I doubt.

We must examine our position on expendable instruments carefully. I would like to emphasize that if we are going to develop a successful, expendable BT, for example, we must look at both the design problem and the packaging problem very critically. Do not assume that our present techniques or past practices are adequate. Let us look hard at possible things which we can use, things we can eliminate, and get down to what is really necessary. Remember that huge volumes of these items will be required. Do not design it for only small production quantities. The design should permit large-volume production. This is the only way that we can get unit costs down. We heard some rather high figures on unit costs for observations given this morning. These are not excessively high. These are the facts. The cost of the little BT slide record to the Navy, not counting labor, is somewhere between $10 and $25 an observation delivered on deck. However, we should use this figure with caution.

I do not believe any reference was made to the fact that repeated surveys are going to be in order. We are not going to be able to go once over the ground lightly or even thoroughly and find all we need to know, because the ocean and its environment change from year to year and from season to season. This is going to require continuous activity.

The problems of marine biology are considerable. Most of you would concede that physical and chemical oceanography have suffered overlong by policies of attempting to build instruments using less than one vacuum tube. Biological oceanography is in a much worse situation. However, it is brighter for the manufacturer by virtue of the fact, as you heard from Dr. McHugh, that there is a large potential market here. There is a large United States and a rapidly expanding worldwide fishing fleet that is just becoming aware of the possibilities of new instrumentation for operational purposes. This is a good field for study.

A word on underwater TV. Many of the applications of underwater TV are inept. It is a nice device, but it has often been misused; we tend to forget some of the things which we can really do with underwater TV or, in fact, TV itself. We should question the use of conventional commercial frame rates of 60 per second. Possibly we could do better if we had frame rates of only one per second with image storage systems. Lower frame rates would permit a very great reduction in transmitted bandwidth or an increase in the resolution, whichever we may wish. We often spend far more to accomplish a task than is necessary, and we do not succeed in doing it well. I am thinking here of really deep TV, because of the cable and transmission problems which accompany the broad bandwidth situation.

Well, as I promised, I will conclude at this point, and leave the rest to our Chairman.

23. CLOSING REMARKS

Donald L. McKernan

Chairman of the Symposium

You have had a long two days and I realize the time is getting late. We have had gratifying attendance and interest in this Symposium (729 attendees). It would not have operated smoothly by itself. There has been long and intense preparation by a small group. It would be neglectful if I did not give credit where credit is due.

Capt. C.N.G. Hendrix of the Hydrographic Office, while acting in the background during the past two days, was in the forefront during the planning stages of the conference. Mr. Howard H. Eckles and Dr. Julius Rockwell, Jr., of our staff have worked nights as well as days organizing the program. Dr. I. Eugene Wallen of the Atomic Energy Commission and Mr. Allyn C. Vine of the Woods Hole Oceanographic Institution have also contributed to a major degree.

As I mentioned in the beginning, this conference is somewhat of a departure from our normal contacts with Industry. We wonder how you liked it. If you have any views, suggestions, or criticisms please write us a note in my care, the Department of the Interior. Who knows, we might wish to hold a similar conference again with you.

On behalf of the Interagency Committee on Oceanography, I want to thank all our speakers who have appeared before us and have come from long distances to participate in this program.

With that, we will adjourn our sessions. You all will be given an opportunity to obtain copies of the Proceedings of these meetings.

APPENDIX A

ANSWERS TO QUESTIONS SUBMITTED AT THE SYMPOSIUM BUT NOT ANSWERED AT THE SYMPOSIUM

Mr. James M. Crossen, Electronic Equipment Specialist, Woods Hole Biological Laboratory, Bureau of Commercial Fisheries.

Lieutenant Commander R. P. Dinsmore, Chief, Patrols and Scientific Programs, Branch of Floating Units Division, U. S. Coast Guard.

Mr. H. W. Dubach, Deputy Director, National Oceanographic Data Center.

Mr. Howard H. Eckles, Chief, Branch of Marine Fisheries, Bureau of Commercial Fisheries.

Dr. Sidney R. Galler, Head, Biology Branch, Office of Naval Research.

Mr. J. R. R. Harter, TV & Facsimile Equipment (Code 687B4), Bureau of Ships.

Mr. Gilbert Jaffe, Director, Instrumentation Division, U. S. Navy Hydrographic Office.

Mr. Feenan D. Jennings, Head, Oceanography Section, Geophysics Branch, Office of Naval Research.

Dr. Julius Rockwell, Jr., Coordinator, Government-Industry Oceanographic Instrumentation Program, Bureau of Commercial Fisheries.

Mr. John J. Schule, Jr., Director, Oceanographic Prediction Division, U. S. Navy Hydrographic Office.

Mr. James M. Snodgrass, Head, Special Developments Division, Scripps Institution of Oceanography.

Mr. Allyn C. Vine, Physical Oceanographer, Woods Hole Oceanographic Institution.

Dr. I. Eugene Wallen, Marine Biologist, Environmental Sciences

Branch, Division of Biology and Medicine, Atomic Energy Commission.

Mr. T. J. Wehe,[7/] Martin Marietta Corporation, Electronic Systems and Products Division, Baltimore, Maryland.

* * *

ANONYMOUS: If various radioisotopes are concentrated by plankton and other biological systems, what happens to the radioisotopes in organic compounds after the organisms die? (Answered on p. 229.) Has a means been developed to sample such compounds?

DR. I. E. WALLEN (AEC): No completely adequate means has been found to sample compounds released by an organism on its death in the ocean. Studies are underway to learn the nature of the compounds and the types of recycling that may result in reconcentration of radioactive materials. Investigators at Texas A & M have isolated organic compounds from ocean waters and several investigators are working on the utilization of compounds in solution. We need to have field data of the nature you suggest.

MR. GEORGE L. BARNARD (Washington Technological Associates, Inc.): Is there an "on site" deep sea materials testing program in progress and when will results be available to us?

MR. J. M. SNODGRASS (SIO): The only truly deep sea testing station that I know of is being established at Port Hueneme, California. I would be pleased to refer you to Mr. Kenneth O. Gray, Project Scientist, Materials Division, U. S. Naval Civil Engineering Laboratory, Port Hueneme, California, who is in charge of the program. Unfortunately, I cannot tell anything about the time scale as to when results would be released, but I suggest you contact Mr. Gray directly.

Another group interested in testing materials in the deep sea is the one at Santa Barbara operated by General Motors, and known as Defense Systems Division, Santa Barbara Laboratories. I would be pleased to refer you to Dr. J. Frederick Dubus of that company. They are concerned with the environmental testing of plastics.

7/ Formerly with Special Projects Office, U. S. Navy Hydrographic Office.

MR. C. E. BRADY (General Electric): I would like to hear some comments on the acceptable compromises or definitions of the requirements which appear to be conflicting, namely: durability, reliability, low cost, and limited production.

MR. G. JAFFE (HO): There is no real conflict between the terms durability, reliability, low cost, and limited production. It is generally recognized that compromises are necessary in order to achieve all of these design goals. However, in the oceanographic application, instruments will be at sea under relatively severe environmental conditions for long periods of time. In addition, the cost of operating instrument platforms (research and survey ships) is very high, and, as a result, "downtime" is expensive.

In the initial phases of the shipboard program, there will probably not be the opportunity to obtain low cost instrumentation because the emphasis will be on reliability and durability. It is hoped, however, that as more platforms become available, production will increase to a point where the previously obtained reliability and durability can be provided at lower cost.

DR. RALPH L. ELY, JR. (Research Triangle Institute): Are any in situ O_2 analyzers in use?

MR. J. M. SNODGRASS (SIO): There are none, to my knowledge, in deep sea work. Some are used in shallow water, principally at installations such as Texas Towers. The instruments used are designed on the basis of the Kanwisher-Carritt electrode systems. At present, the difficulties with the Kanwisher-Carritt systems are as follows: (1) The relatively high temperature coefficient, (2) a substantial pressure coefficient which is sufficient to show the changes due to ocean waves when the instrument is installed in shallow water, (3) a tendency to drift with time, and (4) at present, no way has been devised to prevent fouling when the sensor is left unattended.

There are, of course, industrial O_2 analyzers which are used in the process industry and may be used in open tanks. These may be used in sea water to a limited extent, providing the line between the sensor and the recording equipment is short enough. Commercial analyzers of the latter type are available from the Hays Corporation, Michigan City, Indiana.

MR. VINCE GORDON (Philco Corporation): Regarding picture data input to National Oceanographic Data Center (ice data) -- how many aerial photographs will NODC have to interpret per year?

MR. H. W. DUBACH (NODC): We plan to begin investigation of ice digitalization schemes before January 1962. To date we have not assigned any of our staff to consolidate existing collections and review them; therefore, we have no estimate of the annual rate of accrual of ice photographs. With daily ice reconnaissance by aircraft for the Baffin Bay, Canadian Archipelago, and Alaska-Bering Sea area, the volume could amount to 200 to 300 photos a day. The normal ice season could run from 6 to 9 months. It is not unreasonable to anticipate an accrual of from 5,000 to 7,000 photographs a year for the North American Arctic alone.

MR. LEE HELSER (Fairchild Camera & Instrument Corporation): Does the Government plan to fund significant research, studies, and the development of new instruments and techniques, or does the Government expect Industry to develop new gear on company funds and then contact potential user agencies in an attempt to sell a finished product?

DR. J. ROCKWELL, JR. (BCF): If a company already manufactures an instrument to serve a given purpose and if this instrument can, with a small amount of modification, be adapted to serve the oceanographic effort, then it would be very much to the company's advantage to make this modification itself and sell the Government the patented, finished product. Where a need is present and there is nothing in existence that approaches the required instrument and where the number required is few, of course, the Government must finance development. To assist your company in deciding if its products may be adaptable I suggest that you turn to the list of laboratories dealing in oceanographic research (appendix B) and contact those nearest you, not with the idea of selling them on financing your work, but to learn if your particular instrument is close to the corresponding one on the lists of required instruments (appendices E, F, G, and H). The most productive work in the past and the best instruments have always been produced by technically trained people and oceanographic field personnel working in close harmony. Before developing new gear on your own, I would suggest that you get in touch with a using group, particularly if you do not have an experienced oceanographer on your staff, to be sure that you are on the right track.

REAR ADMIRAL G. N. JOHANSEN (Land-Air, Inc.): Would it be feasible for ICO to establish a centralized information office where representatives of Industry could explain their capabilities and be directed to the agencies interested in these capabilities?

MR. H. H. ECKLES (BCF): A mechanism is being set up for handling this need. At present a master instrumentation proposal and capability file is being compiled at the National Oceanographic Data Center. Reviews of proposals made to each agency are to be placed in the file and also made available to other governmental or nonprofit research groups which might have an interest in the instruments concerned. The file will be organized so as to protect the ideas and rights of companies. It will, however, be a central source of information on instrument possibilities, to be used by governmental agencies. Other research institutions will have access to pertinent, nonproprietary information in the file but will not have access to the file itself.

MR. CHARLES McLOON (Hughes Aircraft Company): In the synoptic survey system of the ASWEPS program, have data sampling rates been determined? If so, will the data link handle the volume?

MR. J. J. SCHULE, JR. (HO): The proposed synoptic survey system, which is planned for installation aboard ocean station vessels, picket ships, and selected fleet destroyers, will provide a representation of the vertical distribution of temperature, sound velocity, and conductivity as a function of depth. The specific vertical sampling interval for these data has not as yet been decided. It may consist of 20 to 30 readings for each variable. When the system is fully developed, we can expect to have about 50 to 60 ships reporting, each ship transmitting four sets of observations a day. When compared to other data handling problems, the volume of data connected with this system is not considered excessive and could easily be handled by the proposed data link.

MR. WILLIAM PRICHEP (Specialty Electronics Development): What areas of instrumentation exist which are satisfactory in their present state -- if any?

MR. G. JAFFE (HO): The following instruments are giving satisfactory service, although there is room for some improvement.

This information is taken from the Instrumentation Summary of Special Publication No. 41, Oceanographic Instrumentation, Final Report of the Committee on Instrumentation, Second Edition, October 1960, U. S. Navy Hydrographic Office, Washington, D. C. (price $1.80).

Instrument	Operating Limits
TEMPERATURE	
Mechanical Bathythermograph	Depth: 0 to 900 ft. Accuracy: ±10 ft. Temperature: -2.2 to 32.2° C. Accuracy: ±0.1° C.
Deep-sea reversing thermometers	Depth: 0 to 20,000 ft. Accuracy: ±100 ft. Temperature: -2 to 30° C. Accuracy: ±0.01° C.
Wire-wound resistance thermometer	Depth: Surface. Temperature: -5 to 30° C., -25 to 5° C. Accuracy: ±0.1° C
Airborne radiation thermometer	Depth: Surface. (Aircraft height 35 to 2,000 ft.) Temperature: -2 to 35° C. Accuracy: ± 0.2° C.
Thermocouples	Depth: 0 to 200 ft. Temperature: -50 to 10° C. Accuracy: ±0.5° C.
SALINITY	
Sea water sampler-- Nansen bottle	
a. Volumetric method (Titration)	Salinity accuracy: ±0.02‰.

b. Conductivity bridge salinometer (University of Washington)	Salinity accuracy: ±0.005‰. Repeatibility: ±0.001‰.
Electrical method--conductivity cell	
a. Foxboro Company	Accuracy: ±0.1‰.
b. Serfass Bridge	Accuracy: ±1.0‰ (0.1‰ if calibrated before and after use).

DEPTH

Unprotected mercury thermometer	Probable error of depths: ±15 ft. for depths less than 3,000 ft.; at greater depths to about 0.5%.
Mechanical pressure transducer (Bourdon tube, bellows, helical coil, aneroid, etc.)	Depth: 0 to 1,500 ft. Accuracy: ±15 ft.
Electronic pressure transducer ("Vibratron," strain gauge, variable reluctance, etc.)	Depth: 0 to 1,500 ft. Accuracy: ±4 ft. (Accuracy of the system is generally limited by the recording apparatus.)

CURRENT

Mechanical current meter (Ekman)	Speed: 0.15 to 2.5 knots. Accuracy: ±0.1 knot. Direction: 0 to 360°. Accuracy: ±10°.
Electro-mechanical current meter	
1. Price meter	Speed: 0.1 to 6.5 knots. Accuracy: ±0.1 knot. Direction: None.

2. Roberts meter, Mod. 3	Speed: 0.2 to 7.0 knots. Accuracy: ± 0.1 knot. Direction: 0 to 360°. Accuracy: ± 10°.
3. Low velocity types	
a. Hytech	Speed: 0.1 to 7.0 knots. Accuracy: ± 0.1 knot. Direction: 0 to 360°. Accuracy: ± 10°.
b. Crouse-Hindes	Speed: 0.1 to 7.0 knots. Accuracy: ± 0.1 knot. Direction: 0 to 360°. Accuracy: ± 10°.
c. Pruitt	Speed: 0.04 to 7.0 knots. Accuracy: ± 0.01 knot. Direction: 0 to 360°. Accuracy: ± 10°.
d. CM-3 (Japanese)	Speed: 0.2 to 5.0 knots. Accuracy: ± 0.1 knot. Direction: 0 to 360°. Accuracy: ± 10°.
Geomagnetic electro-kinetograph (ONR)	Uncertain.
Photographic type of current meter (German paddle wheel)	Speed: 0.3 to 3.0 knots. Accuracy: ± 0.1 knot. Direction: 0 to 360°. Accuracy: ± 10°.
Parachute drouges	Speeds and accuracies determined from tow tests by the Hydrographic Office.

WAVE HEIGHT

Bottom pressure instruments Wiancko pressure measuring system (U.S. Navy Mine Defense Laboratory)	Depth: up to 200 ft. Senses changes in water height of 0.1 to 80.0 in.

Floating wave gauge Electric wave staff	Depth: 0 to 20 ft. Accuracy: ± 0.5 ft.
Fixed wave gauge Resistance wire wave staff (Research by U. S. Navy Hydrographic Office; Development by Atlantic Research Corporation under contract to HO)	Depth: 0 to 15 ft Accuracy: ± 0.2 ft.
Inverted echo sounder (Edo Corp. -- utilized on submarines)	Depth: 55 to 100 ft. relative to keel depth. Accuracy: ± 0.5 ft.

LIGHT

Pyrheliometer -- solar intensity (Eppley Laboratory)	Intensity range: 0.25 to 1.50 g.-cal./cm.^{2}/min. Accuracy: ± 1.5%. Wave length range: 3,000 to 50,000 A.
Radiometer -- long wave and solar radiation; diurnal and nocturnal (Geir and Dunkle)	Unknown.
Submarine photometer	Depth: Approximately 500 ft.
Hydrophotometer, Mark 2	Depth: 200 ft.
Secchi disc	Depth: 20 ft. (maximum)
Water clarity meter (Visibility Laboratory, University of California)	Depth: 500 ft.

BIOLOGICAL

Meter or half-meter plankton samplers	Towing speed: not greater than 2.0 knots.

Clarke-Bumpus Plankton Sampler (Woods Hole Oceanographic Inst.)	Same as above.
Midwater trawl	Same as above.
Hi-Speed Sampler (Scripps Institution of Oceanography)	Towing speeds: 8 to 12 knots.
Hardy Continuous Plankton Recorder (British, used by Woods Hole Oceanographic Institution)	Towing speeds: 15 knots.
Convex-concave fouling plates	Plates in the environment from 1 month to 2 years.
Deep-sea multi-shot camera (Type III, Navy Electronics Laboratory)	Depth: Greater than 20,000 ft. Number of photographs per operation: Approximately 55.

GEOLOGICAL

Mechanical bottom signalling device, "Ball Breaker"	Depth: Unlimited.
Substrata Acoustic Probe (Marine Sono-probe)	Depth: 700 ft. Sediment penetration: 200 ft.
Precision Depth Recorder (Times Facsimilie Corp. and AN/UQN) (Edo)	Depth: Up to 18,000 ft. Sediment penetration: 120 ft. (extreme maximum).
Fathometer -- echo sounder (Model 255B -- Edo Corp.)	Depth: 2.5 to 1,500 ft. Accuracy: ± 1 to 6 ft. depending on depth scale in use. Sediment penetration: undetermined.

Corers

1. Gravity type -- Phleger	Depth: Unlimited -- determined by length of lowering cable used. Sediment penetration: 4 ft.
2. Piston type	
a. Kullenburg	Depth: Unlimited. Sediment penetration: 6 to 12 ft.
b. Ewing	Depth: Unlimited. Sediment penetration: 20 to 60 ft.

Grab samplers

1. Clamshell snapper (Navy Electronics Lab.)	Depth: Unlimited. Sediment penetration: Surface.
2. Mud sampler	Same as above.

TIDES

Portable automatic tide gauge	Senses tide changes to approximately 0.1 ft.

GRAVITY

Submarine and surface ship gravimeters

1. LaCoste and Romberg

2. Askania (Graf)
   West Germany

Geodetic (land) gravimeters

1. Worden gravimeter	Range limit:

	a) Equator to approximately 45° north & south latitude. b) About 30 to 90° north & south latitude. Accuracy: ±0.1 milligal.
2. North American gravimeter	Total range: 1,000 milligals (can be used worldwide by resetting).
3. LaCoste and Romberg gravimeter	

MAGNETISM

Vector airborne magnetometer Types 2A and 2B (Naval Ordnance Laboratory)	Total field: 23,000 to 78,000 gammas. Accuracy: ±0.05%. Inclination: -90 to +90°. Accuracy: ±0.1°. Magnetic heading: 0 to 360°. Accuracy: ±0.1°. Relative Bearing (Astro): 0 to 360°. Accuracy: ±0.1°.
Marine navigational aid magnetometer (Varian free nuclear precision magnetometer, model XN-4901)	Total field: 25,000 to 73,000 gammas. Accuracy: ±0.003% or ±0.5 gamma.
Land magnetic stations Fuska field magnetometer	Magnetic dip: 90° N. to 90° S. ±1'. Magnetic meridian: 0 to 360° ±1' arc. True meridian: 0 to 360° ±1' arc. LOG MH: ±0.001. LOG H/M: ±0.001.

(A) Instruments for measuring angles and distances.

1. Angle measuring	Angle read to 1''; estimated to 0.5''.
a. T-2 Theodolite (H. Wild Co., Switzerland)	Azimuths determined to within 1'' of arc. Distance of measuring line: 10 to 12 nautical miles.
b. T-3 Theodolite	Angle read to 0.2''. Distance of measuring line: 25 to 30 nautical miles.
c. T-4 Theodolite	Angle read on horizontal circle to 0.1'' Angle read on vertical circle to 0.2''.
2. Levels (Wild Models N-II and N-III)	
3. Distance measuring	
a. Geodimeter -- NASM-2 (AGA, Sweden)	Maximum range: 38 to 40 nautical miles. Accuracy: 6 ft.
b. Tellurometer (Tellurometer, Ltd., South Africa)	Maximum range: 38 to 40 nautical miles. Accuracy: 20 ft.

(B) Electronic positioning systems (Navigational Aids).

1. Hyperbolic Systems	
a. Loran-A (Long-range accuracy)	Range (useful): approximately 200 nautical miles. Accuracy: 15 ft. on baseline; 400 ft. at outer limits of usable area.

2. Ranging Systems

a. Shoran (Short-range navigation)	Range: Generally restricted to approximately line-of-sight distances. Accuracy: 30 to 50 ft. in 40 nautical miles.
b. LAMBDA (Decca Navigator, Ltd., England)	Range: 250 nautical miles Accuracy: 100 to 400 ft. depending on which end of the range is being used.

MR. R. B. PRIEST (Fairchild Camera and Instrument Corporation): How much use has been made of television in oceanography? What results have been obtained as to range of view and depth of operation with artificial light and with natural ambient light?

MR. J. M. CROSSEN (BCF): Underwater television has been useful in making oceanographic observations since 1948. However, reduced size and ease in maintenance due to more sensitive cameras, transistorized and modularized construction, and logging cable which incorporates electrical conductors and strength capabilities have resulted in increasingly wider utilization of television.

Television has been used successfully for many applications, such as:

1. Searching the ocean floor for sunken vessels, aircraft, transoceanic cables, and ordnance equipment. Generally, this type of operation requires the use of a remote-controlled trolled vehicle.
2. Bottom surveys of sediments and studies of the demersal fauna. In this application the camera is set in a stand and lowered just off or on the sea floor.
3. Studying the behavior of fish in their natural environment as well as within trawls, traps, and dredges.
4. Observations of individual animals in and out of deep scattering layers in conjunction with sonar.
5. Within submarines as an aid to navigation and for obsering certain operations.
6. Water temperatures, current flow, internal wave motion, and other oceanographic data have been directly monitored on a continuous basis.

7. Where high definition is required it has been used as a view finder with still and/or motion picture cameras.
8. Observations have been made for marine engineering projects.

Basically, two types of television systems are available for making underwater observations. These are the image orthicon and the vidicon. Where low light levels are encountered and high resolution is a requirement, the image orthicon is generally recommended. When artificial illumination is to be used and cost is an important consideration, then a vidicon system may satisfactorily be employed.

A wide range of visibility is encountered in the ocean. Many coastal areas limit viewing range to as little as 2 feet, while offshore, visibility ranges of well over 100 feet have been reported. Of great importance in underwater visibility is the loss of intensity of light, caused by part of the light being reflected from the surface, by absorption, and by scattering. Horizontal scattering of light beneath the surface varies considerably with depth and locality. In coastal waters with much wave action the planktonic life and particles of minerals cause excessive turbidity, and in some places half the total light is absorbed in the first 10 feet.

Artificial lighting was found to improve contrast considerably. However, for optimum results particular care must be used in the physical arrangement of lights. The light source should be placed as near the subject as possible to reduce back scattering from particles.

Observations made with the image orthicon system (tube type #5820) of our Woods Hole Laboratory have shown that adequate visibility of 20 to 30 feet, with natural illumination, was consistently found in certain areas off New England in depths of up to 25 fathoms. One February, on the northeast edge of Georges Bank, we were able to observe, at 40 fathoms with natural illumination, the headrope of a trawl approximately 50 feet from the camera. It should be noted that image orthicons now available are more sensitive than the one we used.

The U. S. Navy Bureau of Ships has reported making observations up to 100 feet away at depths of 800 feet in an area off Newfoundland with the use of high sensitivity image orthicon cameras. Observations have been reported in depths up to 500 meters without the aid of artificial illumination.

MR. J. R. R. HARTER (BUSHIPS): In November 1954 a cooperative project was conducted by the Bureau of Ships and the Bureau of Commercial Fisheries at Miami, Florida. Mr. R. F. Sand, Mr. F. H. Stephens, Jr., and a small group of Bureau of Ships technical personnel continuously observed the performance of experimental midwater trawls to a maximum depth of 60 fathoms. Operations were conducted aboard the Fish and Wildlife Service's ship Oregon in the Bimini area. The optical characteristics of these waters would be classified as "good"; they provided light transmission on the order of 80 percent on this occasion. Horizontal viewing distances as great as 120 feet produced useful information on net and rigging performance, as well as the antics of marine life entering or avoiding the trawl. The underwater television (UW-TV) camera used was the first Image Multiplier Orthicon (IMO) camera expressly designed for this environment, Bureau of Ships model CXRL. The camera was controlled in depth and attitude by our "UW-TV Glider," a towed, remote-controlled vehicle.

Relatively little technological improvement that effects the maximum range of underwater vision has been accomplished since that time. Currently, low light level IMO cameras, having useful performance characteristics at illumination levels on the order of one millionth of a candle per square foot, should provide comparable viewing distances in clear water to depths on the order of 200 fathoms. Increased light sensitivity has relatively little influence on the viewing distance due to the characteristic turbidity of the clearest of natural waters. Improved light sensitivity increases the depth attainment with natural illumination. We have recorded useful, detailed, pictorial information from an UW-TV camera of the low light level IMO type at a depth of 150 fathoms in North Atlantic waters. Natural illumination between the hours of 1000 and 1500 provided viewing distances up to 100 feet.

On the occasion of the 150 fathom surveillance project, the application of artificial illumination by the best practical technique possible reduced the viewing distance by a factor of 66 percent due to the "blinding" effect of scattered light.

In all related instances the UW-TV picture quality obtained provided true halftone detail sufficient to establish shape and textural information. By reducing the information requirement to outline information or object detection, maximum ranges will be increased on the order of 33 percent.

You will note that the information provided consists of specifics rather than broad statements. Due to great variations in the optical characteristics of natural waters, theoretical essays on the subject of hydrological range are presently conceived to be primarily useful in the design of UW-TV equipment. It is hoped that these empirical data will provide the assistance you required. (See also pages 227 - 228.)

MR. SAM O. RAYMOND (Edgerton, Germeshausen & Grier, Inc.): Does the National Oceanographic Data Center have, or does it plan to have, a library of deep sea photographs taken in various parts of the oceans of the world?

MR. H. W. DUBACH (NODC): Yes. We have already acquired a few such pictures; those obtained to date are primarily of interest to the marine geologists. We expect that in the next decade there will be many more bottom photographs obtained and submitted to us as well as pictures of biological life and ice.

MR. R. P. SHAW (Philco Corporation): Does there exist a satisfactory equation of state for water relating pressure, volume, temperature, and entropy or enthalpy; and, if so, does it explain why sound speed increases, then decreases with temperature?

MR. F. D. JENNINGS (ONR): There is an equation of state for sea water and this has been related to entropy and enthalpy by N. P. Fofonoff. This subject was widely discussed at the 1958 meeting in Easton, Maryland, on the Physical and Chemical Properties of Sea Water. The Proceedings of that meeting were published as: Physical and Chemical Properties of Sea Water, National Academy of Sciences -- National Research Council, Publication No. 600, 1959. Whether or not the equation of state for sea water is satisfactory is a matter of some disagreement among oceanographers.

In reality, the velocity of sound only increases with temperature. The minimum sound-velocity channel in the oceans is caused by the combined effects of temperatures, pressure, and salinity.

MR. NATHANIEL SHEAR (Emerson Research Laboratories): Administratively, how is the funding for oceanographic instruments handled?

MR. T. J. WEHE (HO): At present, funding is generally by the using agency insofar as purchase of production items is concerned.

MR. TED SMITH (Packard Bell Computer): What is the significance of bio-oceanographic work to defense programs?

DR. S. R. GALLER (ONR): The answer to this query would entail a complete description of our program and a full discussion of our philosophy as follows:

Although not generally recognized outside of the scientific community, the U. S. Navy through its Office of Naval Research is one of the principal sponsors of fundamental hydrobiological research in the United States. The Navy's major effort in this field occurs through the Office of Naval Research Hydrobiology Research Program and includes sponsorship of over 100 basic research contracts and grants in academic institutions in the United States and abroad involving the research activities of several hundred outstanding scientists throughout the world. As one of the major consumers of hydrobiological information, the Navy is vitally interested in the maintenance of a vigorous, healthy national research effort in this field of scientific endeavor.

The purpose of this presentation is threefold: (1) To describe the reasons for the Navy's interest in hydrobiology; (2) to ascertain the nature and scope of the Hydrobiology Program's contributions to naval operations; and (3) to review the requirements for maintaining an optimum level of scientific activity in this field.

The term "hydrobiology" as used here describes research conducted to identify and characterize the biological components of marine, estuarine, and freshwater environments, and to ascertain the interrelationships of these components with the physical and chemical factors of their environments.

The Office of Naval Research in 1951 instituted a program of basic research in hydrobiology with a twofold objective: (1) To assess the impact of the biological components of the marine environment on naval operations, and (2) to obtain the basic information necessary for developing the means to recognize and cope with the hydrobiological causes of naval problems. During the last decade, the Navy has profited quite substantially from the Hydrobiology Program not only along the lines anticipated when this program was first formulated but in many ways quite unforeseen at that time.

At this point it would be appropriate to present, very briefly, an unclassified inventory of the naval problems and interests which are now recognized as being marine biological in origin and/or which require basic hydrobiological information for their resolution. In general, this inventory may be broken down into two major problem categories:

A. Control of, or protection against, marine biological components interfering with naval operations, and

B. Utilization of marine biological elements and information towards the enhancement of naval operations.

A. Control of Marine Biological Interference with Naval Operations.

1. Prevention and control of marine biological deterioration and fouling: It has been conservatively estimated that the annual cost to the Navy alone for the protection and maintenance of ships, waterfront structures, and outboard equipment against marine biological deterioration and fouling is approximately $100,000,000. This figure does not include the costs of increased fuel requirements or the costs of overcoming the logistic and supply problems resulting from marine boring or fouling damage. This problem is further complicated by the fact that many of the protective agents which were developed since World War II are incompatible with the optimum operational characteristics of a number of modern special purpose components, equipments, and systems. As a consequence, the Navy is engaged in a never-ending search for new means of controlling the activities of marine organisms responsible for deterioration and fouling. The review and assessment of this problem by the scientists engaged in fundamental hydrobiological research under Navy auspices has resulted in a reorientation of the Navy's research and developmental activities in the field of marine protection. It deemphasizes the empirical "trial and error" approach to the development of new protective agents. Instead, it stresses the importance of understanding the vital processes which govern the life cycles and behavior of the organisms causing deterioration and fouling with the objective of characterizing the "weak links" in the chain of vital processes, i.e., those basic functions which are susceptible to external control. Obtaining this information is a requisite for the development of whole "families" of control agents which can be "custom tailored" to protect in manners compatible with the efficient operation of a particular naval equipment or system.

Progress: The Hydrobiology Program has yielded basic information showing that certain types of molluscan fouling organisms depend on an enzyme to control the rate of shell deposition. Also, it appears that this enzyme can be inhibited by external means. A number of substances have been tested in the laboratory to determine their effectiveness as enzyme inhibitors. Several of them show considerable promise and are being field evaluated to determine their suitability for actual use in the field. Also, considerable progress has been made in determining the nutritional requirements and mechanisms of digestion of crustacean marine borers. It has been ascertained that a specific enzyme is required for the utilization of cellulose by the wood gribble -- an organism which is responsible for much of the marine borer damage. In the course of efforts to evaluate a number of compounds as enzyme inhibitors in the wood gribble, it was discovered that a silver compound was extremely effective in preventing attack by the wood gribble and the shipworm. The results of a 3-year field evaluation program conducted both in temperate and semitropical waters indicate that this compound has provided 100 percent protection during this period.

The progress in physiology and biochemistry just presented is cited to show the broad spectrum of scientific research encompassed within the Hydrobiology Program. Hydrobiology, like the closely related field of oceanography, is not a single scientific discipline. It is a multidisciplinary effort extending from taxonomy and the descriptive biological sciences, through ecology and so-called "biological oceanography," well into physiology, biochemistry, biophysics, and the other modern disciplines of quantitative biology. Also, hydrobiological research relies heavily upon modern chemistry, physics, mathematics, and the earth sciences for assistance.

In addition to the progress already cited, the Navy continues to obtain a body of data regarding the worldwide distribution and population fluctuations of marine organisms responsible for deterioration and fouling. This information is of direct benefit to the Navy in the design and construction of waterfront structures and outboard equipment, and in the planning of naval operations. Finally, research data is being obtained relevant to the control of marine borer damage and fouling on a number of classified high priority naval projects.

2. Prediction and control of biological particulates interfering with the propagation of acoustic signals underwater: Ever since it was discovered during World War II that the false bottom echoes or deep scattering layer being picked up on sonar was due to marine organisms, the Navy has been vitally concerned with learning more about the role of marine biological particulates in the transmission and reception of sound underwater. The Hydrobiology Program has yielded basic information implicating marine biological particulates in a number of ways as follows: Marine organisms, even very small ones ranging in size from a few millimeters to less than one millimeter in length, may cause sound reverberation or attenuation if present in sufficient numbers. Larger marine animals may exhibit acoustic target characteristics similar to the characteristics of operational targets, i.e., the so-called "false target" problem.

Marine animal sound emitters may produce sounds which greatly increase the ambient sound level as in the case of snapping shrimp, barnacles, etc., or they may emit sounds which may be confused with sounds produced by surface or underwater vehicles. Also, sedentary marine organisms, i.e., fouling animals and plants, may either camouflage a target, rendering it less susceptible to acoustic detection as in the instance of soft fouling masses covering a bottom mine, or it may increase the acoustic target strength of an underwater object as in the case of barnacle and mussel growth on rubber- or plastic-covered equipments. The immediate objective of the Hydrobiology Program has been to provide the Navy with a body of information which will enable it to predict the degree and type of marine biological interference which it is likely to encounter in any environmental and geographical locality of current or potential operational interest. The program has been quite successful in meeting this requirement except for one aspect; namely, the need to obtain data on deep ocean biological sound producers. However, this problem is being overcome by the establishment recently of a permanent underwater bioacoustic station to which will be added shortly an underwater television system. Both the acoustic and video pickups will be located in the Florida Straits on the bottom of the Gulf Stream. They will be cable-connected to a marine laboratory located on the island of Bimini in the Bahamas and will enable scientists to monitor and record sounds produced by relatively deepwater animals which either live in the Florida Straits or migrate along the Gulf Stream. When completed, this installation will represent the world's first permanent deepwater biological acoustic-video research station.

The problem of control of marine particulates of bioacoustic importance is much more complex and requires a knowledge of the biology and behavior of these forms. This is a long-term project involving taxonomy, chemistry, ecology, physiology, and acoustics. However, good progress is being made in acquiring a body of fundamental information on this subject.

The problems of control of marine deterioration and fouling as well as the problem of marine biological interference with underwater sound propagation have been presented in some detail in order to illustrate the scope of the Hydrobiology Program. In addition, a number of other problems of concern to the Navy may be mentioned briefly.

3. Control of and protection against poisonous, venomous, and carnivorous marine animals: The Navy continues to be confronted with the problem of protecting underwater swimmers as well as survivors at sea against sharks, barracuda, moray eels, and other

carnivorous animals. In addition, it is necessary to develop means for protecting naval personnel against a wide variety of venomous and poisonous organisms which may be encountered in the course of naval operations. The Hydrobiology Program is yielding information on the seasonal and geographic distribution of obnoxious marine forms which enables the Navy to consider this problem during the planning of naval operations. In addition, the scientists engaged in hydrobiological research are conducting physiological, biochemical, and pharmacological investigations to develop means for repelling or deterring dangerous marine forms as well as to evolve therapeutic measures for treating personnel injured by such animals. A number of compounds and techniques have been discovered which show promise of aiding in the control of this problem.

4. Prediction and control of marine bioluminescence: In certain geographic areas during certain seasons there occurs tremendous growths of populations of marine plants and animals which emit visible light when stimulated mechanically. This phenomenon has resulted in rendering surface vessels, submarine and mine fields detectable from the air. During World War II, a number of ships and torpedo boats were detected and attacked because of the bioluminescent wakes resulting from mechanical stimulation of light-emitting organisms. The Hydrobiology Program is providing the Navy with data regarding the geographic distribution, type, and seasonal occurrence of bioluminescence. This data is important in the planning of naval operations. In addition, research is being conducted to establish the biochemical and physiological mechanisms of bioluminescence in the hope that it may become possible to develop means for controlling this phenomenon.

The limitations of space prevent a complete discussion of the other hydrobiological problems of interest to the Navy. However, they are listed as follows:

5. Prediction and control of populations of fishes of commercial and sports importance occurring in areas in which the Navy is conducting underwater acoustic or explosive tests.

6. Prediction and control of populations of marine organisms which could be susceptible to radioactive contamination as a result of exposure to underwater nuclear explosions.

7. Prediction and control of marine organisms interfering with mine warfare, mine countermeasures, as well as submarine and anti-submarine warfare operations. This is a classified research phase of the Hydrobiology Program.

B. The second major objective of the Hydrobiology Program is to provide the Navy with means for utilizing or emulating marine biological phenomena towards the improvement of materials, components, equipments, personnel performance, and systems. Some of the important research activities being conducted under this phase of the program are as follows:

1. Studies of the hydrodynamic characteristics and boundary layer control of marine animals: These studies afford an opportunity to obtain basic information which will be useful in the design and construction of new hulls for surface ships and submarines.

2. Research on the mechanisms of propulsion of marine animals: Data is being obtained to indicate that many marine organisms possess propulsive mechanisms which are not only highly efficient but which are silent, presenting no detectable hydrodynamic turbulence. This is a phenomenon of considerable applied interest to the Navy.

3. Marine animal communications and navigation: It has been established that many kinds of marine animals are able to detect and identify targets and "navigate" towards these targets over great distances with extreme accuracy. Further, it has been ascertained that many of these forms are able to engage in apparently secure underwater communications exchanges. The Hydrobiology Program is yielding data which will lead to the evolution of new concepts of target identification, long-range underwater navigation, and underwater communications. Ultimately, it is hoped that the fundamental information will be used for the design and development of mechanical and electronic analogues of direct value to the Navy.

4. Physiological and biochemical evaluation of deep diving abilities of marine animals: Many marine animals including whales, porpoises, seals, as well as a variety of fishes are able to dive very rapidly to relatively great depths and surface just as rapidly without developing the "bends" or other diseases associated with human divers. It is hoped that the information being obtained from this phase of the program will be helpful in developing means for protecting many divers and underwater swimmers against these occupational hazards.

5. Photosynthetic gas exchangers: One of the important problems in the area of submarine habitability is the need for developing improved means for maintaining a viable atmosphere and getting rid of toxic gases. Plants including algae are able to produce oxygen and consume carbon dioxide through the process of photosynthesis. Research is being conducted which is aimed at elucidating these exceedingly complex reactions. In addition, investigations are being conducted on the nutritional requirements, the physiology and the biochemistry of algae in an effort to determine

the feasibility of establishing photosynthetic gas exchanges for use aboard submarines.

6. Artificial gills: As described in paragraph five above, the Navy is interested in developing improved mechanisms for maintaining an adequate atmosphere aboard a submarine. Many types of large marine animals dwell in the deep ocean which is supposedly very poor in dissolved oxygen content. Nevertheless, these forms are able to thrive in this environment. This suggests that the organisms may have low metabolic requirements or highly efficient gas exchange mechanisms for extracting oxygen from the water and disposing of carbon dioxide back into the water. Efforts are being made to characterize these systems to the point where it would be possible to determine their value as a basis for the development of artificial gills.

7. Utilization of marine biological products: It has been observed that certain marine animals and plants produce substances which either repel other forms or inhibit their normal physiological activities. Many of these substances are being collected and examined in terms of their biochemical composition. Also, the physiological and pharmacological characteristics are being investigated. Ultimately, it is hoped that some of these biologically active substances will prove to be of practical value as shark repellents or deterrents, as antibiotics, as marine preservatives, as well as in other ways of interest to the Navy.

8. Utilization of marine animals and plants in naval operations (classified).

Now that we have considered the Navy's interests in hydrobiological research as well as the nature and scope of the Hydrobiology Program, let us review some of the requirements for maintaining an optimum level of scientific activity in this field. In general there are two requirements:

1. The essential need to maintain a free research atmosphere unfettered by "kibitzing" from the sponsoring organization: At first hand this concept may appear as a contradiction of the statements previously presented in this paper. However, if we examine the <u>modus operandi</u> of the Hydrobiology Program, we find that it is quite in harmony with this concept. The design and plans for this program represent the exclusive responsibility of the Office of Naval Research, i.e., the general mosaic of the research needs and objectives are established and maintained by the Office of Naval Research. However, once the objectives are established, the individual investigations are selected and activated from a large number of unsolicited proposals received from dedicated scientists located for

the most part in universities or other nonprofit research institutions. In a smaller number of instances proposals are received from scientists affiliated with industrial organizations. In no instance is a proposal solicited. Indeed, generally the scientists submitting the basic research proposals are unaware of the Navy's applied programmatic interests in hydrobiology. The result is a happy wedding of the intellectual interests of the scientists and the consumer interests of the Navy. In the first instance, the investigator is free to carry on research sponsored by the Office of Naval Research which represents his personal scientific selection. In the second instance, because of the care used in selecting basic research for Office of Naval Research sponsorship, the Navy obtains the fundamental data which it needs for its own purpose. Thus, under this system the research program manager in the Office of Naval Research has the major responsibility of fitting together the research pieces of the "jigsaw puzzle" to construct a Hydrobiology Program mosaic which is of significance to the Navy.

2. There is a pressing need to provide the scientists engaged in hydrobiological research with improved research facilities and equipment. It is important in this regard to recognize that the great majority of the scientists conducting research in this field are not affiliated with oceanographic institutions. Most of them are associated with biology departments of universities or with marine biological field stations. In a great many cases seagoing research ships are not available to them. Also, in a disturbingly large number of instances the research ships which are made available for their use are available for relatively short periods, and often on a not-to-interfere basis. Also, it is important to note that most of the oceanographic research ships are suitable only for a narrow range of biological researches -- primarily for survey types of biological collecting. As a result, it is exceedingly difficult for the research biologist to conduct so-called "standard station investigations," that is, to investigate the population dynamics and biological activities of marine organisms in a given locality for extended periods or over several seasons. Another important problem quite closely related to the scarcity of suitable research ships is the lack of specialized equipment. There is a pressing need for improved collecting devices. Recently, the Office of Naval Research pioneered in the development of an automatic plankton collector which could be mounted on the hull of a submarine. This device, known as the Gizmo I, was used quite successfully on the U. S. S. Sea Dragon during its circumpolar cruise. This has provided the scientific community with a valuable series of biological collections obtained from middepths and from a variety

of oceanic environments. More devices of this kind are urgently needed. Similarly, there exists a need for deep ocean devices which will enable the biologist to study the physiological behavior of large animals in situ in view of the impossibility of bringing large, deep ocean dwelling animals to the surface in suitable condition for study.

Finally, there is a need for recognizing the important scientific contributions which can be made by limnologists and freshwater biologists in improving our knowledge of the oceans. Many of the scientists currently engaged in oceanic research were originally trained in departments of limnology and at freshwater laboratories. Lakes and ponds can be useful research models for investigating biological phenomena which are closely analogous to biological conditions in the oceans. Additional research facilities and scientific equipment which might be made available for limnological research could bear handsome dividends in improving our knowledge of the oceans.

In conclusion, we would wish to emphasize that there is an urgent need for improved instrumentation for marine biological research, but we feel that before we consider improving the current instruments it is necessary that we evolve new concepts of instrumentation. Therefore, we would want to ask ourselves the question: Are we content to continue to improve equipment which operates on proceeding at a few knots at the most? Are we content to instrument only specially designed research ships or are we prepared to proceed toward the development of radically new sampling and measuring devices that can operate at high speeds from a ship of opportunity? We are of the opinion that the latter is a direction which we must seriously consider.

MR. TED SMITH (Packard Bell Computer): 1. Of the 20-odd transducer types mentioned for survey vessels, indicate the number which provide output in the following ranges: 0 to 10 v.d.c., 0 to 1 v.d.c., 0 to 10 mv.d.c., 1 mv.d.c. or less. 2. What are the normal analog amplifier bandwidths necessary for transducer amplification? 3. Are differential inputs to the amplifiers needed? What is the common mode frequency and what CMR is necessary? (See also page 225.)

MR. G. JAFFE (HO): The answers to Mr. Smith's questions are of a general nature and are as follows: 1. The output of the transducers will be in a range 0 to 5 volts d.c. or a.c., maximum. 2. The normal analog amplifier bandwidths are within the range, 0 to 30,000 c.p.s., maximum. 3. There is a possibility that differential inputs to amplifiers might be needed if the signal is to be amplified at the terminal end. If so, then the common mode frequency will be 60 c.p.s. and the CMR necessary will be the greatest that is practically possible to obtain.

MR. ROBERT M. SPIEGEL (Polorad Electronics): 1. Cannot Omega's 8-mile ambiguity be resolved by audio modulation of the carrier? 2. What firms are developing equipment? 3. Cannot the problem of large distance from shore for fixed stations forming part of navigational systems be overcome by permanently anchoring buoys or "electronic lighthouse" vessels for navigational reference purposes?

LIEUTENANT COMMANDER R. P. DINSMORE (USCG): 1. In the Omega program a 200-cycle FSK modulation originally was included to resolve the 8-mile ambiguity. This is a complex circuit, however, and was dropped about two years ago on the basis that its complexity outweighs its usefulness. 2. Commercial firms presently developing Omega receivers are Motorola and I.T. & T. The Naval Research Laboratory also is conducting developmental research. 3. The large power requirements (30 kw.) and elaborate antenna array obviates the use of buoys in a Loran or other similar chain. Further, Loran is only semi-automatic and requires constant manual monitoring and synchronization. The use of an anchored ship is possible although antennas, maintenance, and positional requirements make such consideration marginal. Coast Guard experience with lightships indicates a station keeping error which would be greater than the accuracy of a high performance system. A moored shipboard transmitter whose position is automatically determined and synchronized to two other stations in a chain is feasible but has not been considered to date.

MR. R. E. TRIPPENSEE (Wildlife Supply Company): Are research pressure tanks available -- small size -- where -- price?

MR. J. M. SNODGRASS (SIO): Yes. The smallest size that I am aware of is rated nominally at 100 ml. The dimensions of the small chamber are 1-1/4 in. (inside diameter) by 5 in. (inside length). This particular one may be obtained in two pressure ranges, one 12,000 p.s.i. at a nominal 650° F. maximum, or 30,000 p.s.i. at 650° F. maximum. They are available all the way up to what may be called plant-size reactors, which are, for instance, 12 ft. inside depth by 12 in. inside diameter. I would be pleased to refer you to two sources of supply: one, Autoclave Engineers, 2930 West 22nd St., Erie, Pennsylvania; the next is the American Instrument Company, Inc., 8030 Georgia Avenue, Silver Spring, Maryland. Either company is well able to supply you with almost any size vessel which you wish and work to any pressure within reason up to 30,000 p.s.i. or even 100,000 p.s.i. The latter company has tended to specialize in "super pressure systems" working in the 100,000 p.s.i. range. As far as price is concerned, the smaller sizes probably can be obtained for less than $100, though the price goes up relatively rapidly to one 3-1/2 in. (inside diameter) by 13 in. deep, capable of working to 30,000 p.s.i., will cost approximately $800.

MR. MORRIS WEISS (Barnes Engineering Company): Mr. Schule talked about infrared scanners for horizontal temperature measurement and for ice survey programs. Could we have more specific information here?

MR. J. J. SCHULE, JR. (HO): The obtaining of an accurate horizontal picture of the sea surface temperature pattern has proven to be of great importance in the ASWEPS program. With the Airborne Radiation Thermometer we now can measure sea surface temperature quite accurately from an aircraft, but only along a line directly beneath the aircraft track. The object of making experiments with an infrared scanner would be to broaden the scope of these measurements by using the scanning device to provide a horizontal presentation of the sea surface temperature gradient, while establishing an absolute temperature reference with the Airborne Radiation Thermometer. In this way a more accurate delineation of small scale temperature features can be obtained; these features have proven to be of great interest to us.

It also seems probably that infrared scanning techniques can be used effectively in Arctic ice reconnaissance. Most such reconnaissance is usually carried out visually; the data, therefore, not only contain a considerable amount of subjectivity, but reconnaissance is precluded during the winter months. The nature of the temperature structure in Arctic sea ice and adjacent open water areas makes it appear feasible to use infrared techniques to obtain objective data on a year-round basis. This, of course, would not solve the problem of providing an all-weather capability, but it would be a step in the right direction.

MR. MORRIS WEISS (Barnes Engineering Company): Please comment on the function of "airborne" data gathering in the oceanographic picture. What variables do you expect to measure from the air?

MR. A. C. VINE (WHOI): To date there have not been many kinds of survey-type measurements made from the air. Perhaps the most successful have been infrared measurements of the sea surface to discover and delineate areas and boundaries between water masses of different temperatures. A great deal of valuable magnetic work has been done from the air and more will be done. Sea state observations with low flying radar is another measurement. Acoustic observations, such as, ambient noise, water depth, reverberation, etc., can probably be made from aircraft except costs, including sonobuoys, seem high compared with those made from ships.

The monitoring of a buoy line or field from a plane on at least an experimental basis seems to be indicated.

APPENDIX B

NON-INDUSTRIAL MARINE SCIENCE LABORATORIES AND OFFICES OF THE UNITED STATES, MEMBERS OF THE ICO AND ITS PANELS, AND OTHER INTERESTED PERSONS

The following lists were compiled from the original ICO list and from appendix B of Chapter 11 of Oceanography 1960 - 1970. The laboratories are arranged alphabetically by institution or by Government Bureau. Where the name of the institution or Bureau is not part of the address, it is enclosed in parentheses. Unless otherwise indicated, correspondence should be directed to the Director of civilian laboratories and to the Commanding Officer of military activities and laboratories.

Marine Science Laboratories and Offices

Academy of Natural Sciences of Philadelphia
Department of Limnology
19th and The Parkway
Philadelphia 3, Pennsylvania

Agricultural and Mechanical College of Texas
Department of Oceanography and Meteorology
College Station, Texas

Agricultural and Mechanical College of Texas
Fort Crockett Marine Laboratory
Bldg. 311, Fort Crockett
Galveston, Texas

U. S. Air Force
Aeronautical Chart and Information Center
Second and Arsenal Streets
St. Louis 18, Missouri

Air Force Cambridge Research Laboratories (LRTE)
L. G. Hanscom Field
Bedford, Massachusetts

U. S. Air Force
Office of the Surgeon General, Headquarters
3800 Newark Street NW
Temporary Building 8
Washington 25, D. C.
Attn: Dr. George M. Leiby, AFCSG-1

Air Force Cambridge Research Laboratory (CRZG)
Terrestrial Sciences Laboratory
L. G. Hanscom Field
Bedford, Massachusetts

Alabama Marine Laboratory
Bayou La Batre, Alabama

Alaska Department of Fish and Game
Subport Building
Juneau, Alaska

Alaska Department of Fish and Game
Kitoi Bay Research Station
Kodiak, Alaska

American Geophysical Union
1515 Massachusetts Ave. NW
Washington 5, D. C.

American Museum of Natural History
Department of Fishes and Aquatic Biology
Central Park West at 79th Street
New York 24, New York

American Society of Limnology and Oceanography
Dr. George H. Lauff, Secretary-Treasurer
University of Michigan
Department of Zoology
Ann Arbor, Michigan

Amherst College
Department of Physics
Amherst, Massachusetts

Arctic Institute of North America
1530 P Street NW
Washington, D. C.

Arctic Research Laboratory
Point Barrow, Alaska

Armor Research and Foundation
10 West 35th Street
Chicago 10, Illinois
Attn: J. E. Bridges

U. S. Army Corps of Engineers (3410)
Army Map Service
Washington 25, D. C.

U. S. Army Corps of Engineers
Beach Erosion Board
5201 Little Falls Road
Washington 16, D. C.

U. S. Army Engineer
Waterways Experiment Station
P. O. Box 631
Vicksburg, Mississippi

U. S. Army Engineer District Los Angeles
Corps of Engineers
P. O. Box 17277, Foy Station
Los Angeles 17, California
Attn: River & Harbor Planning Section

U. S. Army
Geodesy Intelligence and Mapping Research Development Agency
Fort Belvoir, Virginia

Atlantic States Marine Fisheries Commission
200 East College Avenue
Tallahassee, Florida
Attn: Ernest Mitts, Secretary-Treasurer

Atomic Energy Commission
Division of Biology and Medicine
Washington 25, D. C.
Attn: Dr. I. E. Wallen, Marine Biologist

Atomic Energy Commission
Environmental and Sanitary Engineering Branch
Division of Reactor Development
Washington 25, D. C.

Auburn University
Department of Civil Engineering
Auburn, Alabama

Bears Bluff Laboratories
Wadmalaw Island, South Carolina

Battelle Memorial Institute
Department of Economics and Information Research
505 King Avenue
Columbus 1, Ohio

Beaudette Foundation for Biological Research
1597 Calzada Road
Santa Ynez, California

Bermuda Biological Station
St. George's West
Bermuda

Bowdoin College
Department of Biology
Brunswick, Maine

Brooklyn College
Department of Geology
Brooklyn 10, New York

Bureau of Commercial Fisheries
Chief, Division of Biological Research
Washington 25, D. C.

Bureau of Commercial Fisheries
Biological Laboratory
P. O. Box 640, 1220 E. Washington
Ann Arbor, Michigan

Bureau of Commercial Fisheries
Biological Laboratory
P. O. Box 1155
Auke Bay, Alaska

Bureau of Commercial Fisheries
Biological Laboratory
Pivers Island
Beaufort, North Carolina

Bureau of Commercial Fisheries
Biological Laboratory
P. O. Box 280
Brunswick, Georgia

Bureau of Commercial Fisheries
Biological Laboratory,
Bldg. 302
Fort Crockett
Galveston, Texas

Bureau of Commercial Fisheries
Biological Laboratory
Gulf Breeze, Florida

Bureau of Commercial Fisheries
Biological Laboratory
P. O. Box 3830, 2570 Dole Street
Honolulu 12, Hawaii

Bureau of Commercial Fisheries
Biological Laboratory
P. O. Box 271
La Jolla, California

Bureau of Commercial Fisheries
Biological Laboratory
Milford, Connecticut

Bureau of Commercial Fisheries
Biological Laboratory
Oxford, Maryland

Bureau of Commercial Fisheries
Biological Laboratory
P. O. Box 6121, Point Loma Station
San Diego 6, California

Bureau of Commercial Fisheries
Biological Laboratory
2725 Montlake Boulevard East
Seattle 2, Washington

Bureau of Commercial Fisheries
Biological Laboratory
450-B Jordan Hall
Stanford, California

Bureau of Commercial Fisheries
Biological Laboratory
Bldg. 74, Naval Weapons Plant
Washington 25, D. C.

Bureau of Commercial Fisheries
Biological Laboratory
West Boothbay Harbor, Maine

Bureau of Commercial Fisheries
Biological Laboratory
P. O. Box 6
Woods Hole, Massachusetts

Bureau of Commercial Fisheries
Columbia Fisheries Program Office
P. O. Box 4332
Portland 8, Oregon

Bureau of Commercial Fisheries
Chief, Branch of Exploratory Fishing
Washington 25, D. C.

Bureau of Commercial Fisheries
Exploratory Fishing and Gear
Research Base
5 Research Drive
Ann Arbor, Michigan

Bureau of Commercial Fisheries
Exploratory Fishing and Gear
Research Base
P. O. Drawer B
1231 Bay Street
Brunswick, Georgia

Bureau of Commercial Fisheries
Exploratory Fishing Base
State Fish Pier
Gloucester, Massachusetts

Bureau of Commercial Fisheries
Exploratory Fishing and Gear
Research Base
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Laboratorire de Radioactivite Marine
Musee Oceanographique
Principaute de Monaco

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Chief, Materiel French Military Mission
2164 Florida Avenue NW
Washington 8, D. C.

Office of Patent Counsel
Code 1104
Naval Research Laboratory
Washington 25, D. C.

United Kingdom Scientific Mission
Office of the Scientific Attache
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U. S. S. R. Embassy
Assistant Naval Attache
2552 Belmont Rd. NW
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Dr. Jerome B. Wiesner, Chairman
Federal Council for Science and Technology
Executive Office Bldg.
Washington 25, D. C.

APPENDIX C

INDUSTRY LIST
GOVERNMENT-INDUSTRY SYMPOSIUM ON OCEANOGRAPHIC INSTRUMENTATION

August 16-17, 1961

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ACF Industries, Inc.
11 Park Place
Paramus, New Jersey

ACF Industries, Inc.
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Edsall and Lincolnia Road
Alexandria, Virginia

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Division of Northrop Corporation
11975 Sherman Way
North Hollywood, California

Aerojet-General Corporation
Oceanics Division
P. O. Box 296
Azusa, California

Aerojet-General Corporation
P. O. Box 527
Monterey, California
Attn: Leslie A. Welge

Aeronutronic
Ford Motor Company
Ford Road
Newport Beach, California

Aeronutronic
Ford Motor Company
1200 Wyatt Building
Washington, D. C.
Attn: J. D. Movius

Aero Service Corporation
210 E. Courtland Street
Philadelphia 20, Pennsylvania

Airborne Instruments Laboratory
A Division of Cutler-Hammer, Inc.
Comac Road
Deer Park, Long Island, New York
Attn: Harry M. Stephey, Manager,
Military Marketing

Airborne Instruments Laboratory
Research & Systems Engineering Division
Walt Whitman Road
Melville, New York
Attn: Rodney F. Simons

Airpax Electronics, Inc.
P. O. Box 8488
Fort Lauderdale, Florida

Airtronics, Inc.
5221 River Road
Washington 16, D. C.
Attn: Mrs. Margery Cain

Alden Electronic & Impulse Recording
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Westboro, Massachusetts

All American Engineering Company
DuPont Airport & Lancaster Avenue
Wilmington 5, Delaware

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43 Leon Street
Boston 15, Massachusetts

Alpine Geophysical Associates, Inc.
55 Oak Street
Norwood, New Jersey

Alpine Geophysical Associates, Inc.
2418 Tangley
Houston 5, Texas

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Arma Division
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1000 Connecticut Avenue NW
Washington 6, D. C.

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York, Pennsylvania

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Greenwich, Connecticut
Attn: S. Silverman

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American Machine and Foundry Company
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Attn: B. Johnson

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Alexandria Division
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Alexandria, Virginia

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Washington, D. C.

American Research and Manufacturing
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Ashton, Rhode Island

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333 Bond Building
1404 New York Avenue
Washington 5, D. C.

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Illinois Institute of Technology Center
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Shirley Highway & Edsall Road
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Atlas Compass & Manufacturing Company
Vashon Island, Washington

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Automated Controls
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Alderwood Manor, Washington

Autometric Corporation
1501 Broadway
New York 36, New York

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Anaheim, California
Attn: Library

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Woodside 77, New York
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Stamford, Connecticut

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230 East Ohio Street
Chicago 11, Illinois

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San Carlos, California

Beckman Instruments, Inc.
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Baltimore 7, Maryland

Belden Manufacturing Company
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Richmond, Indiana
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College Point 56, New York

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North Hollywood, California
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Ann Arbor, Michigan

The Bendix Corporation
Fisher Building
Detroit 2, Michigan

The Bendix Corporation
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Mail Stop 21-97
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Seattle 24, Washington
Attn: Charles M. Proctor

Mission Equipment
Advanced Marine Systems Organization
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Mail Stop 46-74
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Attn: Bob Gregory

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Manager of Engineering
Borg-Warner Controls
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Bulova Research & Development Laboratories
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Woodside 77, New York

Burroughs Corporation
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La Habra, California

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San Francisco 20, California

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Manager

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P. O. Box 623
San Diego 12, California

Cohu Electronics, Inc.
Massa Division
280 Lincoln Street
Hingham, Massachusetts

Coleman Electronics, Inc.
133 E. 162nd Street
Gardena, California
Attn: Loren W. Hill

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Central Bid Registry
Dallas, Texas

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East Orange, New Jersey

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Daystrom, Incorporated
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Garden City, L. I., New York

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Electric Boat
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Star Division, Emerson Electric
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Fairchild Camera & Instrument Corp.
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Defense Products Division
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Fairchild Camera & Instrument Corp.
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Syosset, L. I., New York

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Phoenix, Arizona

Fenwal, Incorporated
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Kirkland, Washington

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Foerst Mechanical Specialities Company
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New York 17, New York

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P. O. Box 3250
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Marine Technology Laboratory
ASW Engineering
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General Electric Company
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Ithaca, New York

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Defense Systems Department
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Heavy Military Electronics Dept.
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Light Military Electronics Dept.
Utica, New York

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Room 900
777 14th Street NW
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General Geophysical Company
750 Houston Club Building
Houston 2, Texas

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Harris ASW Division
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Westwood, Massachusetts

General Instrument Corporation
433 Wyatt Building
777 14th Street NW
Washington 5, D. C.
Attn: V. B. Terminello

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36 Columbus Avenue
San Francisco 11, California
Attn: William E. Butts

General Metals Corporation
1010 Vermont Avenue NW
Washington 5, D. C.

General Mills Electronics Group
1620 Central Avenue
Minneapolis 13, Minnesota

General Mills Electronics Group
Automatic Handling Equipment Dept.
1620 Central Ave.
Minneapolis 13, Minnesota
Attn: Harold E. Froehlich,
Engr. Section Head

General Motors Corporation
Defense Systems Division
Santa Barbara, California
Attn: Dr. J. Frederick Dubus

General Motors Corporation
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1600 N. Woodward Avenue
Birmingham, Michigan

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12 Mile & Mound Roads
Warren, Michigan

General Motors Corporation
Defense Systems Division
Cafritz Building, Room 702
1625 Eye Street NW
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Kearfott Division
1500 Main Avenue
Clifton, New Jersey

General Precision, Inc.
Kearfott Division
1225 McBride Avenue
Little Falls, New Jersey

General Precision, Inc.
50 Prospect Avenue
Tarrytown, New York

General Precision, Inc.
Kearfott Division
808 17th Street NW
Washington 6, D. C.

General Radio Company
8055 Thirteenth Street
Silver Spring, Maryland

General Scientific Corporation
30 Rockefeller Plaza
New York, New York

General Scientific Corporation
815 15th Street NW
Washington, D. C.

Genisco, Incorporated
2233 Federal Avenue
Los Angeles 64, California

Geodyne Corporation
180 Bear Hill Road
Waltham 54, Massachusetts

Geodyne Corporation
28 Water Street
Woods Hole, Massachusetts

Geonautics, Inc.
1346 Connecticut Avenue NW
Washington 6, D. C.

Viron Division
Geophysics Corporation of America
Char-Gale Building
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Geotechnical Corporation
P. O. Box 28277
Dallas 28, Texas

Geotechnical Corporation
P. O. Box 28277
3401 Shiloh Road
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1314 Cedar Hill Avenue
Dallas 8, Texas

The Geraldines, Ltd.
90 Compromise Street
Annapolis, Maryland

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P. O. Box 305
Hartford, Connecticut

Giannini Controls Corporation
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Washington 16, D. C.

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New Orleans 26, Louisiana

Glotex Importers Company
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New York 10, New York

GM Manufacturing Company
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New York 1, New York

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Instrumentation Test Operations
Dept. 486
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Attn: B. B. Carpenter

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Grumman Aircraft Engineering Corporation
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Rockville, Maryland

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Science Park
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Airport Station, Bldg. 110, Mail Station 100
Los Angeles 9, California
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Washington, D. C.

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1019 North Capitol Avenue
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1030 S. Arroyo Parkway
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Hycon Manufacturing Company
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Monrovia, California
Attn: R. A. Ballweg, Jr.

Hydronautics, Inc.
200 Monroe Street
Rockville, Maryland

Hydro-Space Technology, Inc.
Clinton Road and Route 46
West Caldwell, New Jersey

Hytech Corporation
G Street Pier
San Diego 1, California

Imperial Electronic Systems
8530 Roland Street
Buena Park, California

Industrial Instruments, Inc.
89 Commerce Road
Cedar Grove, New Jersey

International Business Machines
Communications Center
7220 Wisconsin Avenue
Bethesda, Maryland
Attn: B. Bernstein

International Business Machines
Command Control Center
Kingston, New York
Attn: Engineering Library

International Business Machines
Federal Systems Division
1111 Connecticut Avenue NW
Washington 6, D. C.

Interstate Electronics Corporation
707 E. Vermont Ave.
Anaheim, California
Attn: D. A. Armstrong

Itek Laboratories
A Division of Itek Corporation
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Lexington 73, Massachusetts

ITT Federal Laboratories
390 Washington Avenue
Nutley 10, New Jersey

Jackson & Moreland, Inc.
1825 Connecticut Avenue NW
Washington 9, D. C.

Jansky and Bailey, Inc.
A Division of Atlantic Research Corp.
Shirley Highway & Edsall Road
Alexandria, Virginia

The C. O. Jelliff Mfg. Corporation
Southport, Connecticut

Joy Manufacturing Company
Electrical Products Division
338 South Broadway
New Philadelphia, Ohio

Kaar Engineering Corporation
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P. O. Box 1320
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Kahl Scientific Instrument Corporation
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Kaiser Industries Corporation
300 Park Avenue
New York 22, New York

Kollsman Instrument Corporation
80-08 - 45th Avenue
Elmhurst 73, New York

KPT Manufacturing Company
Roseland, New Jersey

Krohn-Hite Corporation
8218 Wisconsin Avenue
Bethesda, Maryland
c/o C. E. Snow Company

Krohn-Hite Corporation
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Cambridge 39, Massachusetts

Laboratory for Electronics
Theory Group
1075 Commonwealth Avenue
Boston 15, Massachusetts
Attn: Dr. Robert L. Sternberg

LaCoste & Romberg
6606 North Lamar
Austin 5, Texas

La Motte Chemical Products Company
Chestertown, Maryland

Land-Air, Inc.
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Chicago 31, Illinois

Land-Air, Inc.
1510 H Street NW
Washington 5, D. C.

Leach Corporation
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Compton, California

Leach Corporation
1700 K Street NW
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Washington 6, D. C.

Lear, Incorporated
Advance Engineering Division
110 Ionia NW
Grand Rapids 2, Michigan
Attn: Ralph C. Raabe

Ledeen, Inc.
Gilman Road & Garvey Avenue
El Monte, California

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North Wales, Pennsylvania

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E. Leitz, Inc.
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Leupold & Stevens Instruments, Inc.
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Portland 13, Oregon

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Ling-Temco-Vought, Inc.
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The Linen Thread Company, Inc.
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Lithium Corporation of America, Inc.
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Lockheed Aircraft Corporation
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Lockheed California Company
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McGraw-Hill Publishing Company
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MacLeod Instrument Corporation
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Mandrel Industries, Inc.
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MEG Products
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Miami 35, Florida

Marine Advisers
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Marine Construction & Design Company
2300 W. Commodore Way
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Marine Geophysical Services Corporation
2418 Tangley
Houston 5, Texas

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Markey Machinery Company, Inc.
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Martin Marietta Corporation
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Maxson Electronics Corporation
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Maxson Electronics Corporation
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M & E Marine Supply Company
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Melpar, Inc.
Applied Science Division
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Miami 47, Florida

Miller-Dunn Company, Inc.
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Missiles & Rockets Magazine
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Orbit Industries, Inc.
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New York 22, New York

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Philco Corporation
Scientific Laboratory
Blue Bell, Pennsylvania

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Long Island City 1, New York
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Popular Mechanics
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Washington, D. C.

Power Instruments Corporation
235 Oregon Street
El Segundo, California

Pratt & Whitney Company, Inc.
Charter Oak Boulevard
West Hartford 1, Connecticut

Precision Instrument Company
1011 Commercial Street
San Carlos, California

Precision Thermometer & Instrument Co.
1434 Brandywine Street
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Quantum, Incorporated
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Alexandria, Virginia

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Radio Corporation of America
Industrial Electronic Products
Camden 2, New Jersey

Radio Corporation of America
M & SR
Moorestown, New Jersey

Radio Corporation of America
David Sarnoff Research Center
Princeton, New Jersey

Radioplane, A Division of Northrop Corporation
8000 Woodley Avenue
Van Nuys, California
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Raytheon Company
Submarine Signal Division
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Newport, Rhode Island
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1048 Potomac Street NW
Washington 7, D. C.

Reeves Instrument Company
Roosevelt Field
Long Island, New York

Reeves Instrument Company
1826 Jefferson Place NW
Washington, D. C.

REF Dynamics
393 Jericho Turnpike
Mineola, New York

Military Department
Remington Rand Univac
2121 Wisconsin Avenue, NW
Washington 7, D. C.
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Republic Aviation Corporation
Conklin Street
Farmingdale, L. I., New York

Research Management Corporation
1625 I Street NW
Washington 6, D. C.

Richfield Oil Corporation
5900 Cherry Avenue
Long Beach 5, California
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Rixon Electronics, Inc.
2121 Industrial Parkway
Montgomery Industrial Park
Silver Spring, Maryland

M. Rosenblatt & Son, Inc.
Naval Architects & Marine Engineers
350 Broadway
New York 13, New York

Ross Laboratories, Inc.
124 Lakeside Avenue
Seattle 22, Washington

Salt Lake Stamp Company
380 West 2nd South
Salt Lake City, Utah

Sanborn Company
175 Wyman Street
Waltham 54, Massachusetts

Sanders Associates, Inc.
Burlington, Massachusetts

Sanders Associates, Inc.
95 Canal Street
Nashua, New Hampshire

Sanders Associates, Inc.
Fairchild Avenue
Plainview, L. I., New York

Sandia Corporation
P. O. Box 5800
Albuquerque, New Mexico

Sangamo Electric Company
11th & Converse Streets
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Advance Research & Development, Sonar

Schlumberger Well Surveying Corporation
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Ridgefield, Connecticut

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Science Service
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Scott Aviation Corporation
Safety Equipment Division
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Scovill Manufacturing Company
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Waterbury 22, Connecticut

Sea-Space Systems, Inc.
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Sheffield Publishing Company, Inc.
Undersea Technology
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Shell Development Company
Emeryville, California

Shell Development Company
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Houston 1, Texas

J. H. Shepherd Son & Company
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Elyria, Ohio

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Universal Match Corporation
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Vare Industries, Inc.
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Video Engineering Company
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Vitro Laboratories
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The Washington Post
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Washington Science Trends
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Western Gear Corporation
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Western Geophysical Company of America
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APPENDIX D

LIST OF ATTENDEES AT THE GOVERNMENT-INDUSTRY SYMPOSIUM ON OCEANOGRAPHIC INSTRUMENTATION

AUGUST 16 - 17, 1961
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APPENDIX E

REQUIRED OCEANOGRAPHIC INSTRUMENT SUIT FOR OCEANOGRAPHIC SURVEY VESSELS

By Captain C. N. G. Hendrix and Working Group

PREFACE

In recent conferences and discussions, an attempt has been made to determine the oceanographic instrumentation needs of oceanographic survey vessels. Although the resulting instrument and system descriptions contained herein have been particularly oriented toward outfitting oceanographic survey vessels, a number of these instruments and systems are considered to have additional application to both basic and applied research investigations.

These descriptions are presented in the combined form of both performance and general engineering specifications. This has been done intentionally, in order to stimulate the needed and desired new thinking and fresh approach that must be applied to oceanographic instrumentation. The engineering specifications have been presented primarily for information and not to restrict or channel thought on how any given problem may best be solved. Likewise, the performance specifications have been presented as guideline goals, to be improved where possible. Should the state-of-the-art prevent the attainment of one or more of the goals set forth, it may be necessary to consider interim solutions. However, interim instruments or instrument systems will have to be individually evaluated on: (1) the inherent merit of the method employed, (2) the degree to which the proposal attains the stipulated goal, (3) its relationship in time to the achievement of the desired goal, and (4) development and production model costs.

The priorities, which have been tentatively assigned to the instruments and instrument systems described herein, have been dictated primarily by the urgency of the requirement for the information that the particular instrument or system can provide. Unit and development costs, the current state-of-the-art, and the estimated time period required to perfect a particular instrument or system have not entered into the setting of these priorities. Furthermore, these priorities will not prevent the procurement of a fully-developed, low-priority instrument merely because all of the higher priority instruments have not yet come into being.

A general requirement for all instruments and instrument systems, excluding those whose sole function is the collection of various samples, is that the data which they collect must be able to be read directly into the Master Shipboard Data Logging and Processing System. This requirement remains regardless of whether the information is internally recorded within the instrument or system vehicle or whether the instrument or system transmits or telemeters the data directly to the survey vessel. In this connection, the final data output of the Master Shipboard Data Logging and Processing System must be in proper form for direct inclusion in the archives of the National Oceanographic Data Center.

Modular construction, both of sensors and of consoles, has been particularly specified in these instruments and instrument systems. This has been done primarily to facilitate field maintenance and repair; however, it also allows for the different lengths of time that may be required to develop any given sensor. Additional factors, which have prompted specification of this mode of construction, are:

1. Higher resolutions and accuracies are more economically attained with a group of modular sensors, each interchangeable and covering a different sensing range;

2. A greater demand may be generated for a particular sensor than the overall demand indicated in these descriptions for the total instrument or systems;

3. Standardization will afford the widest possible sensor application and market, inasmuch as many of these sensors are to be utilized in more than one of the described instruments and instrument systems;

4. Interchangeable, modular sensors will permit many companies, who may have neither the interest nor the capability to contract for an entire system, to devote their specialized talents to development of a particular sensor. This is expected to be especially true of companies having a specialized chemical analysis capability.

In conjunction with this policy of modular construction, vehicles or capsules proposed as components of the described instruments or instrument systems must be capable of accommodating the standardized sensors and their associated recording or transmitting units in the groupings stipulated in the accompanying instrument descriptions.

Although projected estimates of the numbers which may be utilized have been presented for each instrument or system, in order to acquaint industry with the possible extent of the market, these numbers are obviously a function of: (1) the unit cost of production models, (2) opportune breakthroughs in the state-of-the-art, (3) budgetary considerations of the various agencies that may comprise the market, and (4) the individual requirements of segments of the national oceanographic community other than those concerned principally with survey operations.

The following are additional general requirements which inherently apply to all oceanographic instruments or instrument systems:

1. Provision must be included for rapid, accurate, shipboard calibration.

2. Wherever electronic components are utilized, long electronic life must be a basic factor in their design. In this regard, military specifications, especially those written for existing specialized projects, are not always adequate criteria.

3. Operation and maintenance of both individual instruments and instrument systems must not be so complicated as to require extensive, specialized training for their use.

4. Instrument and instrument system power requirements must not necessitate elaborate voltage and frequency controls.

5. Possibly the least understood and, yet, the most important is the fact that all of these instruments and instrument systems must be especially designed to be used at sea. Their construction and operation must be reliable, accurate, and compatible with the shipboard and marine environment which can be very severe on occasions.

Inasmuch as all of the described instruments and instrument systems are to be designed for use aboard oceanographic survey vessels, the following general background information is provided regarding ship characteristics:

1. U. S. Navy

a. AGS 30 and 50	Length: 310 feet Beam: 41 feet Draft: 14 feet Displacement: 2, 800 tons
b. AGS 18 Class	Length: 221 feet Beam: 32 feet Draft: 10 feet Displacement: 1, 221 tons
c. AGOR SCB 185 Class	Length: 208 feet Beam: 37 feet Draft: 15 feet Displacement: 1, 387 tons

2. U. S. Coast and Geodetic Survey

a. Class I Ships	Length: 300 feet Beam: 48 feet Draft: 20 feet Displacement: 3, 100 tons
b. Class II Ships	Length: 210 feet Beam: 40 feet Draft: 15 feet Displacement: 1, 300 tons
c. Class III Ships	Length: 150 feet Beam: 30 feet Draft: 10 feet Displacement: 750 tons

3. Bureau of Commercial Fisheries

a. Coastal vessels	Length: 40 feet to 75 feet Beam: (various) Draft: (various) Displacement: 150 tons (approx.)

b. Short-range, offshore vessels — Length: 75 feet to 125 feet; Beam: (various); Draft: (various); Displacement: 600 tons (approx.)

c. Extended-range, ocean vessels — Length: 125 feet to 200 feet; Beam: (various); Draft: (various); Displacement: 1,000 tons (approx.)

The estimated numbers of instruments and instrument systems contained in the descriptions have been based upon the following considerations: (1) That, from the TENOC Report, NASCO Report, and personal communications, the following oceanographic ships exist and/or are proposed for future construction, and (2) that some of the proposed ships will replace some of the older, existing ships.

1. U. S. Coast and Geodetic Survey

5 Existing Class I hydrographic ships
10 Existing Class II and III hydrographic ships
8 Proposed Class I oceanographic ships
2 Proposed Class II oceanographic ships
7 Proposed Class III oceanographic ships

2. U. S. Navy Hydrographic Office

2 Existing oceanographic ships (AGS 30, 50)
4 Existing inshore oceanographic ships (AGS 18 Class)
2 Existing large hydrographic ships (AGS 15, 16)
3 Proposed oceanographic ships (AGOR SCB 185)
7 Proposed hydrographic ships (AGS SCB 214)
4 Proposed hydrographic ships (AGS SCB 193)
5 Proposed AGC (3,000 tons)

3. Bureau of Commercial Fisheries

27 Existing oceanographic-type research vessels, including chartered vessels
16 Proposed coastal vessels
12 Proposed short-range, offshore vessels

3 Proposed extended-range, ocean vessels, including 1 submarine

4. U. S. Navy Research Laboratories

4 Existing research vessels (EPCE type)
3 Proposed oceanographic ships (AGOR SCB 185)
1 Proposed VC-2 conversion

5. Scientific Community

a. Lamont Geological Observatory

1 Existing 750-ton oceanographic vessel (VEMA)
2 Proposed oceanographic ships (AGOR SCB 185)

b. University of Washington

1 Existing 300-ton oceanographic vessel (BROWN BEAR)
1 Proposed oceanographic ship (AGOR SCB 185)

c. Scripps Institution of Oceanography

1 Existing 2,100-ton oceanographic ship (ARGO)
2 Existing 900-ton oceanographic vessels (HORIZON and BAIRD)
1 Existing 550-ton oceanographic vessel (HUGH SMITH)*
1 Existing 400-ton oceanographic vessel (STRANGER)
2 Existing 200-ton oceanographic vessels (ORCA and PAOLINA T)
2 Proposed oceanographic ships (AGOR SCB 185)
1 Proposed AGC (3,000 tons)

* On loan from Bureau of Commercial Fisheries, Honolulu.

d. Oregon State College

1 Existing oceanographic vessel (ACONA)
1 Proposed oceanographic ship (AGOR SCB 185)

e. University of Miami

1 Existing 135-ton oceanographic vessel (GERDA)
1 Proposed oceanographic ship (AGOR SCB 185)

f. Hudson Laboratories

1 Existing 2,800-ton oceanographic ship (GIBBS)
1 Existing 750-ton oceanographic vessel (ALLEGHENY)
1 Proposed AGC (3,000 tons)

g. Woods Hole Oceanographic Institution

1 Existing 3,100-ton oceanographic ship (CHAIN)
1 Existing 565-ton oceanographic vessel (ATLANTIS)
2 Existing 300-ton oceanographic vessels (CRAWFORD and BEAR)
2 Proposed oceanographic ships (AGOR SCB 185)

h. Agricultural and Mechanical College of Texas

1 Existing 400-ton oceanographic vessel (HILDAGO)
1 Proposed oceanographic ship (AGOR SCB 185)

i. University of Southern California

1 Existing 580-ton oceanographic vessel (VELERO IV)

In addition, New York University, Chesapeake Bay Institute, and Narragansett Marine Laboratory, as well as some of the above institutions, have various smaller vessels that are equipped for oceanographic data collection and could possibly use some of the described instruments, or portions thereof.

INDIVIDUAL INSTRUMENTS/EQUIPMENTS AND INSTRUMENT SYSTEMS FOR OCEANOGRAPHIC SURVEY VESSELS

Table of Contents

I.a. HYDROGRAPHIC PRECISION SCANNING ECHO SOUNDER

Primary Use:

For use on oceanographic survey ships in conducting underway precision developmental (detailed) types of bathymetric surveys in deep oceanic areas. This instrument is needed to obtain a high resolution, stabilized, echo-sounding picture, including an automatically plotted contoured chart of the sea floor topography, extending a certain distance (about 2 miles in 4,000 fathoms of water) perpendicular to and on each side of the ship's track.

Requirements and Specifications:

a. To perform reliably at ship's speeds of 0 to 18 knots and in sea states 0 through 5.

b. Operating Depth Range:

(1) Automatic contour plotting (sweep width) 0 to 6,500 fathoms.

(2) Single-ping and regular echo-gram recording operation 0 to 6,500 fathoms.

c. Recording Accuracy: 1 fathom over full range of each scale.

d. Transducer(s):

(1) Type: narrow beam, 1^{o} to 3^{o}, at the 10 db point.

(2) Array: multiple series of transducers faired in to ship's hull, electronically stabilized, and so installed as to scan the sea floor for a specified distance on either side of the ship's track.

(3) Transducer(s) should be located at a point along ship's hull so as to have minimum cavitation interference.

(4) Should be capable of scanning up to 30^{o} on either side of ship's track.

(5) Should incorporate a feature for "plug-in" of a portable/towed transducer.

e. Stabilizer:

(1) Maximum stabilization angle of 60^{o}.

(2) Constant stabilization to $1/2^{o}$ of arc from the vertical.

(3) Minimum lag in stabilization action, easy accessibility for maintenance.

(4) Alarm system to detect malfunctions.

f. Receiver-transmitter:

(1) Frequency: 10 - 18 kc.
(2) Transmission: Pulsed CW emission and reception.
(3) Frequency Control: Precise intermediate frequency (IF).
(4) Scale Range: Several and concurrently shifted.
(5) Phasing: Automatic phase detection.
(6) Pinging: Single or continuous.
(7) Output: Output suitable for audible depth indication and use with an external precision recorder.

g. Recording:

(1) Data Display: To present travel-time data to a display which automatically connects horizontal and vertical components and displays data from successive sweeps as contours at pre-selected intervals varying between 5-100 fathoms.

(2) Data Recording: Output data to be compatible to present and planned data reduction methods.

(3) Must record continuous bottom profiles in addition to plotting "contours."

(4) "Alternate" Recorder:

(a) Paper Width: 18 inches.
(b) Time Accuracy: 1 part/million.
(c) Paper Speeds: 24 and 72 inches/hour and also geared to own ship's speed for various chart scales.
(d) Marking area of recorder paper to have accessibility for ease of immediate reading of trace.
(e) Adjustable for setting correction for ship's draft.
(f) Provision for a gating circuit.
(g) Means for a numerical depth print-out.
(h) Means for changing vertical scale of recording.
(i) Automatic depth phase recording on trace.
(j) A reflectivity meter should be built into the system to provide a continuous recording of the reflectivity of the sea floor.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (hydrographic-oceanographic survey ships, basic research ships, and applied research ships) - 19 to 25.

b. U. S. Coast and Geodetic Survey - 2 to 6.

c. Certain activities within scientific community - 10 to 15.

d. Bureau of Commercial Fisheries - 2.

Total: 33 to 48.

Recommendation Where System Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument priority 1.

I.b. CURRENT METER FOR CONDUCTING COASTAL AND OCEANIC SUBSURFACE CURRENT SURVEYS

Primary Use:

This is a precision instrument to be utilized on oceanographic survey vessels for conducting subsurface current studies and surveys in coastal and oceanic areas with the ship anchored or "lying-to." It must measure and record precisely the direction and speed of the subsurface currents.

Requirements and Specifications:

a. To perform reliably and accurately on survey ships which are anchored or "lying-to."

b. To be operable in depths varying from 0 to 6, 500 fathoms with no adverse effects thereto due to hydrostatic pressure.

c. To be so designed as to be utilized individually or in multiple groupings on one cast.

d. To be so designed that the adverse effects of platforms and sensor motions (horizontal and vertical accelerations) are eliminated or minimized considerably.

e. To be designed to include four (4) interchangeable, modular, depth-sensor units: (1) 0-600 feet, (2) 0-6,000 feet, (3) 0-15,000 feet, (4) 0-39,000 feet.

f. Depth accuracy for each <u>module</u> to be ±1/4% of full scale.

g. Current range and accuracy:

(1) Speed: 0.05 knot - 8.0 knots; ±0.05 knot accuracy at readout.

(2) Direction: 000-360°; ±10° accuracy at readout.

(3) Instrument output should be linear with respect to the current measured over full range of interest.

(4) Time response: 95% response to speed step-function from zero to 1 knot in 1 second or less.

h. In designing this instrument, consideration shall be given to utilizing this instrument on other than research or survey ships, i.e., on ships conducting special current studies such as certain fleet units, commercial auxiliaries, oil exploration activities and the like.

i. Shipboard monitoring components:

(1) Computer/recorder capable of averaging current over varying time intervals as well as providing instantaneous values.

(2) Visual analog and digital tape readout.

(3) Electric or electronic sensor signals must be such as to permit the Master Shipboard Data Logging and Processing System to accomplish (1) and (2) above where this data logging and processing system is installed. Where this system is not installed, separate computing and recording equipment must be available to accomplish (1) and (2) above.

<u>Potential Users and Estimated Number of Units Which They May Require</u>:

a. U. S. Navy (basic research, applied research, hydrographic-oceanographic survey ships) - 50 to 250.

b. U. S. Coast and Geodetic Survey - 15 to 30.

c. Certain activities within scientific community - 20 to 40.

d. Bureau of Commercial Fisheries - 15 to 50.

Total: 100 to 370.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument priority 2.

I.c. SHIPBOARD WAVE METER

Primary Use:

This instrument will be utilized on oceanographic survey ships to measure and record the wave spectra in the oceanic areas for general survey and other purposes.

Requirements and Specifications:

a. For use on board oceanographic survey ships in oceanic areas with ship "lying-to" or underway at slow speed (0-3 knots).

b. It is desirable that this instrument operate without the necessity of immersing any sensors in the water, in order to reduce danger of deterioration of sensors or damage to the instrument.

c. The instrument will be capable of being operated from inside a shipboard laboratory and will require no work on deck, except for preliminary calibrations and rigging the instrument for operation. There is to be no requirement to work on deck while measurements are being taken.

d. The instrument should be so designed as to require minimum installation on the ship. In particular there shall be no requirement for ship drydock availability to install the gear. It is highly desirable that the instrument be capable of being moved from one ship to another with a minimum of effort.

e. In high waves considerable spray is to be expected. The instrument is to be so designed to withstand and minimize the effect of the spray. The instrument should be able to withstand total immersion.

f. Amplitude: The instrument is to be capable of measuring the relative displacement of the sea surface from mean sea level with an allowable error of not more than ±5%. It must be able to do this continuously with minimum phase lag and small time constant.

g. Wave Height Range: The instrument must be able to sense displacements from mean sea level of ±20 feet, giving a total wave height of 40 feet. Resolution should be such that wave heights of 1/2 foot or greater will be measured.

h. Period-Length: The instrument should be capable of sensing all variations in relative sea surface height which have periods between 2 and 25 seconds. In terms of lengths, waves of from 20 to 2,500 feet should be sensed by the instrument. Should the sensor use as its operating principle one which averages readings over a small area of sea surface, the area involved should be less than 5 feet in diameter.

i. Duration: The instrument should be capable of measuring the relative height of the sea surface as a continuing function of time. Although measurements of 1/2 hour duration will be required ordinarily, special problems will require records of many hours duration.

j. Recording and Analysis:

(1) Visible: A visible, strip chart record of wave height, as function of time, is required. This recording should be normalized, and should be of such a scale as to permit manual digitizing to the accuracy of the instrument at 1/2 second intervals.

(2) In addition to visual recording, the wave data must be amenable to spectrum analysis on board ship.

(3) Electric or electronic sensor signals must be such as to permit the Master Shipboard Data Logging and Processing System

to accomplish (1) and (2) above where this data logging and processing system is installed. Where this system is not installed, separate computing and recording equipment must be available to accomplish (1) and (2) above.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 30.

b. U. S. Coast and Geodetic Survey - 10 to 15.

c. Certain activities within scientific community - 10 to 15.

d. U. S. Air Force Ocean Range Vessels - 6 to 8.

e. Bureau of Commercial Fisheries - 2.

f. U. S. Coast Guard - 15 to 30.

Total: 63 to 100.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance of Interest to U. S. National Oceanographic Program:

Individual instrument priority 3.

I.d. MULTI-PURPOSE, CONSTANT TENSION, HEAVY-DUTY OCEANOGRAPHIC WINCH

Primary Use:

This winch will be used primarily to handle the majority of oceanographic instruments and will be utilized in most of the oceanographic survey operations. Some of these major types of operations include:

a. Conducting "ocean-station" operations with ship "lying-to," in oceanic areas, during which a multiple number of instruments and sensors will be lowered to interim or maximum depth.

b. Conducting deep or shallow ocean-floor dredging with either light or heavy loads.

c. Conducting "bottom coring" operations.

d. Conducting "towed operations," at varying speeds, utilizing various oceanographic instruments either singly or in multiple groupings.

Requirements and Specifications:

a. To be utilized for underway and stopped ("lying-to") operations.

b. To perform reliably at slow ship speeds (0-3 knots) under heavy deep-sea dredging loads and at high ship speeds (10-15 knots) under light trawling or towing loads.

c. Cable Reels:

(1) Should be designed so as to facilitate rapid removal and change of cable reels.
(2) The "non-conducting" wire reel should have a capacity equivalent to 40,000 feet of 5/16 inch wire.
(3) The "conducting" wire reel should be constructed of non-ferromagnetic material to reduce eddy losses and to minimize noise.
(4) The "conducting" wire reel shall be capable of providing a number of electrical pick-offs, varying from 1 to 12.
(5) The "conducting" wire reel shall have a capacity equivalent to 40,000 feet of 0.3 inch diameter "conducting" cable.

d. The design shall incorporate a "winding machine" feature for controlled laying of the cable on the storage reel during in-haul. This feature must be adjustable to accommodate wire and cable sizes varying from 0.1 to 0.9 inch diameter.

e. There shall be a provision for constant tension control, i.e., fine control of the load's vertical motion. This constant tension should be ±2% or better of the load at any given instant. This feature should be readily removable or by-passed when not required. A cable load indicator must also be included.

f. It shall incorporate controlled torque for shockless stopping and starting.

g. It shall be capable of ascent-descent rates of up to 150 meters/minute.

h. The operating depth range of this equipment shall be 0 to 6,500 fathoms (0 to 39,000 feet).

i. It shall be capable of performing with an in-haul dynamic load of 8,000 lbs., and of withstanding a "break-load" of 20,000 lbs.

j. It shall include an emergency retrieval system.

k. Although the largest and the highest priority winch is described here, it should be the basis of a series of standard-type, varying-sized winches.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 15 to 30.

b. U. S. Coast and Geodetic Survey - 6 to 15.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 2.

Total: 33 to 67.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 4.

I.e. SUB-SEA FLOOR STRATA PROFILER

Primary Use:

To be utilized by oceanographic survey ships in determining the types, characteristics, and discontinuities in the upper layer sediments which cover the sea floor. In those oceanic areas where the sediment carpet is thin, it will be utilized to provide pertinent information concerning the basement rock structure.

Requirements and Specifications:

a. To perform reliably on oceanographic survey ships with the ship stopped ("lying-to") or underway at ship speeds of 0-10 knots.

b. The instrument shall be designed to perform reliably in ocean areas varying in depth from 0 to 6,500 fathoms. Within this depth of water range, it shall be capable of penetrating sediments to at least 2,000 feet in depth.

c. The transducer(s):

(1) Shall include a fixed active transducer (or other sound source) attached to the ship's hull, and/or

(2) It shall have an active streamlined transducer (or other sound source) capable of being towed at a depth suitable for maximum sediment penetration.

d. Recorder:

(1) Shall afford maximum accessability for immediate reading and marking of traces.

(2) In addition to a selection of fixed recorder paper speeds, it shall provide variable paper speeds to conform to own ship's speed.

(3) It shall permit direct navigational position data on the trace.

(4) This recorder shall be located with and controlled by the

Master Shipboard Data Logging and Processing System wherever that system is available.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 30.

b. U. S. Coast and Geodetic Survey - 10 to 15.

c. Certain activities within scientific community - 15 to 30.

Total: 45 to 75.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry and the Scientific Community.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 5.

I.f. SMALL CRAFT, SHALLOW WATER ECHO SOUNDING INSTRUMENT

Primary Use:

To be portable and to be utilized primarily by those small craft carried on board oceanographic survey ships for the purpose of conducting detailed, controlled shallow water bathymetric surveys in continental shelf areas and rivers throughout the world.

Requirements and Specifications:

a. To be portable and utilized primarily in those small boats and launches which are carried on board oceanographic survey ships.

b. To perform reliably at boat/launch speeds of 0-12 knots and in water depths of 0-250 fathoms, with an accuracy at readout of

±0.5 fathom (3 feet) or better over the entire operating range.

c. Power Supply:

(1) Should be capable of both a.c. and d.c. operation.
(2) Should be equipped with a frequency meter and voltage regulator.

d. Transducer(s):

To include two (2) transducers of different frequency ranges, for the purpose of obtaining fine resolution of bottom detail as well as reliable performance under severe environmental conditions. These transducers are to be enclosed within the same streamlined housing.

e. This system should include a streamlined housing for the dual transducer plus a streamlined sword-arm for supporting the transducer housing assembly. The transducer housing, the sword-arm, and associated support arms should be streamlined, light weight, of simple design, rugged, and easy to rig and unrig. Additionally, the entire assembly should be designed to permit installation on either side of the small craft/launch, at the bow or stern, and with a capability of positioning the transducer housing at any depth between 2-10 feet below the surface of the water.

f. Recording:

(1) To provide a graphic recording of the bottom, in feet and in fathoms.
(2) Scales:

(a) 0-100 feet.
(b) 0-600 feet.
(c) 0-1,500 feet.

(3) Recorder design should emphasize ruggedness, simplicity, compactness, ease of maintenance, and ease of annotating the recording trace.

g. The transducer housing and sword-arm should be designed so that they can readily and easily be shipped and unshipped by two men. The same applies to the power pack-recording unit.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and hydrographic-oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 15 to 30.

c. Certain activities within scientific community - 10 to 20.

d. U. S. Coast Guard - 10 to 20.

e. U. S. Navy (Bureau of Ships) - Unknown.

f. Bureau of Commercial Fisheries - 10 to 30.

Total: 65 to 140.

Recommendations Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 6.

I.g. SURFACE SHIP AND SUBMARINE GRAVITY METER FOR SURVEY USE

Primary Use:

This is a precision instrument designed for survey use. It will permit the continuous measurement of gravity profiles from surface ships and submarines.

Specifications and Requirements:

a. This is primarily an underway instrument and should perform with accuracy and reliability for ship's speeds between 0 and 15 knots.

b. It should also perform effectively in sea states 0 through 5 and under the influence of long-period swells.

c. It must be capable of measuring over an overall range of 7,000 milligals without resetting; this range to cover 977 to 984 gals.

d. Individual readings must be accurate to ±2 milligals over the entire operating range.

e. It must have a zero or a constant drift rate (not to exceed 5 milligals) over periods of at least one month, and have automatic input of corrections to readout.

f. It must be rugged, easy to maintain, and of such size and weight as to permit installation aboard surface ships and submarines.

g. It must be capable of making automatic corrections for horizontal accelerations, and must not be adversely affected by the average horizontal or vertical accelerations of the vessel.

h. It must eliminate secondary vertical effects.

i. Its readout must be compatible with Master Shipboard Data Logging and Processing System inputs, where navigational and other related data can be added to gravity data.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (hydrographic-oceanographic survey and applied research vessels) - 10 to 20.

b. U. S. Coast and Geodetic Survey vessels - 2 to 3.

c. U. S. Air Force (ocean range vessels) - 6 to 8.

d. Scientific Community - 6 to 15.

Total: 24 to 46.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 7.

I.h. MARINE ELECTRON RESONANCE MAGNETOMETER

Primary Use:

To be utilized on oceanographic survey ships for the purpose of obtaining continuous profiles of the earth's total magnetic intensity.

Requirements and Specifications:

a. To be designed primarily for underway operations and secondarily for stopped operations.

b. To perform reliably at ship's speeds of 0-15 knots in sea states of 0 through 5.

c. To be designed with emphasis on simplicity, ruggedness, compactness, and minimum maintenance requirements.

d. To be designed primarily for survey type of operations with primary emphasis on installation in the survey surface ship, but with consideration of and possible application to survey use from aircraft.

e. Sensors:

Data	
(1) Total magnetic intensity	Range: 20,000-100,000 gammas Accuracy: ±0.01 gamma
(2) Depth of sensor below surface of water	Range: Underway Mode: 0-1,000 feet Accuracy: Underway Mode: ±1/4% full scale Range: Lying-to Mode: 0-6,500 fathoms

Accuracy: Lying-to Mode: ±1/4% full scale

The depth sensor modules should be interchangeable.

f. Data recording and Readout:

(1) Visual analog at the instrument.
(2) Data from this instrument must be an input into the Master Shipboard Data Logging and Processing System.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, hydrographic-oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. National Aeronautics and Space Agency - Unknown.

Total: 40 to 80.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 8.

I.i. SELF-CONTAINED, DEEP-DIVING OCEANOGRAPHIC SENSING INSTRUMENT

Primary Use:

This instrument shall be designed for utilization from oceanographic survey ships to allow the measurement and recording of certain key oceanographic data simultaneously with other underway or stopped operations. Emphasis shall be placed on simplicity and rapidity of data collection.

Requirements and Specifications:

a. For use on oceanographic survey ships with ship stopped ("lying-to"). It may also be utilized in multiple drops, all positioned and later retrieved by one underway vessel, within a given area.

b. To be designed as a "free" descent/ascent deep-diving instrument, capable of performing reliably to depths of 6,500 fathoms.

c. The instrument should be designed to sink to any pre-programmed depth, at a uniform rate compatible with the time response of attached sensors, recording certain key data during the descent. Upon reaching the pre-specified depth, a mechanism or weight would be released allowing the instrument to rise uniformly to the surface, recording the data during the ascent. It would then be retrieved by maneuvering the ship and hoisting it on board.

d. The vehicle shall be so designed that it is compact, light weight, and easy to handle on board ship and in the water. It shall incorporate a provision to aid in the vehicle's location upon surfacing, day or night.

e. The following modular data sensors shall be included: (1) temperature, (2) salinity, (3) sound velocity, (4) oxygen, (5) depth.

f. The sensor ranges and accuracies desired are:

Sensor	
(1) Temperature	Range: -2° to 35°C. Accuracy: $\pm 0.02^\circ$C.
(2) Salinity (two interchangeable modules)	Range: 0 to 25‰ 25 to 45‰ Accuracy: ± 0.01‰ ± 0.01‰
(3) Sound velocity	Range: 4,500 to 5,500 feet per second Accuracy: ± 1.0 foot per second absolute at readout

(4) Oxygen	Range: 0 to 10 milliliter/ liter Accuracy: ± 0.1 milliliter/ liter
(5) Depth (four inter-changeable modules)	Range: 0 to 600 feet 0 to 6,000 feet 0 to 15,000 feet 0 to 39,000 feet Accuracy: ± 0.25% of full range for each module

g. The sensor time responses desired are:

(1) Temperature: 95% response to a step function of 0.02° C. in 1 second.
(2) Salinity: 95% response to a step function of 0.01‰ in 1 second.
(3) Sound velocity: 95% response to a step function of 1.0 foot per second in 1 second.
(4) Oxygen: 95% response to a step function of 0.1 milliliter per liter in 1 second.
(5) Depth: 95% response to a step function of 1 fathom (6 feet) in 1 second.

h. Recording:

(1) Within the instrument, there shall be continuous analog recording of all five variables simultaneously on magnetic tape.

(2) On deck, after the instrument has been retrieved, this data must be capable of immediate, direct input into the Master Shipboard Data Logging and Processing System.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 200.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 30 to 100.

Total: 70 to 360.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument priority 9.

I. j. SURFACE NAVIGATION AND BUOY LOCATION TRANSPONDER

Primary Use:

To be utilized on oceanographic survey ships during miscellaneous oceanographic operations for three purposes: (1) To permit seaward extension of existing shore navigation control stations in certain areas designated for specific survey assignments (hydrographic-oceanographic), (2) To aid in the location and "homing in" on deep-sea anchored buoys and/or other devices, and (3) To provide a system for establishing reference grids in extended ocean areas lacking electronic navigational aids for conducting special research and/or survey operations.

Requirements and Specifications:

a. Buoy-Mounted Transceiver Unit:

(1) Transceiver unit to be mountable on various size buoys and at a sufficient height above the surface of the water so as to permit maximum range performance.

(2) To consist of a low-powered transceiver unit which would be activated by the servicing ship's interrogation pulse and then transmit a signal back automatically on the same frequency. The transceiver should be transitorized, compact, light-weight, rugged, and provide for reliable unattended operation.

(3) Transceiver should be designed so that it can be activated, if possible, by existing survey/research surface ship's radar/ radio systems and also by existing aircraft systems which might be utilized in oceanographic investigations and surveys. In brief, it

should be capable of being attuned to and broadcast back on a preselected frequency band.

(4) Transceiver unit should contain its own power supply and this should have an assured 6-12 month life unattended, in this intermittent type of interrogation.

(5) Transceiver unit to shut down automatically when interrogation has ceased.

(6) Transceiver to perform reliably at ranges varying from 10-50 miles.

b. Shipboard/Airborne Transceiver Unit:

(1) The instrument to be designed for operation from either an oceanographic research/survey ship or from an aircraft (scientific or military).

(2) For reasons of flexibility and economy, existing radar/radio systems as now installed in research/survey ships and scientific/military aircraft should be utilized, if feasible, for the shipboard/airborne transceiver unit.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and hydrographic-oceanographic survey ships) - 20 to 200.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. U. S. Coast Guard - 10 to 20.

e. Bureau of Commercial Fisheries - 10 to 100.

Total: 60 to 360.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 10.

I.k. SHIPBOARD DYE DETECTOR PROBE FOR OCEANOGRAPHIC INVESTIGATIONS

Primary Use:

To be utilized on oceanographic survey ships for the direct detection and evaluation (quantitative) of certain dyes which are used in tagging water masses for the purposes of studying diffusion, turbulence, and ocean circulation.

Requirements and Specifications:

a. To be utilized by oceanographic survey ships when stopped ("lying-to") and when underway.

b. Instrument design should stress simplicity, ruggedness, and light weight in construction.

c. The sensor (dye) should have its wave length sensitivity peaked to correspond to the wave length of rhodamine-type dyes. This will reduce the effect of spurious, natural background fluorescence.

d. To be utilized in coastal and oceanic areas and in water depths of 0-6,500 fathoms.

e. Sensors, range, and accuracy:

Sensor

(1) Depth — Range: 0-6,500 fathoms; Accuracy: 1/4% full scale of each module

NOTE: Depth modules: 0-600 feet, 0-1,000 feet, 0-6,000 feet, 0-39,000 feet.

(2) Rhodamine — Range: 500 parts/million to 0.01 parts/billion; Accuracy: 0.01 part/billion

(3) Time response: (a) Depth: 95% response to a step function of 1 fathom (6 feet) in 1 second at mid-range.

(b) Rhodamine dye concentration: 95% response to a step function of 0.1 part per billion in 1 second.

f. Recording and Readout:

(1) To provide for visual analog.

(2) The data sensed by this instrument is to be an input into the Master Shipboard Data Logging and Processing System.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (applied research, basic research, and oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 2 to 14.

e. Atomic Energy Commission - 10 to 20.

Total: 52 to 114.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 11.

I.1. DEEP SEA PLANKTON SAMPLER

Primary Use:

This is an instrument designed for "underway" operations from an oceanographic survey ship at moderate speeds. Its purpose is to permit quantitative sampling of a variety of sizes of plankton, at selected depths.

Requirements and Specifications:

a. To be designed for "underway" operation and to perform reliably at ship speeds of 0-15 knots and at operating depths of 0 to 6,000 feet.

b. Net opening to be adjusted prior to lowering in water.

c. Net to be designed so as to be opened and/or closed on signal from the ship.

d. Net screen (mesh) size must be capable of being adjusted remotely from the ship, with an end view of achieving a minimum of six (6) screen changes per cast.

e. Water volume flow through net to be measured to an accuracy of ±1 percent.

f. This instrument should provide for attaching standard modular temperature and depth sensors to the net frame to measure and continuously transmit this data to a recorder topside. The characteristics of such standard sensors should be:

(1) Depth Sensor:

0-6,000 feet; ±1/4% of full range
Time Response: 95% response to a step function of 6 feet in 1 second.

(2) Temperature:

-2° to 35°C.; $\pm 0.1^{\circ}$ C.
Time Response: 95% response to a step function of 1°C. in 1 second.

g. Data Readout:

(1) Proper form and type for direct input into the Master Shipboard Data Logging and Processing System.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (oceanographic survey ships, basic research ships, and applied research ships) - 19 to 22.

b. Certain activities within scientific community - 12 to 20.

c. U. S. Coast and Geodetic Survey - 8.

d. Bureau of Commercial Fisheries - 2 to 20.

Total: 41 to 70.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 12.

I.m. SHIPBOARD GAMMA RAY DETECTOR OF NUCLEAR WASTE IN THE SEA

Primary Use:

To be utilized on oceanographic survey ships for identifying and measuring abnormal gamma ray concentrations in the ocean areas, such as would result from nuclear powered vessel refuse and special concentrations from other sources, such as nuclear waste dumping grounds and experimental nuclear tests conducted at sea.

Requirements and Specifications:

a. To perform reliably in depths of water varying from 0-6,500 fathoms, in both coastal and oceanic regions.

b. Sampling operation to be conducted with the ship stopped ("lying-to") and when underway.

c. Sensor module should contain, for example, a pressure protected 6 in. by 9 in. sodium iodide or plastic scintillating crystal with its associated photomultipliers and preamplifiers. It should also include:

(1) A device for indicating the depth of the module with an accuracy of ±1/4% full range.

(2) A discriminator analyzer element to discriminate gamma ray photon energy. The range of this element should be not less than 100 energy categories (channels).

(3) A counting rate range selective from extreme sensitivity downward by at least 5 orders of magnitude and to incorporate the following:

(a) Should measure environmental gamma ray radiation in the ocean.

(b) Should incorporate a multi-range system for special circumstances.

(c) Should range from below the natural background of the ocean to 5 orders of magnitude higher gamma intensities.

(4) Accessory equipment for analyzing a liquid or solid sample on shipboard, including a well-shielded scintillating crystal and electronic equipment connecting this to the shipboard pulse analyzer.

d. Shipboard Recording and Data Readout:

(1) The data from this system should be one of the "inputs" into the Master Shipboard Data Logging and Processing System.

(2) This should include: (a) a multi-channel pulse height analyzer with direct dial readout, (b) visual analog readout and magnetic tape recording, (c) background storage and direct subtraction accessory.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 2 to 8.

e. Atomic Energy Commission - 10 to 20.

Total: 52 to 108.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 13.

I.n. OCEANOGRAPHIC RADIOACTIVE WATER SAMPLER

Primary Use:

To be utilized on oceanographic survey ships for the purpose of collecting sea water samples in order to trace and investigate radioactivity background and anomalies.

Requirements and Specifications:

a. To be utilized when the ship is stopped ("lying-to").

b. The sampler and associated gear to be constructed of non-contaminating material.

c. The sampler to contain a plastic liner of about 15 gallon capacity.

d. The sampler must be of a non-contaminating type which can be opened and closed at any desired depth by remote operation from shipboard. This may or may not require the need for the sampler to withstand hydrostatic pressure.

e. To be designed so that one to two men can conduct the sampling operation, utilizing standard hydrographic wire and equipment.

f. To be designed to permit operation in multiples of four or more samplers per cast.

g. The system must include approximately 15-gallon size shipping containers for shipment of samples to laboratories for analysis and also include spare plastic liners to replace those which are used.

h. Analysis of water samples to be performed either on shipboard, if facilities are available, or at shoreside laboratories.

i. This 15-gallon size sampler is the first and highest priority of a series of sampler sizes, which should increase by an order of two, three, and/or four.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 2 to 10.

e. Atomic Energy Commission - 20 to 40.

Total: 62 to 130.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 14.

I. o. UNDERWATER CAMERA

Primary Use:

To be utilized on oceanographic survey ships for the purpose of obtaining close-up photographs, both single-frame and stereo, of the detailed topography of the sea floor. It will also be employed for photogrammetric mapping of the sea floor.

Requirements and Specifications:

a. To be utilized primarily for stopped ("lying-to") operations but also for slow-speed operations with ship underway at 0-5 knots.

b. To be operable in coastal and oceanic waters, at depths of 0-6,500 fathoms.

c. Film capacity: Approximately 100 to 150 feet of 70mm. film.

d. Photographic distance:

(1) Single-frame photographs: should accept object distances of 2-30 feet.

(2) Stereo photographs: should accommodate close (2 feet) and long (35-50 feet) object distances.

e. The camera instrument must include, or have attached thereto, a device which measures and indicates at all times to an observer on deck the precise height of the camera unit above the sea floor.

f. A deep-water, synchronized illuminating device must be incorporated in this instrument in order to light adequately the photographic field.

g. The instrument must incorporate variable, preprogrammed shutter operation to provide for both continuous and time-series studies.

h. The camera unit must be capable of taking both horizontal and vertical underwater photographs.

i. The camera and its associated devices should provide and photograph the following minimum supporting information in the corner of each frame: (1) date/time, (2) location, (3) camera attitude, and (4) camera direction.

j. In addition, a turbidity meter shall be incorporated into the system for on-deck indication of operational photographic conditions and/or for general environmental knowledge.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 2 to 8.

Total: 42 to 88.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 15.

I. p. SEA FLOOR SAMPLING SYSTEM

Primary Use:

This is primarily a series of interchangeable bottom sampling devices designed for utilization by oceanographic survey ships in the collection of various samples of the sea floor.

Specifications and Requirements:

a. The system shall be designed for utilization by oceanographic survey ships "lying-to" and/or underway with slight "headway."

b. The system shall be operable in water depths varying from 0-6,500 fathoms.

c. The system shall include, but not be restricted to, the following interchangeable sampling devices: (1) small "grab" samplers, (2) short corers (0-15 feet), (3) long corers (0-100 feet), (4) light-weight dredge, (5) heavy-weight dredge, (6) long in situ sampling device, (7) large volume interface sediment sampler (capacity 1 cubic foot), (8) short in situ sampling device.

d. The in situ sampling devices indicated above shall be capable of obtaining an undisturbed sample of the water/bottom interface, including retention of ambient pressure at sampling depths of 1 to 20 feet for the long and up to 6 inches for the short in situ devices.

e. Although certain types of corers and samplers now exist, they are considered to be in need of improvement and consequently, new and radical scientific and engineering techniques are needed to develop an overall improved Sea Floor Sampling System.

f. The various attachments associated with this system, if tended by a wire, shall be so designed that they can be used with the Multi-Purpose Heavy Duty Oceanographic Winch described separately in this Oceanographic Survey Ship instrument system.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (for oceanographic survey ships, basic research ships, and applied research ships) - 19 to 22.

b. Certain activities within scientific community - 12 to 20.

c. U. S. Coast and Geodetic Survey - 8 to 15.

d. Bureau of Commercial Fisheries - 2.

Total: 41 to 59.

Recommendation Where System Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument/equipment priority 16.

I.q. SEA FLOOR GEOTHERMAL PROBE

Primary Use:

To be utilized on oceanographic survey ships, with the ship stopped ("lying-to"), to measure the heat-flow characteristics and values across and within the sea floor sediments.

Requirements and Specifications:

a. To be utilized during stopped ("lying-to") operations.

b. To perform reliably and accurately in water depths of 0 to 6,500 fathoms.

c. Instrument should be simple in design and construction, rugged, and easy to transfer from one ship to another for reinstallation. Modular sensors could be attached to the long and short sediment corers of the Sea Floor Sampling System.

d. Data to be measured:

Data	
Heat Flow	Range: 0 to 10 microcal./cm.^{2}/sec. Accuracy: 0.05 microcal./cm.^{2}/sec.
Temperature gradient	Range: 0 to 0.6° C./m. Accuracy: 0.001° C./m.
Temperature	Range: 0 to 5° C. (0 to 20 feet) Accuracy: 0.001° C. Range: 0-10° C. (0-100 feet) Accuracy: 0.001° C.
Depth of probe (corer) in sea floor	Range: 0 to 20 feet 0 to 100 feet Accuracy: 0.1 foot (or measured

mechanically or visually
on core barrel)

e. Data Recording and Readout:

Data to be displayed and recorded on Master Shipboard Data Logging and Processing System; or, if more practicable, recorded internally at the probe.

Potential Users and Estimated Number of Units They May Require:

a. U. S. Navy (applied research, basic research, and oceanographic survey ships) - 20 to 30.

b. U. S. Coast and Geodetic Survey - 10 to 15.

c. Certain activities within scientific community - 10 to 20.

Total: 40 to 65.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Individual instrument priority 17.

II. a. SHIPBOARD OCEANOGRAPHIC SURVEY SYSTEM

Primary Use:

To be utilized on oceanographic survey ships incorporating the most up-to-date techniques for collection, storage, reduction, and possible transmission of oceanographic data.

Requirements and Specifications:

a. For utilization on oceanographic survey ships with the ship in any of the following modes of operation: (1) stopped ("lying-to"), (2) at anchor, and (3) underway at slow speeds (0-3 knots).

b. To perform efficiently, effectively, and safely in sea states of 0 through 5.

c. To be operable in water depths of 0-6,500 fathoms.

d. To be able to simultaneously accommodate any or all of the sensor modules listed in subparagraph e. following.

e. Sensor - Range - Accuracy:

Sensor	
(1) Depth (4 modules)	Range: 0-600 feet 0-2,400 feet 0-6,000 feet 0-39,000 feet Accuracy: ±.25% of full scale for each range
(2) Temperature	Range: -2° to 35°C. Accuracy: $\pm 0.01^\circ$C.
(3) Sound Velocity	Range: 4,500-5,500 feet/sec. Accuracy: ±1.0 foot/sec. absolute at readout
(4) Light Absorption	Range: 0-100% Accuracy: ±1.0%
(5) Density	Range: 1.00000-1.08000 Accuracy: ±0.00001
(6) Subsurface Currents	Range: 0-8 knots $0-360^\circ$

	Accuracy: ±0.1 knot or better $\pm 10^{\circ}$
(7) In Situ, Modular Ion Analyzer	
(a) Oxygen	Range: 0-10 milliliters/liter Accuracy: ±0.1 milliliter/liter
(b) Salinity (two interchangeable modules)	Range: 0-25‰ 25-45‰ Accuracy: ±0.01‰ ±0.01‰
(c) Nitrate-Nitrogen	Range: 0-50 microgram atoms/liter Accuracy: ±0.1 microgram atoms/liter
(d) Phosphate-Phosphorus	Range: 0-5 microgram atoms/liter Accuracy: ±0.01 microgram atoms/liter
(e) Silicates	Range: 0-200 microgram atoms/liter Accuracy: ±0.1 microgram atoms/liter
(8) Total Magnetic Intensity	Range: 20,000-100,000 gammas Accuracy: ±0.1 gamma

Note: Sensor Time Response: All sensors should have a 95% response to a step function in a period of 1 second.

f. Recording and Readout:

The system shall be designed so that the above data will be read directly into the Master Shipboard Data Logging and Processing System either continuously (time-series) and/or intermittently.

g. If multi-conductor electric cable is employed, this cable and the various sensors associated with this system shall be compatible and useable in conjunction with the Multi-Purpose Constant Tension, Heavy Duty Oceanographic Winch, described elsewhere.

h. Sensors shall be constructed in modular form, with simplicity so that they can be easily repaired and/or replaced at sea.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 2 to 10.

e. U. S. Coast Guard - 10 to 20.

Total: 52 to 110.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Instrument system priority 1.

II. b. PRECISION NAVIGATIONAL CONTROL SYSTEM FOR OCEANOGRAPHIC SURVEY OPERATIONS

Primary Use:

To be utilized by oceanographic survey ships for obtaining precise navigational positioning incidental to routine oceanographic surveys and/or special oceanographic investigations.

Requirements and Specifications:

a. To be utilized on oceanographic survey ships in the conduct of routine oceanographic surveys and special oceanographic investigations.

b. To be utilized in both coastal and oceanic operations, day and night, and to have an all-weather capability.

c. The system operation must be reliable, i.e., have an on-the-air time in excess of 95% and signals must be free of any ambiguity.

d. To be readily adaptable to automatic plotting of position on a plotting sheet.

e. To be designed to support a dual-range operational capability as follows:

(1) Short range (0-200 miles); accuracy ±50 feet.
(2) Long range (0-5,000 miles); accuracy ±1/2-1 mile.

f. Shipboard system to be designed emphasizing modular construction, compactness, ruggedness, and ease and simplicity of operation and maintenance. In any case, ship's crew should be able to operate and service the system at sea without extensive specialized training. If feasible, both short and long range systems should be incorporated into one console.

g. "Position" information obtained from both of these systems must be capable of being read automatically into the Master Shipboard Data Logging and Processing System simultaneously and in conjunction with any environmental data.

h. Provision also shall be made for direct "read-in" of "position" information from both the short and long range system into the Hydrographic Precision Scanning Echo Sounder System.

i. Geographic Coverage:

This system(s) must be worldwide, oceanwide; however, the short range system coverage may be limited by shore station site availability.

Potential Users and Estimated Number of Shipboard Units Which They May Require:

a. U. S. Navy (basic research, applied research, hydrographic-oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 10 to 15.

e. U. S. Coast Guard - 10 to 20.

Total: 60 to 115.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Instrument system priority 2.

II. c. MASTER OCEANOGRAPHIC SHIPBOARD DATA LOGGING AND PROCESSING SYSTEM

Primary Use:

To be utilized on oceanographic survey ships. In view of the many ships scheduled to be employed in oceanwide research and survey programs, it is imperative that the maximum quantity of data possible be processed on board ship. This data processing system, through being sufficiently versatile to handle a variety of data inputs, should provide the required on-board data analyzing, logging, processing, and storage capability. This system will expedite the availability of "smoothed" field data for utilization by either the scientific leader or survey party chief "in the field" in order to achieve optimum results.

Requirements and Specifications:

a. To be utilized and perform reliably under the following modes of survey type of operations: (1) ship stopped ("lying-to"), (2) ship anchored, and (3) ship underway at speeds 0-18 knots.

b. System to function reliably in sea states 0 through 5.

c. The system should employ solid state circuitry wherever possible to reduce size, weight, and heat generation.

d. It should be versatile enough to record information from a large variety of sensors and transducers, in both digital and analog form, and to include such key information as time, position, course, speed, ship, and cruise number on all data records.

e. It should employ modular construction, plugboard system programming, and stored program system control.

f. It should incorporate, but not be limited to, the following major components to achieve the above:

(1) A multichannel, high quality, analog magnetic tape recorder, having modular read-write electronics for direct and FM recording.

(2) Input commutators:

(a) A 100 channel simple sequential commutator having a variable sampling rate up to 100 samples per second. This commutator also should have a switching mode wherein sequential groups of 10 channels can be selected.

(b) A multichannel simultaneous sample hold and multiplex commutator having a variable sampling rate up to 12,000 per second.

(c) A commutator control unit to permit combined or independent use of the two commutators.

(3) Analog to digital converters:

(a) A 12 bit bipolar A-D converter having a variable sampling rate up to 12,000 samples per second. (Small aperture, 50 microsecs.)

(b) A 12 bit bipolar voltage to frequency type A-D converter having a variable sampling period in the range of 10 msec. to 1 sec.

(4) A small scale digital computer having the following characteristics: (1) 12 microsecond add time, (2) 4,096 words of random

access memory, (3) two independent serial by word input/output channels at least one of which can be used in an automatic buffer mode at a word rate of 60 kc., (4) at least one on-line digital magnetic tape unit, (5) punched paper tape input/output at not less than 110 characters per second, and (6) an on-line monitoring typewriter.

(5) A system programming board having the following characteristics: (1) 500 audiofrequency jacks, (2) a removable 1,000 hole plugboard.

(6) A 30 by 30 inch combined digital-analog X-Y plotter with punched paper tape input.

(7) Several independent analog display units to monitor while recording.

(8) 250 inches of standard 19 inch rack for mounting special instrumentation. Racks are to be equipped with power outlets and signal lines running to system programming board.

(9) Air conditioning and humidity control.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 25.

b. U. S. Coast and Geodetic Survey - 5 to 8.

c. Bureau of Commercial Fisheries - 2.

d. Certain activities within scientific community - 2 to 6.

e. U. S. Coast Guard - 5 to 10.

Total: 34 to 51.

Recommendation Where System Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Instrument system priority 3.

II. d. TOWED SUBSURFACE INSTRUMENT SYSTEM

Primary Use:

This device is designed for utilization on oceanographic survey ships for underway operations to obtain horizontal profiles of certain key oceanographic variables. It is to be a streamlined, compact platform to which will be attached modular sensors and other special miniaturized instruments capable of being towed submerged at moderate speeds.

Requirements and Specifications:

a. The platform with associated instruments shall be capable of being towed from an oceanographic survey ship at any constant depth within a depth range of 0-2,000 feet at any ship's speed ranging from 3 to 15 knots. In addition, a feature should be incorporated in the vehicle design to permit continuous, controlled variation of the platform's depth over the entire operating depth range or any increment thereof.

b. The towing wire angle shall not exceed 25° from the vertical.

c. The platform and associated instruments shall be compact, streamlined, and not excessively heavy or bulky in order to allow rapid and adequate deck stowage and/or to permit smooth entry into or hoisting out of the water.

d. The following sensors shall be included:

Sensor	
Temperature	Range: -2 to 35°C. Accuracy: ±0.01°C.
Salinity (two interchangeable modules)	Range: 0 to 25‰ 25 to 45‰ Accuracy: ±0.01‰ ±0.01‰
Sound Velocity	Range: 4,500 to 5,500 feet/second

	Accuracy: ±1 foot/sec. absolute at readout
Depth (two interchangeable modules)	Range: 0 to 600 feet 0 to 2,000 feet
	Accuracy: ±0.25% of full scale

Sensor Time Response: All sensors, except depth, should have a 95% response to a step function in a period of 1 second. The depth sensor should have a 95% response to a step function of 1 fathom (6 feet) in a period of 1 second.

e. Data Recording and Readout:

Temperature, salinity, sound velocity, and depth data shall be transmitted from the sensors into the Master Shipboard Data Logging and Processing System.

f. This platform should be able to be rigged from and towed by the Multi-purpose, Constant Tension, Heavy Duty Oceanographic Winch where it is available.

g. If this unit can be mass-produced cheaply, it may have widespread commercial fishing application.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 30.

b. U. S. Coast and Geodetic Survey vessels - 10 to 15.

c. Bureau of Commercial Fisheries vessels - 2 to 20.

d. Certain activities within the scientific community - 10 to 20.

Total: 42 to 85.

Recommendation Where Equipment Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Instrument system priority 4.

II.e. AIR-SEA SURFACE INTERFACE ENVIRONMENTAL DATA RECORDING SYSTEM

Primary Use:

To be utilized by oceanographic survey ships primarily for underway operations, and secondarily for stopped operations, to sample and record the key environmental data found at and/or near the air-sea interface.

Requirements and Specifications:

a. To be designed and constructed primarily for underway operations at ship's speeds of 0-15 knots.

b. A strict requirement is that the sensors be designed and located so as to measure the environment immediately at the interface or as close thereto as possible, without being adversely affected by own ship's motion and air turbulence over the ship projections as the ship moves through the water.

c. Sensors: Ranges and Accuracies:

Sensor	
Sea surface temperature	Range: -2° to 35°C. Accuracy: ±0.1°C.
Sea surface salinity (two interchangeable modules)	Range: 0 to 25‰ 25 to 45‰ Accuracy: ±0.01‰ ±0.01‰
Sea surface oxygen	Range: 0 to 10 milliliters/liter Accuracy: ±0.1 milliliter/liter
Air temperature	Range: -40° to 70°C. Accuracy: ±0.01°C.
Relative humidity or Dew point	Range: 0 to 100% or -40° to 50°C. Accuracy: ±5% or ±0.1° C.

Barometric pressure	Range: 950 to 1,050 millibars Accuracy: ±0.1 millibar
Wind speed and direction	Range: Speed: 0 to 200 knots Direction: 0 to 360° Accuracy: Speed: ±0.5 knots Direction: ±5°
Incident radiation	Range: 0 to 40 Langleys/minute Accuracy: ±5% overall range
Reflected radiation	Range: 0 to 100 (U. S. Weather Bureau special scale) Accuracy: ±5% overall range

The system should include provision for a towed, submerged, constant depth device to measure wave spectra and transmit this data to the Master Shipboard Data Logging and Processing System for correlation with other recorded data.

Sensor Time Response: All sensors should afford a 95% response to a step function in a period of 1 second.

d. Recording and Readout:

Above data must be a direct and immediate input into the Master Shipboard Data Logging and Processing System, on a continuous and/or intermittent recording basis.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 30.

b. U. S. Coast and Geodetic Survey - 10 to 15.

c. Certain activities within scientific community - 10 to 20.

d. Bureau of Commercial Fisheries - 2 to 8.

e. U. S. Weather Bureau - 10 to 20.

Total: 52 to 93.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Instrument system priority 5.

II. f. MARINE SEISMIC RECEIVING SYSTEM

Primary Use:

To be utilized on oceanographic survey ships to measure and record the various characteristics of the structure of the sea floor as applicable to acoustical propagation studies of the water volume, the bottom sediments, and the underlying structures.

Requirements and Specifications:

a. To perform reliably on oceanographic survey ships, in sea states of 0 through 5, with ship stopped ("lying-to").

b. To be operable in coastal and oceanic regions, in water depths of 0 to 6,500 fathoms.

c. To be designed so that the equipment is portable, compact, rugged, simple, requiring minimum maintenance, and readily and easily transferable from one ship to another.

d. The receiving hydrophone must be so designed as to permit reliable detection of shots as far as 100 nautical miles away.

e. Receiving hydrophone frequency:

(1) Range: 0 to 10 kcs.
(2) Accessory Filters:

(a) Filters to permit the selection of high frequency band (usually greater than 4 kcs.) for the resolution of thin-bedded strata.

(b) Filters to permit the selection of low frequency band (usually lower than 500 c.p.s.) for maximum penetration of the sediments.

f. Data Recording and Readout:

(1) Data to be directly read into the Master Shipboard Data Logging and Processing System.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 20 to 40.

b. U. S. Coast and Geodetic Survey - 10 to 20.

c. Certain activities within scientific community - 5 to 10.

d. U. S. Geological Survey - 2 to 4.

e. Commercial oil companies - Unknown.

Total: 37 to 74.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Instrument system priority 6.

II.g. UNDERWATER TELEVISION SYSTEM FOR SEA FLOOR INVESTIGATIONS

Primary Use:

To be utilized on oceanographic survey ships in coastal and oceanic areas to obtain continuous observations of and to investigate the sea floor topography.

Requirements and Specifications:

a. To be operable in water depths of 0 to 6,500 fathoms, with the ship stopped ("lying-to") or underway at slow speeds (0 to 5 knots).

b. The system must include a device for indicating the precise height of the camera above the sea floor.

c. The design of this system must include a provision for "taping" all of its coverage for re-run at a later time.

d. The camera carrying unit must contain, or have attached to it, an illuminating device which is capable of adequately lighting the TV picture field at all depths and which has a duration of at least two hours of sustained operations.

e. There must be provision for remote focus and lens control from shipboard.

f. The camera carrying unit must be streamlined, rugged, compact, and capable of being handled readily and easily on board ship during operations.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy (basic research, applied research, and oceanographic survey ships) - 15 to 30.

b. U. S. Coast and Geodetic Survey - 5 to 15.

c. Certain activities within scientific community - 5 to 15.

d. Bureau of Commercial Fisheries - 2 to 8.

Total: 27 to 68.

Recommendation Where Instrument Should Be Researched and Developed:

U. S. Industry.

Relative Importance to U. S. National Oceanographic Program:

Instrument system priority 7.

APPENDIX F

U. S. NAVY HYDROGRAPHIC OFFICE REQUIREMENTS FOR OCEANOGRAPHIC INSTRUMENT SUIT FOR SHIPS OF OPPORTUNITY

Primary Use:

This is a special oceanographic "instrument suit" for utilization on certain "ships of opportunity" to collect much needed oceanographic data. These ships of opportunity include, but are not restricted to: (1) Certain U. S. Navy combatant fleet units such as aircraft carriers, cruisers, destroyers, amphibious ships, mine sweepers, and submarines, (2) U. S. Navy Radar Picket Ships (YAGR's and DER's), (3) certain U. S. Navy auxiliary units (oilers, refrigerator ships, cargo ships, ice breakers), (4) units of Military Sea Transportation Service, (5) units of U. S. Merchant Marine, (6) U. S. Air Force Ocean Range Vessels, (7) larger units of U. S. Fishing Fleet. The installation and operation of this "instrument suit" on the above indicated platforms is predicated on a not-to-interfere basis with the ship's primary mission.

Requirements and Specifications:

a. This "instrument suit" is primarily designed for utilization by ships "underway," as during long transits between ports, extended operations in certain geographic areas, and involving special operations related to the primary mission of the ship.

b. This "instrument suit" to perform reliably and accurately, with minimum maintenance, at ship's speeds of 0 to 18 knots and in sea states 0 through 5.

c. This "instrument suit" to be so designed and constructed as to be capable of being installed and removed from one platform to another with minimum expenditure of time, effort, and money. In this connection, it should be compact, light weight, rugged, and reliable to withstand the severe treatment in shipment to, installation on, and removal from the various ship platforms.

d. Components:

(1) AN/UQN type of Sonic Sounding Set to record 0 to 6,000 fathoms.

(2) Precision depth/graphic recorder for utilization with AN/UQN Sonic Sounding Set.

(3) One electronic bathythermograph with associated winch-wire-boom-recorder/readout assembly.

(4) An automatic recording sea-surface temperature probe.

(5) A suitcase size meteorological instrument to record automatically key air-sea interface meteorological data, including total incident and reflected solar radiation.

(6) Towed magnetometer with an all-weather capability.

(7) An "interim" wave height measuring/recording device.

In the design and fabrication of this "instrument suit," consideration shall be given to two different applications: (1) installing all of the above in a small "van" for trans-shipment to and on-deck stowage on the particular ship, or (2) integrating certain of the above components into already existing "instrument suits" of certain ships such as destroyers, etc.

e. Accuracies and Range:

(1) Sonic Sounding Set
Range: 0 to 6,000 fathoms
Accuracy: As in present AN/UQN system

(2) PDR/PGR
Range: 400 fathom incremental presentation of 0 to 6,000 fathom range
Accuracy: 1 part per million (time)

(3) Electronic Bathythermograph
Range: (1) Depth: 0 to 2,500 feet
(2) Temperature: -2 to 35° C.
Accuracy: (1) Depth: ±0.25% of full range
(2) Temperature: ±0.1° C.

(4) Sea Surface Temperature Recorder
Range: -2 to 35° C.
Accuracy: ±0.1° C.

(5) Meteorological Suitcase - Type Package

To be determined, but to include: (1) air-surface temperature, (2) barometric pressure, (3) relative humidity, (4) surface wind direction and speed, (5) total incident and reflected solar radiation with following ranges and accuracies:

Sensor	
Air-surface temperature	Range: -40 to +70° C. Accuracy: ±0.01° C.

Sensor	
Barometric pressure	Range: 950 to 1,050 millibars Accuracy: ±0.1 millibar
Relative humidity	Range: 0 to 100% Accuracy: ±5%
Surface wind: speed direction	Range: 0 to 200 knots 0 to 360° Accuracy: ±0.5 knot ±5°
Radiation: incident	Range: 0 to 40 Langleys/minute Accuracy: ±5% overall range
reflected	Range: 0 to 100 (U. S. Weather Bureau special scale) Accuracy: ±5% overall range

(6) Magnetometer
Range: 20,000 to 100,000 gammas
Accuracy: ±0.01 gamma

(7) Wave Meter
Range: 0 to 40 feet
Accuracy: ±0.5 foot

f. Modular construction should be used throughout the system to: (1) facilitate maintenance and repair, and (2) to permit special "tailor-made" assembling of sensors and recorders in order to augment the particular ship's existing instrumentation (such as in the case of fleet units which are already partially equipped).

g. The recording of all data should be automatic insofar as possible. In addition, data readout and recording should be in such form that it can be a direct input into the archives of the National Oceanographic Data Center.

Potential Users and Estimated Number of Units Which They May Require:

a. U. S. Navy - 25 to 100
b. U. S. Air Force Ocean Range Vessels - 4 to 8
c. MSTS and U. S. Merchant Marine - 25 to 50

d. U. S Fishing Fleet - 2 to 5

Total: 56 to 163

Recommendation Where System Should Be Researched and Developed:

U. S. Industry

Relative Importance to U. S. National Oceanographic Program:

(1) Of intermediate importance and priority as related to the overall U. S. National Oceanographic Program.

(2) Has a potential of increasing in importance as the National Oceanographic Program progresses, and it can be of valuable assistance to the Navy ASWEPS program.

APPENDIX G

U. S. NAVY HYDROGRAPHIC OFFICE REQUIREMENTS FOR SHIPBOARD OCEANOGRAPHIC SYNOPTIC SYSTEM FOR REGIONAL AND MOBILE OBSERVATIONAL NETWORKS (ASWEPS)

Primary Use:

This is a specialized oceanographic, synoptic, collecting-reporting instrument system; it is designed especially for the rapid collection and reporting by radio communications of key oceanographic data. It will be utilized by ocean station vessels, radar picket ships, and selected combatant fleet units. These three ship classes will be employed primarily as part of a regional observation network, and secondarily as part of a mobile network.

Requirements and Specifications:

1. For use on board ocean station vessels, radar picket ships, and certain combatant fleet units, with the ship "lying-to" or underway at slow speeds (0 to 5 knots), and in sea states 0 through 6.

2. This system must include, but not necessarily be limited to, the following major components:

   a. Modular sensors
   b. Sensor housings
   c. Sensor electrical cable handling devices
   d. Monitoring and display consoles
   e. Accessory equipment to prepare the data for rapid, automatic, radio transmission

3. The following sensors shall be included:

Sensor	
Depth	Range: 0 to 2,500 feet Accuracy: ±0.5% or better over full range

Sensor

Temperature: Sea surface (See subparagraph 6 below.)	Range: -2 to 35° C. Accuracy: ± 0.1° C.
Vertical profile	Range: -2 to 35° C. Accuracy: ±0.1° C.
Sound velocity	Range: 4,500 to 5,500 feet per second Accuracy: ±1.0 foot per second absolute at readout
Conductivity (two interchangeable modules)	Range: 10 to 40 millimhos per $cm.^2$ 30 to 60 millimhos Accuracy: ± 0.01 millimho per $cm.^2$ ± 0.01 millimho per $cm.^2$

Spare sensor outlet (See subparagraph 5 below.)

4. Data Storage and Transmission:

a. It is required that the data output from all sensors be recorded continuously and/or be sampled sequentially as sensors are lowered and raised.

b. The following modes of data recording and display must be available:

(1) Visual analog display on strip charts or X-Y recorders.

(2) Continuous analog tape recording for subsequent reduction and analysis ashore.

(3) Provision to permit the rapid radio transmission of the data collected to other fleet units at sea and/or to shore control centers. It is estimated that the reliable radio transmission range must be 2,000 to 2,500 miles.

5. Spare sensor outlet:

A further requirement of this system is that provision must be made for inclusion at a later date of at least one additional sensor, which is yet to be determined. Cable handling devices, recorders, and transmission processing equipment all must allow for this contingency.

6. Sea surface temperature sensor:

This system must be capable of determining the water temperature immediately at the air-sea interface.

7. General design criteria:

a. Portability - This system must be so designed and constructed as to permit rapid, economical removal from one ship and relocation on another ship; need for such a transfer may arise, for example, when a ship commences yard overhaul. No drydock time shall be required to effect the relocation of this system.

b. All-weather capability - It is required that this system be so designed, constructed, and installed as to permit satisfactory operation, without risk to operating personnel, in sea states 0 through 6 (wave heights 0 to 20 feet).

c. A future requirement of this system will be, perhaps with certain modifications, that it be capable of operation aboard ships underway at speeds as high as 15 to 20 knots.

d. Ship types - Inasmuch as it is planned that this system be installed principally on board ships, the following characteristics are considered representative of the smallest and largest ship types on which it is expected this system will be utilized: <u>Displacement</u>, 1,200 tons to 4,000 tons; <u>length</u>, 209 feet to 440 feet; <u>beam</u>, 33 feet to 57 feet; <u>draft</u>, 15 feet to 27 feet; <u>freeboard</u>, 10 feet to 30 feet.

<u>Potential Users and Estimated Number of Units Which They May Require</u>:

a. U. S. Coast Guard - 21
b. U. S. Navy - 45
c. Bureau of Commercial Fisheries - Needs unknown
d. U. S. Coast and Geodetic Survey - Needs unknown
e. Scientific Community - Needs unknown

Total: 66 (approximately)

Recommendation Where System Should Be Researched and Developed:

U. S. Industry

Relative Importance to Potential Users:

a. U. S. Navy - Top priority for ASW purposes
b. Other activities - Unknown

APPENDIX H

REQUIRED INSTRUMENTS FOR FISHERIES RESEARCH

by

Dr. Julius Rockwell, Jr., and Fisheries Instrumentation Committee of the Bureau of Commercial Fisheries

PREFACE

The Bureau of Commercial Fisheries requires other instruments to meet its special needs in addition to those described in preceding appendices. The nature and purpose of descriptions, priorities, readouts for the National Oceanographic Data Center, modular construction, and additional general requirements as well as estimates of numbers required, have been covered in the preface of appendix E (p. 349).

The sensor modules (Section 1.1100) represent the most vital and the least developed part of all systems. Existing telemetering devices may be adequate except for special applications.

Two basic areas of instrumentation are covered: instruments or instrument systems for measuring and recording physical and chemical parameters, and those for sampling, collecting, or studying the biota. The list is not complete because in some areas the basic instrumentation problem of calibrating devices designed to collect quantitative biological samples has not been solved.

The stated requirements of instruments to collect biological samples imply, in general, improvements and refinements of existing techniques rather than the development of entirely new approaches. For example, in Sections 1.3200 and 1.3300, sampling devices which consist of plankton or nekton nets, instrumentation is intended to accommodate existing nets. While it is desirable to construct new collecting devices, the basic information of how animals react to them is lacking. The purpose of these devices is, in general, to obtain a quantitative estimate of living creatures and plants per unit volume of the water body. Research in this area is urgently needed before better collecting devices can even be suggested. Also, there is an equal need for an understanding of the hydrodynamics of existing sampling devices.

More than one modular form has been described for sensing a given characteristic of the water. The basis of separation has been use. It would be desirable if several of these could be combined at no extra cost. If a decided cost advantage would result by dividing the range of capability of a module still further, the Bureau should be consulted.

It may be desirable from the manufacturer's standpoint to combine several sensors into one module -- such as the dissolved gas sensors (Section 1.1160). It will not be mandatory to use separate modules for each sensor providing it can be demonstrated to be to the Bureau's advantage to combine them.

The effect of one environmental factor on the sensor of another can be significant. The effect of depth is the most pronounced since it may subtly affect the operation of the electronic components, as well as the sensing element. (See pages 32-35.) In general, sensors should be self-compensating.

It is suggested that a manufacturer having a capability for making a product very similar to one that appears on the list contact the Bureau to determine a group with which he can work, and the extent and nature of support he can expect without impairing his right to patent.

The Bureau buys what is available and makes what is not available and will work with Industry to build a more serviceable instrument.

The following general requirements are applicable to most of these instruments and instrument systems. They must:

1. Operate in severe environments, particularly ones of high humidity and salt corrosion and withstand storage temperatures of from -25° to 60° C.;

2. Resist vibration and shock;

3. Have high reliability and long life;

4. Provide for accurate calibration on board ship;

5. Be simple to operate and be easy to maintain;

6. Be compact and portable; and,

7. Meet requirements of NODC.

The general number of items required by the Bureau is indicated subject to the availability of funds and tolerable costs. These figures do not include those that may be required by state and international agencies or by commercial fishing enterprises.

1.0000 FIELD EQUIPMENT

Numbers required (See p. 415.)

1.1000 SYSTEM COMPONENTS

1.1100 SENSOR MODULES

1.1110 Temperature (3 modules).

Range and accuracy:

(1) -2° to 45° C. $\pm 0.1^{\circ}$ C. at depths 0 to 500 m. . . . . (47)

(2) -2° to 35° C. $\pm 0.01^{\circ}$ C. at depths 0 to 500 m. . . . . (554)

(3) -2° to 35° C. $\pm 0.01^{\circ}$ C. at depths 0 to 12,000 m. . . . . (121)

Response: 95% in 0.5 second.

1.1120 Salinity (3 modules).

Range and accuracy:

(1) 0 to 45‰ ±0.2‰ at depths 0 to 500 m. . . . .(46)

(2) 25 to 40‰ ±0.01‰ at depths 0 to 500 m. . (537)

(3) 25 to 40‰ ±0.01‰ at depths 0 to 12,000 m.(120)

Response: 95% in 0.5 second including flushing time.

Temperature compensation: -2° to 45° C.

1.1130 Pressure (depth) (4 modules).

Range and accuracy:

(1) 0 to 50m. ±0.25%. . . . . (25)

(2) 0 to 500 m. ±0.5%. . . . . (542)

(3) 0 to 2,500 m. ±0.5%. . . . . (125)

(4) 0 to 12,000 m. ±0.5%. . . . . (56)

Response: 95% in 1 second.

Temperature compensation: -2° to 35° C.

1.1140 Density (2 modules) (In situ directly as opposed to computation from temperature, salinity, and pressure).

Range and accuracy:

(1) 0.9800 to 1.0320 g./cm.^{3} ±0.0001 at depths 0 to 500 m. . . . . (48)

(2) 1.0200 to 1.0400 g./cm.^{3} ±0.00002 at depths 0 to 2,500 m. . . . . (112)

Operating environment: -2° to 35° C.

1.1150 pH (2 modules).

Range and accuracy:

(1) 0 to 8 pH units ±0.03 at depths 0 to 500 m. . (29)
(2) 6 to 14 pH units ±0.03 at depths 0 to 500 m. (56)

Response: 95% in 1 second including flushing time.
Operating environment: -2° to 45° C.; Salinity 0 to 45‰.

1.1160 Dissolved Gases[1/]

1.1161 Oxygen (3 modules).

Range and accuracy:
(1) 0 to 15 ml./l. ±0.02 at depths 0 to 50 m. . (47)
(2) 0 to 10 ml./l. ±0.02 at depths 0 to 500 m. . (535)
(3) 0 to 10 ml./l. ±0.02 at depths 0 to 2,500 m. . . . . (118)

Response: 95% in 1 second including flushing time.
Operating environment: -2° to 45° C.; Salinity 0 to 45‰.

1.1162 Carbon Dioxide. (44)

Range and accuracy:
0 to 4 ml./l. ±0.01 at depths 0 to 500 m.

Response: 95% in 1 second including flushing time.
Operating environment: -2° to 45° C.; Salinity 0 to 45‰.

1.1163 Hydrogen Sulfide. (19)

Range and accuracy:
0 to 5 ml./l. ±0.5 at depths 0 to 500 m.

Response: 95% in 1 second including flushing time.
Operating environment: -2° to 45° C.; Salinity 0 to 45‰.

1.1164 Nitrogen. . . . . (17)

Range and accuracy:
0 to 5 ml./l. ±0.02 at depths 0 to 500 m.

Response: 95% in 1 second including flushing time.
Operating environment: -2° to 45° C.; Salinity 0 to 45‰.

1.1170 Light.

1/ Two or more may be combined in one module if economically desirable.

1.1171 Incident visible irradiance (to monitor ambient visible irradiance at surface during submarine irradiance measurements). . . . .(62)

Range and accuracy:

0 to 1 g. cal./cm.^{2}/min. ±0.1% (for visible light only)

Specifications and requirements:

(1) Remote controlled filter-changing mechanism.
(2) Equipped with a cosine collector.
(3) Gimbal-mounted.

Operating environment: Exposed marine atmosphere, tropical to polar.

1.1172 Ambient irradiance (to measure visible irradiance <u>in situ</u> at depth). . . . .(73)

Range and accuracy:

0.001 to 1.1 g. cal./cm.^{2}/min. ±2% at depths 0 to 500 m.

Specifications and requirements:

(1) Detectors shall be provided with cosine collectors and be capable of being oriented in any direction.
(2) Provision in some designs to measure the spectral distribution of light.

Operating environment: -2° to 45° C.

1.1173 Beam Transmission (to measure the absorption and scattering of light in water). . . . . (207)

Range and accuracy:

0 to 100%/m. ±0.05% at all wave lengths.

Specifications and requirements:

(1) Capable of employing a variety of interference-type filters which may be changed while submerged.
(2) Capable of operation in full sunlight.
(3) Design to provide adequate flushing when in motion.
(4) Can be towed up to 15 knots.
(5) Path lengths adjustable (a) 5 to 50 cm.
(b) 50 to 200 cm.

1.1180 <u>Current</u> (2 modules).

Range and accuracy:

(1) 0 to 4.0 m./sec. ±0.1 at depths of 0 to 500 m. . . . .(131)

(2) 0 to 1.0 m./sec. ±0.03 at depths 0 to 2,500 m. . . . . (38)

Direction: Accurate to ±5°.

Operating environment: -2° to 45° C.

1.1200 COMMUNICATION MODULES.

1.1210 Data Telemetering Module. . . . . (96)

Purpose: To accept the output from up to six standard data sensors and transmit this information to the surface monitoring and recording unit.

Specifications and requirements:

(1) Operating environment:
   (a) Temperature: -2° to 50° C.
   (b) Depth: Maximum of 12,000 m.
   (c) Cable length: Maximum of 18,000 m.

(2) The total underwater system including the sensors shall not require more than one 3-conductor cable excluding the strength member. This cable shall supply the required power.

(3) The total system may have up to 20 telemetering modules on one cable.

1.1220 Cables (A family of improved steel cables which contain electrical conductors). . . . .(76,000 m.)

Purpose: To serve as towing, trawling, and support cables for research survey and commercial fishing gear, and to serve as electrical conductors for instruments and equipment.

Specifications and requirements:

(1) Must be compatible with anticipated uses in telemetry, television, control, lighting, fish shocking, and power supply.

(2) Must be able to withstand severe conditions of pressure, temperature, tension, torsion, shock, chafing, abrasion, vibration, and repeated bending over small radius sheaves.

(3) Must have life expectancy greater than presently available cable.

1.1230 Buoy Location Transponder.

Purpose:

(1) For position fixing in making oceanographic measurements.

(2) For locating free floating or anchored buoys, instrument capsules, and nets.

1.1231 Buoy or Instrument Capsule-mounted Transceiver Module. . . . . (135)

Specifications and requirements:

(1) The unit shall transmit a coded identification signal whenever it is activated by a coded interrogation signal.

(2) The unit shall not respond to any signal that does not contain its own particular code.

(3) The transmitter shall turn itself off when transmission is completed. Duration of transmission shall be no longer than required by the interrogator for obtaining its bearing.

(4) It shall be possible to change the code by replacing a plug-in unit within the module.

(5) The range shall be at least 50 miles when used with the shipboard or airborne interrogator.

(6) The module shall contain internal batteries or other power supply sufficient for at least 30 days of continuous receiver and intermittent transmitter operation. Provision shall be available to increase life of power supply to at least 6 months. No maintenance shall be required during this period.

(7) Only nonspillable or dry batteries shall be used.

(8) The module shall be capable of normal operation without maintenance after being submerged to a maximum depth of 2,500 meters for at least 30 days.

(9) The module shall operate reliably over the temperature range of -25° to 50° C.

(10) The maximum weight of the module complete with antenna and internal power source shall not exceed 40 pounds, exclusive of pressure case, if any.

1.1232 Shipboard or Airborne Interrogation Module. . . (25)

Specifications and requirements:

(1) This module shall allow the operator to interro-

gate selectively, identify, and determine the bearing of each buoy or capsule-mounted module.

(2) It shall operate from internal, non-spillable, rechargeable batteries.

(3) It shall operate reliably over a temperature range of -25° to 50° C.

(4) Maximum weight including batteries shall not exceed 30 pounds.

1.2000 VEHICLES.

1.2100 TOWED VEHICLES.

1.2110 Parameter Following Device (three models for 3 depth ranges).

Purpose: To provide a vehicle that will follow constant value of a given parameter, and carry special sensor modules and other equipment.

Specifications and requirements:

This device is to be used on an electrically conducting cable and will be towed from a vessel at speeds up to 15 knots.

(1) Depth:

(a) 0 to 50 m. . . . . (8)

(b) 0 to 500 m. . . . . (27)

(c) 0 to 2, 500 m. . . . . (16)

(2) The device shall contain any or all of the standard or special sensor modules. Continuous surface monitoring of the outputs of these modules is required.

(3) The parameter being followed shall be selectable from the surface. It shall also be possible to vary the level of the parameter being followed within the full range of the respective sensor module, providing the depth capability is not exceeded.

For example, the device shall be capable of following one temperature level and upon command from the surface proceed directly to any other temperature level that the operator selects. It shall then follow this new level. If the operator desires to stop following the temperature level, he may by turning a switch command the device to follow any other parameter for which there is a sensor module. Similarly, the level of the new parameter being followed shall be continuously variable from the surface.

(4) Accuracy in following any level of any parameter shall be limited only by the accuracy of the standard sensor modules and the response time of the entire system.

(5) Utility of the system is directly dependent upon fast vehicle response time.

(6) The device shall position itself by controllable vanes or fins and/or by a winch aboard ship.

(7) Provision shall be made for the attachment of detection, observation, and sampling devices. The effect of these attachments upon the guidance or positioning system should not impair the unit's ready response to variables.

1.2200 TETHERED VEHICLES.

1.2210 Self-Propelled Robot Vehicle. . . . . (5)

Purpose: To operate from ships of opportunity to carry sensing elements for vertical profiles while the ship is underway without necessity for special installation of heavy winch and boom on board.

Specifications and requirements:

(1) Must have a streamlined body which can be towed (or powered through cable) astern of ship traveling at speeds 15 to 20 knots for distances up to 4,000 miles. By guidance system and with power supplied through cable, vehicle could be made to dive without heavy strain on cable, or to move forward of ship and sink to depth required as ship passed over. It might also be operated continuously at constant or varying depth below ship throughout trip.

(2) It must be capable of operation from surface to depths of 300 m.

1.2300 FREE VEHICLES.

1.2310 Large Submersible Research Vessel. . . . . (4)

An oceanographic research vessel capable of independent operation from the surface to at least 300 meters for observing the behavior of organisms in relation to their environment. For this purpose we envision a boat of approximately 40 meters, with an Albacore-type hull, a sail, a submerged speed of 20 knots, and capable of dives of at least 8 to 10 hours at full speed for a large part of the diving time. The ability to operate more or less continuously underwater would greatly increase the usefulness of such a vessel. It would have viewing ports, water and plankton sampling devices, television, several kinds of acoustical gear, a suit of modular sensors with readouts on board, and remote manipulators. A converted Navy submarine would not be suitable.

1.2320 Small, Manned, Pressure Resistant Vehicle. . . . . (10)

There is also need for a much smaller vehicle for two or three men, which could operate from a mother ship.

1.2330 Drone. . . . . (8)

An instrumented surface or subsurface vessel which could either be programmed to a search pattern or commanded from a mother ship or shore, to operate at depths of up to 500 m.

1.3000 SAMPLING DEVICES.

1.3100 WATER.

1.3110 Micro Water-sampler. . . . . (26)

Purpose: A device for obtaining a small water sample from a thin stratum.

Specifications and requirements:

(1) Capacity: 10 to 50 ml.
(2) Filling time less than 10 sec.
(3) Must sample a stratum of 2 cm. or less without drawing in water from strata above or below that being sampled.
(4) Positioning of this sampler above the bottom to within ±2 cm. is necessary.

1.3200 PLANKTON.

1.3210 Low Speed Plankton Sampler Frame. . . . . (75)

Purpose: To provide opening and closing capability and environment sensor carriage for standard 1-meter, 1/2-meter, and other conventional plankton nets.

Specifications and requirements:

(1) Contain a mechanism which will open and close net on command.

(2) Permit installation of conventional flowmeter.

(3) Permit simultaneous use at intervals along the towing wire.

(4) Opening and closing of nets, when more than one net is used in series, should be simultaneous to within ±1 min. per 100 m. of towing cable length.

(5) The opening and closing events on each net shall be automatically recorded.

(6) The opening-closing commands may be given either from the vessel and/or by preprogramming.

(7) Operate down to 2,500 m. and from 1/2 to 3 knots.

1.3220 High Speed Plankton Sampler Frame. . . . .(75)

Purpose: To collect at high speed a quantitative plankton and larval sample at a specified depth and to measure the environmental parameters encountered.

Specifications and requirements:

(1) Net to open and close on signal from ship.

(2) Mouth openings of from 2 to 20 cm. diameter to be provided either adjustably or interchangeably before tow.

(3) To accept all or any of the environmental parameter sensors.

(4) To measure volume of water filtered to within ±5%.

(5) So constructed to permit simultaneous use at intervals along towing wire.

(6) To operate down to 500 m. and from 5 to 15 knots.

1.3300 NEKTON

1.3310 High Speed Nekton Net. . . . . (50)

Purpose: To improve present designs of collecting nets which will quantitatively sample nekton.

Specifications and requirements:

(1) Range: 0 to 500 m.

(2) To fish at desired depth controllable to within 3 m.

(3) Operating speeds 5 to 18 knots desired.
(4) Include standard sensing modules.
(5) Include a water meter device.

1.4000 BIOTA OBSERVATION.

1.4100 ECHO RANGING DEVICES.

1.4110 Fish Detector - Shipboard Mounted. . . . . (37)

Purpose: To detect schools and individual fishes at greater ranges than presently attainable and permit determination of size and species of individual fishes and abundance.

Specifications and requirements:
(1) Manual and automatically trained transducers.
(2) Transducer stabilized for roll of ship.
(3) 360° transducer with PPI scope and chart recorder.
(4) Range: 0 to 100 m., 0 to 1,000 m., 0 to maximum.
(5) Spectrum analyser circuit for target evaluation.

1.4120 Fish Detector - Gear Mounted. . . . . (26)

Purpose: To determine the catching efficiency of fishing gear, particularly trawls.

Specifications and requirements:
(1) Remote recording via conducting cable.
(2) Automatic 360° scanning normal to axis of trawl.
(3) Range: 0 to 100 m.
(4) Operating depth: 0 to 500 m.

1.4130 Whale Detector - Tethered. . . . . (1)

Purpose: To count migrating gray whales.

1.4200 WEIGHING DEVICES.

1.4210 Shipboard Weighing Machine (4 modules).

An accurate, rapid weighing machine for use on shipboard to weigh objects of the following groupings:
(1) 0 to 50 g. . . . . (25)
(2) 0 to 500 g. (22)
(3) 0 to 5 kg. (17)
(4) 0 to 50 kg., all within ±1% with printed and punched tape readout. . . . . (16)

1.4300 SPECIAL TELEVISUAL DEVICES

1.4310 Fisheries Research Underwater Television. . . . . . . (1)

Purpose: To provide positive visual information regarding behavior of fishes, environmental conditions, reaction of fish to fishing and sampling gear, performance of fishing and sampling gear unrestricted by seasonal, light, turbidity, or weather conditions.

Specifications and requirements:

(1) Miniaturized camera and monitoring unit.
(2) Depth range:
    (a) 0 to 500 m.
    (b) 0 to 2,500 m.
    (c) 0 to 12,000 m.
(3) Remote focus, iris, and scanning controls.
(4) Electronic visible or infrared lighting system with intensity, interruption, frequency, and on-off duration controls.
(5) Independently battery powered for 24-hour period.
(6) Fitted with device to allow camera to travel along track line attached to moving and stationary fishing gear, sampling gear, or sea bed.
(7) Adaptable to separate electrical or combination electrical-towing cable.

1.5000 SYSTEMS.

1.5100 OCEANIC BUOY SYSTEMS.

1.5110 Buoy System (Continuous or intermittent recording for storage and/or transmission upon interrogation) . . . (119)

Purpose: To provide for the collection, recording, storage, and/or transmission of important meteorological and oceanographic data utilizing moored buoys.

Specifications and requirements:

(1) For anchoring in depths of 10 to 12,000 m.
(2) Designed to operate unattended for 1 to 6 months.
(3) Designed to transmit data to a shore station upon interrogation 0 to 3,000 (nautical) miles away or upon interrogation by ships or airplanes 0 to 100 (nautical) miles away.
(4) Subsurface sensors located at a maximum of 20 different levels down to 500 m.
(5) 3 to 6 different standard sensor modules at each level.
(6) Sensors on or above the buoys to measure sea

surface temperature, air temperature, barometric pressure, wind speed, wind direction, humidity, incident radiation, and reflected radiation. (Sensors for the latter two parameters must provide data which meet specifications of the U. S. Weather Bureau.)

(7) Output must be compatible with automatic data processing (NODC).

1.5200 FIXED MONITORING SYSTEMS.

1.5210 Fixed Monitoring System (shallow waters) (continuous or intermittent recording for storage and/or transmission upon interrogation). . . . .(135)

Purpose: To provide for the collection, recording, storage, and/or transmission of meteorological and oceanographic data.

Specifications and requirements:

(1) For use in depths from 0 to 10 m.

(2) Designed to operate unattended from 24 hours to 1 month.

(3) Designed for continuous or intermittent recording and storage of data. (Transmission of data upon interrogation over distances of 100 miles would be optional.)

(4) Subsurface and surface sensors should meet the same requirements as for buoy system (Item 1.5110).

(5) Output must be compatible with automatic data processing (NODC).

1.5300 FISH COUNTING.

1.5310 Fish Census Device. (23)

A television camera or a photographic camera positioned forward of the codend of a trawl to observe the fish that pass through the net and an electric shocker at the mouth of the net to insure that each fish would pass through as it was overtaken.

1.5400 TAGS AND TAGGING EQUIPMENT

1.5410 Micro-miniature Sonic or Other Tags (for monitoring movements aquatic animals. . . . .(7,013)

Purpose: To study the migration, spawning habits, distribution, and behavior of animals, such as tuna, menhaden, salmon, herring, sardines, shrimp, seals, and sea lion.

Specifications and requirements:

(1) Small lightweight tags with minimum drag.

(2) Tags to be a self-contained, acoustic transducer having a detection range of 2 km. and a life of 10 to 30 days. (Present tags are too large, and lack longevity.)

1.5420 Environment Measuring Tags. . . . .(17,502)

To register minima or maxima characteristics of environment, such as depth and temperature.

1.5430 Underwater Fish Tagger. . . . . (10)

A system that would permit television observation of fish in a trawl and which would shoot a single dart tag into the fish in target position when triggered from the ship.

1.5440 Fur Seal Tagger and Tags. . . . . (1)

A tagging device and suitable tag for fur seal studies. Such would inject a numbered and sealed radioactive slug coated with a biological marker (perhaps tetracycline) subcutaneously. It should be a magazine or hopper fed, gas operated, hand held, highly portable, gun-type instrument delivering a visually coded cylindrical slug approximately 2.5 by 17 mm.

1.5500 AUTOMATIC CHEMICAL ANALYSER. . . . .(24)

Purpose: To provide an automatic system for chemical analysis of sea water aboard research vessels. (Such systems exist for laboratory use for other purposes, but none have been developed to analyse sea water samples at sea.)

Specifications and requirements:

(1) Automatic system to analyse and readout results.

(2) Provide quantitative analysis of the following: Inorganic phosphate, total phosphorus, oxygen, nitrite, nitrate, silicate, particulate iron, and certain vitamins.

(3) Accuracy: to customary laboratory accuracy.

1.5600 EXPENDABLE SYSTEMS.

1.5610 Bathythermograph. . . . .(18,014 expendable units)

Purpose: A ship and/or airborne system is needed for making temperature-depth, and possibly other measurements while underway at high speeds utilizing expendable sensing units.

Possible method: Drop over side of ship a sensing vehicle with buoyed radio-telemetry unit which would remain on surface. After short interval, vehicle would sink at suitable rate through water sending information from depth and temperature sensor to telemetering buoy through gradually uncoiled wire or by sonic means. Signals from buoy would be received and recorded by system aboard ship or aircraft. Entire expendable unit would sink after pre-determined time. (System would be analogous to radiosounde for atmospheric data.)

Range and accuracy:

(1) Temperature: -2^{o} to 35^{o} C. $\pm 0.1^{o}$.

(2) Depth: 0 to 300 m. ± 1.

Specifications and requirements:

(1) Sinking rate: 1 m./sec. ± 0.2.

(2) Response time of sensors: 95% in 1 second.

(3) Range of radio transmission: 5 miles.

Cost of expendable units: Not to exceed $30.

1.5620 Thermographs. . . . . (316)

Purpose: There are several different types of thermographs available but there is a need for one which is quite small, light, and above all, inexpensive.

Range and accuracy: -2^{o} to 30^{o} C. 0.5^{o}.

Specifications and requirements:

(1) Duration: 200 to 400 days.

(2) Depth: 0 to 400 m.

(If these units could be produced for less than $100 each, preferably less than $50, they could be thrown overboard on the fishing banks relying on fishermen to retrieve them for a suitable reward as with tagged fish.)

1.5700 TELEMETERING SYSTEM. . . . . (20)

Develop a telemetering system which does not require an insulated cable. Multiplexing on the uninsulated trawl wire or improved sonic modulation might be investigated.

1.5800 THERMISTOR CHAIN (cheaper and lighter than existing models). . . . .(12)

Specifications and requirements:

(1) Depth: 0 to 200 m.
(2) Operable to 15 knots.
(3) Standard depth sensing module at end of chain.
(4) Readout same as existing model.
(5) Range and accuracy: -2° to 35° C. $\pm 0.02^{\circ}$.

1.5900 CURRENT METER. . . . .(47)

Purpose: To measure from shipboard, anchored buoy, or bottom mount the velocity of low currents.

Range and accuracy:

(1) Speed: 0 to 30 cm./sec. ± 1.
(2) Direction accurate to $\pm 5^{\circ}$.

Specifications and requirements:

(1) Two types:
  (a) Self-contained data storage.
  (b) Telemetering.
(2) For use singly or attached in series on a cable.
(3) Depth: To 12,000 m.
(4) Temperature: -2° to 45° C

1.6000 <u>FISHING GEAR.</u>

1.6100 TRAWLS.

1.6110 <u>Instruments for Gear Performance Studies.</u>

Purpose: To provide foundation for analysis leading to design of most effective capturing devices.

Instruments to measure:

(1) Strain on netting and lines (immediate commercial application). . . . . (21)
(2) Vertical and horizontal net openings. . . . . .(21)
(3) For hydrofoil and conventional trawl-door studies: angle of attack, angle of inclination, drag, and separation distance (lift). . . . . (19)
(4) Water velocity at the trawl. . . . .(21)
(5) Speed over bottom. . . . .(21)
(6) Total distance traveled. . . . . (20)
(7) Distance between points on trawl. . . . . . (20)

Specifications and requirements:

(1) Instantaneous readout on shipboard through use of

trawl cables containing electrical conductors.

(2) Usable to depth of 2,500 meters.
(3) Should be resistant to extreme shock and vibration.
(4) Temperature range: -24° to 50° C. on deck and -2° to 35° C. when in use.
(5) Limits of measurements:
    (a) Angles: 0 to 45° and 0 to 90°.
    (b) Distance between points: 0 to 100 and 0 to 200 m.
    (c) Speeds: 0 - 5, 0 - 10, and 0 - 15 knots.
    (d) Tension: 0 to 3 kg., 0 to 25 kg., 0 to 250 kg., and 0 to 1,000 kg.

2.0000 LABORATORY EQUIPMENT.

2.1000 PLANKTON ANALYSIS.

2.1100 PLANKTON SEPARATOR AND COUNTER. . . . .(21)

Purpose: A device to separate and count a sample of living and/or dead plankton organisms on the basis of size, density, and shape.

2.1200 EGG SEPARATOR AND COUNTER. . . . . (16)

Purpose: To enumerate on the basis of size the abundance of living and/or dead eggs of vertebrate or invertebrate animals in fresh or salt water samples.

Specifications and requirements:

(1) To accommodate a variety of egg sizes and shapes ranging in size from 0.1 to 10 mm. in maximum dimension.
(2) Capable of use on shipboard.

2.1300 SEDIMENT PARTICLE SIZE ANALYSER. . . . . (13)

Manufacture a device to analyse the sediment sample according to particle size distribution. (A prototype has been developed by Dr. T. J. Van Andle of Scripps Institution of Oceanography.)

2.1400 SORTING DEVICE FOR BENTHIC ORGANISMS. . . . . (15)

A device that could be used aboard a vessel for sorting bottom organisms from sediments. This device might incorporate an electrical current or high density fluids.

2.2000 MORPHOMETRIC ANALYSIS.

2.2100 ANNUAL RING RECORDER. . . . . (6)

Mollusk studies often require that large numbers of shells be read to locate annual rings and their distance from some reference point recorded. There is a need for a device which will be positioned by an operator but the distances will be automatically digitized and punched on cards.

2.2200 AUTOMATIC FISH MEASURING MACHINE. . . . . (43)

A device that would receive fish from a hopper, weigh and measure each one and give data readout preferably on magnetic tape, and may take scale sample in identifiable sequence to correspond with measurement.

APPENDIX I

OCEANOGRAPHIC BIBLIOGRAPHY

The following bibliography consists of three parts: a list of books, a list of journals in which articles on oceanography appear, and a list of other bibliographies of oceanography. These lists are not complete, merely suggestive of what is available. Original articles on technical aspects may be found in the journals. References to others may be found in the reference list of the article of the journals and in many of the books.

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APPENDIX J

INFORMATION ON CONTACTING GOVERNMENT CONTRACTING AGENCIES

PROPOSAL PROCEDURES

1. The purpose of the Government-Industry Oceanographic Instrumentation Symposium was to acquaint Industry with critical parts of the National Oceanographic Program which require new thinking and technique development. Representatives of Industry were provided with the technical aspects of current instrumentation problems, and with general background information on oceanography necessary for the successful solution of these problems.

2. Since the ultimate fruit of a symposium of this nature must be harvested in accordance with Government Procurement Regulations, the following specific information is pertinent:

   a. Presentations and general specification handouts (appendices E, F, G, and H) are considered guidelines to stimulate thinking on instrument design, development, and production by Industry.

   b. Bid sets for survey, and applied and basic research instrument requirements will be promulgated at a later date.

   c. Those organizations which have not forwarded an up-to-date statement of capability (to cognizant governmental activities and to the National Oceanographic Data Center) are urged to do so at their earliest opportunity.

   d. Those organizations interested in any or all of the instruments and systems outlined during the Symposium are urged to express this interest to the cognizant governmental activity(s) in order to be considered for bid sets on these items as they are issued.

3. The following are the cognizant activities:

Survey instruments and systems: The Bureau of Commercial Fisheries, U. S. Navy Hydrographic Office, and U. S. Coast and Geodetic Survey. In addition, the U. S. Navy Hydrographic Office is the cognizant activity for "ASWEPS" and "Ship-of-Opportunity" instrumentation.

Basic Research instruments and systems: The Office of Naval Research.

Applied Research instruments and systems: The Bureau of Ships and the Bureau of Naval Weapons.

Other specific instrumentation requirements: Directly to the agency or activity presenting a specific requirement during this Symposium.

4. At the request of the Interagency Committee on Oceanography's Panel on Facilities, Equipment, and Instrumentation, the National Oceanographic Data Center has activated a file on proposals for the development of oceanographic instruments which are sent to various Government agencies by Industry. This file is to be a central depository for proposals which can be reviewed by Government agencies interested in oceanographic instrumentation development. It is the aim of the Interagency Committee to establish one file which will be dependable and complete.

The file will be privileged in that Government members only will have access to it. Industry's proposals are submitted as their own property; thus could not be released to other members of Industry.

Copies of proposals prepared by Industry may be addressed to Director, National Oceanographic Data Center, Washington 25, D. C.

FURTHER INFORMATION

General Procurement Information on Guided Missile Programs, Rockets, and Target Drones. Office of the Secretary of Defense, Central Military Procurement Information Office, Washington 25, D. C. Available from the U. S. Government Printing Office, Washington 25, D. C. Price 15 cents. 32 pp.

Inventions Wanted by the Armed Forces and Other Government Agencies. Cumulative List. National Inventors' Council. U. S. Department of Commerce, Washington 25, D. C. Available from National Inventors' Council. 104 pp.

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Revised Guide for the Submission of Research Proposals. U. S. Atomic Energy Commission. Division of Research, Division of Biology and Medicine, and Division of Reactor Development.

APPENDIX K

BIOGRAPHIES OF CONTRIBUTORS

VERNON E. BROCK, Laboratory Director, Bureau of Commercial Fisheries, Biological Laboratory, Building 75, Naval Weapons Plant, Washington 25, D. C.

Born in Fillmore, California, June 24, 1912, Mr. Brock obtained a B.A. at Stanford University in 1935, and his M.A. there in 1944.

He served as a field investigator for the Committee on the Evidence of Depletion of the California Sardine in 1936. He served the Fish Commission of Oregon as Fisheries Biologist (1936 to 1940), and as Chief Biologist (1940 to 1943). He was Product Administrator and Analyst Officer for Fishery Coordination, U. S. Department of Interior, from 1943 to 1944. From 1944 to 1958 he was director of the Division of Fish and Game of the Territory of Hawaii. From 1958 to 1961 he served in the Bureau of Commercial Fisheries, U. S. Fish and Wildlife Service, as Assistant Director of the Pacific Oceanic Fisheries Investigations (from 1958 to 1959), and as area director from 1959 to 1961 when he left to assume his present responsibilities.

He is a member of the American Association for the Advancement of Science, the Society of Ichthyologists and Herptologists, Wildlife Society, American Institute of Fishery Research Biologists, and the Society of Systematic Zoologists. He is a widely recognized authority on tropical fishes and has published many scientific papers in the field of oceanography and fisheries. He has specialized in ecology and population studies of tropical marine fishes, systematics of fishes, and the early development of life histories of fishes.

In addition to his present advisory role, Mr. Brock represents the Bureau of Commercial Fisheries in the development and coordination of the national oceanographic program. The Washington Laboratory carries out fishery-oceanographic research programs in the Atlantic, and, as its director, he is responsible for development of a fishery and oceanographic research plan for a high seas survey of the equatorial Atlantic from the South American to the African Coasts.

REAR ADMIRAL LEONIDAS D. COATES, Chief of Naval Research, Office of Naval Research, Washington 25, D. C.

Rear Admiral Coates was born on October 24, 1907, in Fresno, California. He was graduated from the U. S. Naval Academy and was commissioned Ensign on June 5, 1930, and through subsequent promotions attained the rank of Rear Admiral to date from August 1, 1956.

He was assigned successively to the USS New York, USS Texas, USS Pennsylvania, and the USS Saratoga, until 1933 when he was ordered to the Naval Air Station, Pensacola, Florida. He was designated a Naval Aviator in 1934. He served in Scouting Squadron 10-S, then attended postgraduate school at Annapolis from 1936 to 1938, continued at the California Institute of Technology to receive an M.S. (aeronautical engineering) in 1939. He served with Fighting Squadron 3 (USS Saratoga) and Patrol Squadron 74 (Norfolk, Virginia). He was transferred to the Patrol Plane Design Section of the Bureau of Aeronautics in 1941, and became Section Head and continued duty there until 1946, when he became Bureau of Aeronautics Representative for Douglas Aircraft Company, Inc. In 1947 he was Aircraft Material Officer, Commander Air Force, Pacific Fleet, Pearl Harbor. In 1949 he returned to the Bureau of Aeronautics, as Deputy Director of the Aircraft Division. He went to Harvard University in 1950 for the Advanced Management Program, returned to Bureau of Aeronautics as Director of the Guided Missile Division until 1951 when he became Deputy Assistant Chief for Research and Development. He served at Jacksonville, Florida, as Overhaul and Repair Officer at the Naval Air Station from 1952 to 1954. He then was assigned as Deputy and Assistant Chief of Naval Research, Navy Department. In 1956 he became Air Force Maintenance and Material Officer of Commander Air Force, U. S. Atlantic Fleet, and, in 1957, Assistant Chief of Bureau of Aeronautics (Research and Development). In 1959 he was Deputy Chief of that Bureau and Director of Development Planning for the Chief of Naval Operations.

Rear Admiral Coates has the American Defense Service Medal, American Campaign Medal, the World War II Victory Medal, and the National Defense Service Medal. He is a member of the Institute of Aeronautical Sciences, the U. S. Naval Institute, and the Armed Forces Communication and Electronics Associations.

MR. B. KING COUPER, Head, Oceanographic Section, Applied Science Branch, Bureau of Ships, Navy Department, Washington, D. C., and Coordinator for Oceanography, TENOC Program.

Mr. Couper obtained his B.S. at Massachusetts Institute of Technology and his M.S. at the University of California (Scripps Institution of Oceanography).

He has been employed by the Woods Hole Oceanographic

Institution, Scripps Institution of Oceanography, and the U. S. Navy Hydrographic Office, prior to his assumption of duties with the Bureau of Ships in 1951. During World War II he served on active duty with the Navy in the Pacific Theater and in Washington, D. C. He was a member of Joint Task Force I during the Bikini Crossroads. He holds a rank of Commander in the U. S. Naval Reserve.

JAMES M. CROSSEN, Instrument Technician, Instrumentation Laboratory, Bureau of Commercial Fisheries, Biological Laboratory, Woods Hole, Massachusetts.

Mr. Crossen was born in Boston, Massachusetts, January 1926. After leaving the service (as a Navy Quartermaster at the end of World War II), he attended and was graduated from the American Television Institute of Technology in radio and television engineering. At the Air Force Cambridge Research Center, Bedford, Massachusetts, he worked on prototype transformers and other electro-mechanical devices. In 1952 he joined the engineering staff at Sanders Associates, Nashua, New Hampshire, he was attached to the Sonobuoy "Project Tinkertoy." He took further training in Chemical, Biological, and Radiological Warfare and is currently a Departmental Radiological Officer. In 1955 he became a Program Leader of the Bureau of Commercial Fisheries where he is responsible for the planning, design, and development of instruments for obtaining fishery biology data. He was responsible for the development of underwater television and related equipment used in making several films of fish behavior in trawls. Among other instruments, he invented an automatic photoelectric fish egg counter.

LIEUTENANT COMMANDER R. P. DINSMORE, U. S. Coast Guard, Chief, Aerology and Oceanography Branch, U. S. Coast Guard Headquarters, Washington 25, D. C.

LCDR Dinsmore was born October 20, 1925, in Catonsville, Maryland, attended Baltimore Polytechnic Institute from 1940-43, and obtained his B.S. from the U. S. Coast Guard Academy, New London, Connecticut, in 1946. He had general duties on board Coast Guard weather ships, salvage vessels, and buoy tenders, 1946-49. He took graduate studies at the Scripps Institution of Oceanography from 1949-51. He was then Assistant Oceanographer, U. S. Coast Guard until 1953 (International Ice Patrol and Woods Hole Oceanographic Institution) and Instructor in Science and Meteorology, U. S. Coast Guard Academy, until 1957. He served as Commanding Officer, U. S. Coast Guard

Oceanographic Unit (International Ice Patrol) Woods Hole, Massachusetts, which he left in 1960 to assume his present responsibilities.

HAROLD W. DUBACH, Deputy Director, National Oceanographic Data Center, Washington 25, D. C.

A native of Missouri, he attended colleges in Missouri and Iowa and was graduated from Baker University with an A.B. (chemistry), in 1942. For graduate work, he attended the University of Chicago (meteorology) and the Johns Hopkins University (oceanography).

During World War II he served as a Weather Officer in the U. S. Alaskan-Aleutian Theater as Forecaster, and he is now a member of the Air Force Reserve, holding the rank of Major.

He served as a Research Meteorologist in the Weather Bureau's Thunderstorm Project from 1946 to 1948. His professional career in oceanography began in 1948 with his appointment as an oceanographer at the U. S. Navy Hydrographic Office. At the Hydrographic Office he occupied numerous responsible positions. In 1960 he was selected to complete arrangements for the establishment and organization of the National Oceanographic Data Center and served as Acting Director until July 1961.

He has authored several papers and publications on oceanography and meteorology and has presented several papers and talks to professional societies including meetings of the American Meteorological Society, American Geophysical Union, and the American Society of Computer Machinery.

He is a member of the American Meteorological Society and the American Society of Limnology and Oceanography.

HOWARD H. ECKLES, Chief, Branch of Marine Fisheries, Division of Biological Research, Bureau of Commercial Fisheries, Washington 25, D. C.

Mr. Eckles was born in Porterville, California, July 3, 1920, and was graduated from the University of California at Santa Barbara as a B.S. in 1942. From 1942 to 1946 he served the U. S. Navy as a Lieutenant. From 1946-48 he attended Stanford University. From 1948-53 he was a Fishery Research Biologist with the United States Fish and Wildlife Service in California. He then assumed his present responsibilities.

He is a member of the American Fisheries Society and the American Institute of Fishery Research Biologists.

His main interests lie in fishery research biology and oceanography. He serves on a number of interagency committees and represents the Bureau in many aspects of oceanographic work.

CAPTAIN RAYMOND D. FUSSELMAN, Deputy Hydrographer, Navy Hydrographic Office, Washington 25, D. C.

Captain Fusselman was born in West Farmington, Ohio, on September 30, 1910. He was graduated from the U. S. Naval Academy and was commissioned Ensign on June 14, 1934. He attained the rank of Captain to date from July 1, 1952. He served on board the USS Raleigh and on the USS Selfridge (DD-357), and commanded the USS Wadsworth (DD-516), USS Wiltsie (DD-716), and the USS Lenawee (APA-195). After a distinguished career during the last war as a shipboard commander, Captain Fusselman came into prominence in 1953 as Head, Underseas Warfare Research and Development Branch in the Office of the Chief of Naval Operations. Additional assignments have included Chief of Staff, Anti-Submarine Development Detachment, Key West; Commander, Amphibious Division 11; and Chief, Naval Mission Venezuela. In September 1957 he reported as Commanding Officer of the Office of Naval Research Branch Office, San Francisco, California, and in 1958 he was detached for sea duty as Commander, Destroyer Squadron 25. In April of 1960 he assumed his duty which he was holding at the time of the Symposium.

In addition to the Navy Cross and the Presidential Unit Citation Ribbon, Captain Fusselman has received several area service medals, and the Cruz de Miranda, awarded by the Government of Venezuela.

DR. SIDNEY R. GALLER, Biology Branch, Office of Naval Research, Navy Department, Washington, D. C.

Dr. Galler was born in Baltimore, Maryland, on November 9, 1922. He received his B.S. at the University of Maryland in 1944, his M.S. in 1947, and his Ph.D. (limnology) in 1948. At the Agricultural Experiment Station of the University of Maryland he served as an assistant and later as an assistant zoologist. He was collaborater with the Fish and Wildlife Service in 1947. Coming to the Office of Naval Research in 1948, he has served as Consultant on Human Ecology and Biophysics, Head of the Ecological Section of the Biological Branch, and Acting Head of the Biophysics Branch. Dr. Galler was in the United States Army from 1942-44.

His organizational affiliations include the American Association for the Advancement of Science and the American Society of Limnology and Oceanography. The areas in which he has done research include chemical, physical, and biological investigations of acid ponds, polluted streams, development of microtechnique for cytological studies of marine organisms, and research administration.

ANTHONY J. GOODHEART, General Physical Scientist, Instrument Division, U. S. Coast and Geodetic Survey.

Mr. Goodheart was born August 14, 1922, attended the University of Montana and the University of Minnesota, and has a degree in mathematics. During the war he served in the Navy as an Electronics Technician. He joined the Coast and Geodetic Survey in 1946 as Mathematician in the Tides and Currents Division, and later became an Oceanographer in this particular department. He has directed field operations of tide stations, with arrangements for installation and maintenance.

In his present capacity he coordinates and supervises the Division's activities involving oceanographic instruments and instrumentation and also plans and develops systems and techniques for operational use, including research and development work.

He is a member of the American Society of Civil Engineers.

J. R. R. HARTER, Head, Television and Facsimile Unit, Electronics Division, Bureau of Ships, Washington 25, D. C.

Born in State College, Pennsylvania, May 17, 1917, he attended Pennsylvania State College. He also attended the University of Connecticut and the University of Maryland Postgraduate School. During World War II he was Chief Instructor, Advanced Electronic Theory Department, United States Coast Guard Engineering and Maintenance School, Groton, Connecticut. At the close of the war he became Senior Research and Development Engineer for TV systems and equipment, Allen B. DuMont, Washington, D. C., on an experimental TV project. Since 1948 he has been occupied principally with televisual communications engineering positions in the Bureau of Ships. In addition to his present duties, he is a consultant and specialist for underwater visual surveillance, techniques, systems, and equipment.

He is a member of S. M. P. T. E., I. R. E., Panel Committee on Undersea Warfare of the National Research Council, and U. S. C. C. I. R., Group XI.

CAPTAIN CHARLES NELSON GRAN HENDRIX, USN, Deputy Chief of Staff for Plans and Operations, Joint Task Force EIGHT, Christmas Island.[1/]

1/ At the time of the Symposium, Captain Hendrix was attached to the Hydrographic Office as Special Projects Officer. In this capacity he served in the forefront of the planning and organization of the Symposium in the months preceding it, and coordinated the list of instruments (appendices E, F, and G) for the Hydrographic Office.

Captain Hendrix, born April 8, 1916, in Maryland, was commissioned and graduated from the U. S. Naval Academy with a B.S. in 1939. He attended Scripps Institution of Oceanography and in 1951 received an M.S. in oceanography. He has served on battleships, destroyers, and submarines; he saw service in World War II and in the Korean War. He has served in the Office of Naval Research, with Commander Transport Division 13, with Commander Amphibious Squadron 5, with Commander Mine Force Pacific, as Commander Submarine Division 61, with the U. S. Navy Hydrographic Office, and with Joint Task Force EIGHT.

Captain Hendrix is considered an expert in undersea warfare and is the senior naval field officer oceanographer in the Navy. In addition to serving and commanding submarines during the past 22 years, he has studied nuclear physics and atomic power plants, participated in one of the first extended underwater cruises in a snorkel submarine, done extensive research in submarine operations under the polar ice cap, and participated in AEC/DOD tests during atomic detonations in the Pacific.

He has the following decorations: Two Silver Stars with Oak Leaf Cluster, Bronze Star with "V," Navy Commendation Ribbon, Army Distinguished Unit Badge, Viet Nam Presidential Unit Citation "Ribbon of Friendship," Philippine Presidential Unit Citation Badge, and service ribbons for World War II, Korean, and UN with battle stars.

DR. WOODROW C. JACOBS, Director, National Oceanographic Data Center, Washington 25, D. C.

Dr. Jacobs was born September 11, 1908, in Pasadena, California. He obtained both his B.A. in 1930 and his Ph.D. in 1948 at the University of California, Los Angeles, and his M.S. in oceanography and meteorology in 1934 at the University of Southern California. From 1931-36 he was a meteorologist at the U. S. Weather Bureau. From 1936-41 he was a forecaster at Pomona and assisted at the Scripps Institution of Oceanography. He then became Chief Civilian Meteorologist for Headquarters, U. S. Army Air Force from 1942-46, and then Head, Climatological Branch, U. S. Weather Bureau, Washington, D. C., from 1946-48. He served as Director of Climatology for the Air Force Air Weather Survey from 1948-61 which he left to assume his present duties.

He has been a lecturer in Oceanography and Meteorology of the Graduate School of the U. S. Department of Agriculture from 1942 to the present time, at the Massachusetts Institute of

Technology in 1950, and the University of Chicago in 1956.

He has been a member of the Climatological Committee of the World Meteorological Organization, a delegate to the International Union of Geodesy and Geophysics in Brussels in 1951, in Rome in 1954, and in Toronto in 1957. Also, he is a council member of the American Meteorological Society and the American Geophysical Union.

His interests include marine meteorology, applied climatology, agricultural and industrial meteorology, atmospheric radiation and energy transformation processes.

GILBERT JAFFE, Director, Instrumentation Division, Navy Hydrographic Office, Washington 25, D. C.

Mr. Jaffe was born in Buffalo, New York, December 6, 1925. He received both his B.S. and his M.S. from the University of Buffalo in 1949 and 1950, respectively.

During World War II he served in the European Theatre of Operations with the 3rd Army Corps of Engineers, specializing in instrumentation for petroleum distribution.

He has been with the Hydrographic Office for the past 12 years and has served as an oceanographer in charge of physical and chemical testing, as Head of the Laboratory and Instrumentation Section, as an instrumentation engineer in charge of the Instrumentation Branch, and, since 1957, in his present capacity as Director of the Instrumentation Division.

At the Hydrographic Office, he has been responsible for establishing and managing the engineering program for oceanographic instrumentation, as well as many innovations in oceanographic instrument design.

Mr. Jaffe is a senior member of the Instrument Society of America, a senior member of the Institute of Radio Engineers, a member of the Interagency Committee on Oceanography, Panel on Facilities, Equipment, and Instrumentation, as well as a member of many other governmental and non-governmental committees and panels.

FEENAN D. JENNINGS, Head, Oceanographic Section, Geophysics Branch, Office of Naval Research, Washington 25, D. C.

Mr. Jennings was born in Los Angeles, California, on August 11, 1923. He served in the U. S. Navy from 1942-1946. Receiving his B.S. at New Mexico College of Agricultural and Mechanical Arts in 1950, he then studied at the University of California from 1950-52. While at Scripps Institution of Oceanography he served as an assistant oceanographer (1950-51), chemist (1952-53), research chemist (1953-55), and senior engineering oceanographer (1955-58). In 1958, Mr. Jennings joined the Office of Naval Research in his present capacity.

He is a member of the American Association for the Advancement of Science and the American Geophysical Union.

His primary interests lie in physical oceanography, nuclear and atomic instrumentation, and chemical engineering.

DR. J. LAURENCE McHUGH, Chief, Division of Biological Research, Bureau of Commercial Fisheries, Washington 25, D. C.

Dr. McHugh was born in Vancouver, British Columbia, Canada, on November 24, 1911. He received his B.A. in 1936 and his M.A. in 1938, both at the University of British Columbia. In 1950 he received his Ph. D.(zoology) from the University of California.

From 1938 to 1948 Dr. McHugh was a member of the staff of the Pacific Biological Station of the Fisheries Research Board of Canada, Nanaimo, British Columbia. From 1941-46 he served as an infantry officer in the Canadian Army in England and in France. From 1946-51 he was a member of the staff of the Scripps Institution of Oceanography at La Jolla, California. From 1951-59 he was Director of the Virginia Fisheries Laboratory at Gloucester Point, Virginia. He joined the Bureau of Commercial Fisheries, Fish and Wildlife Service, U. S. Department of the Interior, as Chief, Division of Biological Research, in January 1959. In 1961 he was appointed United States Commisioner of the Inter-American Tropical Tuna Commission.

His professional societies are: The American Fisheries Society, the American Society of Limnology and Oceanography, the American Association for the Advancement of Science, the International Oceanographic Foundation (Trustee), the American Institute of Fishery Research Biologists, Atlantic Estuarine Research Society (Past President), and Sigma Xi.

Dr. McHugh is the author of some fifty publications on fishery biology, ichthyology, and biological oceanography.

DONALD L. McKERNAN, Director, U. S. Bureau of Commercial Fisheries, Washington 25, D. C.

Born in Eugene, Oregon, on January 29, 1918, Mr. McKernan received his B.S. in fisheries in 1940 from the University of Washington (Seattle).

From 1938-41 he served as laboratory assistant for the Bureau of Fisheries and from there went to the Washington

State Department of Fisheries as a research biologist. In 1945 Mr. McKernan became Director of Research for the Fish Commission of Oregon and served in that capacity until 1952 when he was appointed Assistant Director of the U. S. Fish and Wildlife Service Pacific Oceanic Fishery Investigations in Hawaii. From 1948-1949 he was a teaching fellow at the University of Washington. After holding the position, following 1952, of Administrator of Alaska Commercial Fisheries, U. S. Fish and Wildlife Service, Mr. McKernan was appointed in 1957 to his present post.

He is a member of the American Association for the Advancement of Science, the American Society of Limnology and Oceanography, the American Fisheries Society, and the American Institute of Fisheries Research Biologists.

Mr. McKernan has specialized in fisheries management, marine biology, tuna biology, shellfish, and oceanography.

He is a member of the Interagency Committee on Oceanography and is Chairman of its Panel on Equipment, Facilities, and Instrumentation.

DR. HUGH J. McLELLAN, Professor, Department of Oceanography and Meteorology, Agricultural and Mechanical College of Texas, College Station, Texas.

Dr. McLellan was born in Sydney, Nova Scotia, Canada, on March 16, 1921, and he received his B.S. in 1941 and his M.S. in 1947, both at Dalhousie University in Halifax, Nova Scotia. In 1956 he completed his Ph.D. (physical oceanography) at the University of California at Los Angeles. He was a junior physicist of the National Research Council of Canada from 1941-1942, then entered the Canadian Army where he served until 1945 coming out as Captain. From 1947-1956 he served as an associate oceanographer of the Atlantic Oceanographic Group for the Fisheries Research Board of Canada, and from 1956-1957 as a senior scientist. Since 1957 he has been a research scientist of the Agricultural and Mechanical College of Texas.

Dr. McLellan is a member of the American Society of Limnology and Oceanography, the American Geophysical Union, and the Canadian Association of Physicists. His main interest is physical oceanography.

DR. ARTHUR E. MAXWELL, Head, Geophysics Branch, Office of Naval Research, Washington 25, D. C.

Dr. Maxwell was born in Maywood, California, on April 11, 1925. His educational background includes a B.S. from New Mexico

College of Agricultural and Mechanical Arts in 1949, an M.S. from the University of California in 1952, and a Ph.D. (oceanography) from the University of California in 1959. In 1949 at the Scripps Institution of Oceanography he successively was assistant oceanographer and junior research geophysicist. He came to the Office of Naval Research in 1955 as Head Oceanographer, Geophysics Branch, and became Head of the Geophysics Branch in 1959. He served in the Navy from 1942-46. In 1958 he received the Civilian Meritorious Service Award of the U. S. Navy.

He is a member of the American Miscellaneous Society, Committee of the National Academy of Sciences -- National Research Council, the American Association for the Advancement of Science, the Research Society of America, the Geochemical Society, and the American Geophysical Union.

His principal interests include physical oceanography and geophysics, particularly the measurement and interpretation of heat flow through the ocean floor, and factors contributing to our understanding of the nature of the earth's crust.

REAR ADMIRAL DONALD McGREGOR MORRISON, U. S. Coast Guard, Washington 25, D. C.

Admiral Morrison was born December 4, 1906, at Glens Falls, New York. He attended the Universities of Chattanooga (Tenn.) and Washington (Seattle), and was graduated from the U. S. Coast Guard Academy at New London, Connecticut, and commissioned Ensign on May 15, 1931. Through subsequent promotions he attained the rank of Rear Admiral on February 1, 1961.

He served aboard the cutters Snohomish, Tallapoosa, Gresham, Seneca, Pontchartrain (1936 and 1937 on the International Ice Patrol), and Northland. During 1942 and 1943 he was assigned to the Cooper-Bessemer Corporation, Grove City, Pennsylvania, as machinery inspector for 180-foot buoy tenders, and the Marine Iron and Shipbuilding and Zenith Dredge Companies, Duluth, Minnesota, to supervise the installation of machinery, tests, and trial runs. He was assigned Coast Guard representative in the Office of Inspector of Machinery, U. S. Navy, at the Fairbanks-Morse Corporation, and the training of personnel. He then became executive officer of the USS Cambria (APA-36) in the Pacific war campaigns of Majuro in the Marshalls, Kwajelein, and Eniwetok. In 1944 he helped place the USS General M. C. Meigs (AP-116) in commission and served as engineer officer in the Mediterranean, and later served as training and then as executive officer at Coast Guard Training Station, Groton, Connecticut. In 1945-46 he served as Executive Officer and then as Commanding Officer of the Joseph T. Dickman (APA-13) in the Pacific. He was Chief, Marine Engineering Section, Chief, Engineering Division in the 14th Coast Guard District, Honolulu, until 1949, and then Chief, Engineering Division and aide to Ernest Gruening, Governor of Alaska. He commanded the cutter Bibb (WPG-31) (1952-54) on ocean station (weather patrol) duty in the North Atlantic. From 1955-58 he was Chief, Shore Units Division at Coast Guard Headquarters, until he became a special assistant to the Commandant, and then Chief, Operations Division of the 5th Coast Guard Office, Norfolk. In 1960 he was ordered to San Francisco to assume the post of Deputy Commander, Western Area.

He has the American Defense Ribbon with "A," Asiatic-Pacific Area, European-African-Middle Eastern Area, and World War II Victory Medal.

ARTHUR L. NELSON, Supervisory Engineer, Naval Electronics Laboratory, San Diego 52, California.

Mr. Nelson was born in 1915 in Texas, was graduated by the University of Arkansas (electrical engineering) in 1938, became a design engineer for the Radio Corporation of America, the Farnsworth Television and Radio Corporation, Aircraft Accessories Corporation, and other companies, and started and operated his own Nelson Electric Corporation, Santa Monica, California.

He has formerly been Planning Engineer, Patrick Air Force Base, Florida, in charge of long-range instrumentation in various missile tracking stations in the West Indies, and he was Senior Engineer at the Scripps Institution of Oceanography from 1956-59 where he did graduate work in physical oceanography. Mr. Nelson now is an engineer with the U. S. Navy Electronics Laboratory, San Diego, California, where he is program manager of the bathyscaphe Trieste.

He is a member of the Instrument Society of America (Executive Committee of the Marine Science Division).

REAR ADMIRAL CHARLES PIERCE, USC&GS (Ret.), (Rear Admiral Charles Pierce served as Deputy Director of the Coast and Geodetic Survey from August 1957 to August 1961).

Born in Somerville, Massachusetts, he received his early education at local schools and was graduated by Tufts University in 1922 with a B.S. in Civil Engineering. The following year he entered upon duty with the U. S. Coast and Geodetic Survey.

During his 38 years of service with the Bureau, which includes over 15 years of sea duty, Admiral Pierce has held many responsible positions including field assignments along the coasts of the United States, Alaska, and the Philippines. During the years 1945-47 he initiated and organized the Airport Survey parties for the production of Airport Obstruction Plans.

He served as Director of Coast Surveys of the Philippine Islands from 1947-50 with headquarters at Manila. He was Chief of the Coast and Geodetic Surveys Mission on the Phillipine Rehabilitation program with responsibility for establishing a counterpart Agency in the Republic of the Philippines. For this work he was awarded the Philippine Legion of Honor, Commander, by the Chief of Staff, Armed Forces of the Philippines.

In the fall of 1956 he conducted a reconnaissance of the highlands of Ethiopia which resulted in a complete geodetic survey of over 100,000 square miles of rugged and sparsely inhabited terrain. He was U. S. delegate at the 12th General Assembly of the International Union of Geodesy and Geophysics held in Helsinki, Finland, in the summer of 1960. His service at sea included various shipboard assignments including Commanding Officer of the largest ships in the surveying fleet, the Pathfinder and Pioneer. He served for 18 months in the Washington Office as Chief, Division of Geodesy.

He is past President and life member of the Army and Navy Club of Manila. He is a past President of the Washington Society of Engineers, Past President of the Washington Post of the American Military Engineers, Past President of the Section of Geodesy, American Geophysical Union.

Rear Admiral Pierce retired in August 1961, and, at this writing, is proceeding to the 8th Conference of the International Hydrographic Bureau, at Monaco, as U. S. candidate for the Directing Committee and as U. S. delegate.

DR. WILLIAM S. RICHARDSON, Physical Chemist, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Dr. Richardson was born at Providence, Rhode Island, on October 27, 1923, served in the Navy from 1942-45, was graduated by Brown University in 1947 (B.S.), and received his Ph.D. (chemistry) from Harvard in 1950. From 1950-52 he was a fellow at the Mellon Institute. He is a member of the American Geophysical Union.

His principal fields of interest are spectroscopy, polymer chemistry, and oceanography. Dr. Richardson is an outstanding pioneer in the development of deep water anchored buoys for use in obtaining time-series, oceanographic observations.

DR. JULIUS ROCKWELL, JR., Coordinator, Government-Industry Oceanographic Instrumentation Symposium, Bureau of Commercial Fisheries, Washington, D. C.

Dr. Rockwell was born in Taunton, Massachusetts, July 25, 1918, was graduated by the University of Michigan with a B.S. (zoology) in 1940, served in the United States Navy from 1940-46, mainly in shipboard engineering and deck capacities, and is now a Commander in the Naval Research Reserve (inactive). From 1946-54 he was employed by the Fisheries Research Institute of the University of Washington in various studies of Alaska salmon in Southeastern Alaska, in Bristol Bay, and on the high seas. He received his Ph.D. (fisheries) from the University of Washington (Seattle) in 1956. He is presently developing and evaluating automatic fish counting devices and an automatic scale reader. He has worked in a joint Air Force - Navy operations research problem, and has participated in the Union College Character Research Project as a local research coordinator. Work has included human engineering, experimental psychology (of fishes), and equipment design.

He is a member of the American Association for the Advancement of Science, the American Society of Limnology and Oceanography, the American Fisheries Society, and the American Institute of Fisheries Research Biologists.

MURRAY H. SCHEFER, Oceanographer, ASW Division, Bureau of Naval Weapons, Washington 25, D. C.

Mr. Schefer was born January 1, 1918, at Hartford, Connecticut. He was graduated in 1938 with a B.S. from the College of the City of New York. In 1940 he received his M.S. from the State University of Iowa where he majored in inorganic analytical chemistry. He served in the Army Air Force from April 1941 to January 1946. The latter half of this period he served as an aerial navigator and navigation instructor. He is presently in the active reserve as a MATS navigator.

In November of 1948 he joined the U. S. Navy Hydrographic Office. During employ at the Hydrographic Office, he was associated with the oceanographic survey program. He served as Head, Oceanographic Survey Branch, and later as Deputy Director, Marine Surveys Division. In June 1961 he assumed his present assignment with the Bureau of Naval Weapons.

JOHN J. SCHULE, JR., Director, Oceanographic Prediction Division, U. S. Navy Hydrographic Office, Washington 25, D. C.

Mr. Schule received his B.A. (mathematics) at the St. Johns University, Brooklyn, New York. He took an Aviation Cadets course in meteorology at New York University, and studied oceanography at the Johns Hopkins University.

He had wartime service as a Weather Officer, U. S. Army Air Corps. He also served as Chief Meteorologist, American Overseas Airlines, Instructor in the Department of Meteorology at New York University, and as Instructor at the U. S. Air Force Weather Officer's School. He has been with the Navy Hydrographic Office for the past 11 years, where his principal work is the development and operation of oceanographic prediction systems in support of Navy and other Department of Defense activities. Major areas have been in the fields of sea ice prediction, wave forecasting, optimum ship routing, and ASWEPS, an environmental prediction system for Antisubmarine Warfare operations.

MR. JAMES M. SNODGRASS, Head, Special Developments Division, Scripps Institution of Oceanography, University of California, La Jolla, California.

Mr. Snodgrass was born in Marysville, Ohio, May 3, 1908, received his A.B. at Oberlin College (1931), and studied at the University of Pennsylvania and at Harvard. He served as Assistant in Psychology, Oberlin College, 1931-37, as research associate, Fertility Clinic, Free Hospital for Women, Brookline, Massachusetts, 1937-40, and as Research Instructor of Psychology at Oberlin from 1940-46. He was a member of the technical staff, Division of War Research, Columbia University (1942-43), a Research Associate and Field Representative, Division of War Research, University of California (1943-46), and Chief Engineer, Motion Picture Sound Division, Dayton Acme Company (1946-48). He joined the Scripps staff in 1948 as an associate research biologist and was a member of the scientific staff on the Scripps Mid-Pac Expedition in 1950. In his present capacity he has been responsible for the design and development of many of the new instruments that are allowing many striking advances in the science of oceanography.

He is a member of the American Association for the Advancement of Science, Acoustical Society of America, a Senior Member of the Instrument Society of America (Director of its Marine Sciences Division), American Institute of Biological Sciences (Special Consultant), and is active on the Air-Sea Interaction and New

Devices Panels of the National Academy of Sciences Committee on Oceanography. He is a member of the Editorial Board, Journal of Marine Research, the Eastern Pacific Oceanographic Conference Committee on Radio Transmission of Oceanographic Data, the Physiological Society of Philadelphia, the Committee on Radio Frequency Allocations for Scientific Research of the National Academy of Sciences, and Sigma Xi.

His interests include electro-physiology, sonar, kinesiology, radio location, sound recording, deep-sea instrumentation, and acoustics.

REAR ADMIRAL EDWARD CLARK STEPHAN, Oceanographer, U. S. Navy Hydrographic Office, Suitland, Maryland.

Rear Admiral Stephan was born in Washington, D. C., June 12, 1907. He was commissioned Ensign by the U. S. Naval Academy following graduation on June 8, 1929. He subsequently advanced to the rank of Rear Admiral, August 1, 1956.

Admiral Stephan has had the following duty: Staff of Commander Scouting Force; USS Lawrence; Submarine Training; USS Bass; Postgraduate School at Annapolis; First Lieutenant Submarine Base, New London, Connecticut; Command USS S-35; Command USS S-28; Postgraduate Course in Law; USS Griffin; Command USS Seawolf; Command USS Grayback; and Command USS Devilfish.

Following the war, Admiral Stephan has served on the Secretary of the Navy's Committee on Research and Organization; commanded Submarine Division 82; served as Reserve Coordinator on the Staff of Commander Submarines, Atlantic Fleet; and commanded Submarine Squadron 4 in Key West, Florida. He next had duty on the Submarine Desk with the Office of the Assistant Chief of Naval Operations until 1951 when he became Legislative Counsel, Office of the Judge Advocate General. In 1953 he commanded Transport Division 21, and subsequently Transport Squadron 2. In 1956 he reported to the Office of the Comptroller of the Navy and in June became Chief of Legislative Liaison, Navy Department.

In 1958 he assumed command of the South Atlantic Force, where he remained until his appointment as Hydrographer in April 1960. In January 1962 he was additionally designated Oceanographer of the Navy under the Chief of Naval Operations.

For his participation in World War II, the Admiral was awarded the Navy Cross, three Silver Star Medals, American Defense Service Medal, American Campaign Medal, Asiatic-Pacific Campaign Medal, World War II Victory Medal, National Defense Service Medal, and the Ribbon for the Navy Unit Commendation awarded the USS Grayback.

ALLYN C. VINE, Physical Oceanographer, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Mr. Vine was born in Garrettsville, Ohio, on June 1, 1914, received his B.A. from Hiram College in 1936, and his M.S. from Lehigh University (physics) in 1938. Since 1940 he has been an outstanding staff member of the Woods Hole Oceanographic Institution, where he has specialized in geophysics, underwater acoustics, and instrumentation. From 1947-50 he worked half-time in the Bureau of Ships in oceanography.

In addition he has been Chairman of the Panel on Special Devices for Exploring the Oceans of the National Academy of Sciences Committee on Oceanography. In this capacity he has shown keen leadership in the field of oceanographic instrumentation.

Some of his other activities are: Trustee, Ocean Resources Institute, Trustee, International Oceanographic Foundation, membership in the American Geophysical Union, the American Association for the Advancement of Science, the American Physical Society, American Acoustical Society, Association of Applied Solar Energy, and the Arctic Institute of North America.

DR. JAMES H. WAKELIN, JR., Assistant Secretary of the Navy (Research and Development), Department of the Navy, Washington 25, D. C.

Dr. Wakelin was born in Holyoke, Massachusetts, May 6, 1911. He received an A.B. (physics) from Dartmouth College in 1932. During 1932-34 he attended Cambridge University, Cambridge, England, where he was granted a B.A. (natural sciences) in 1934 and an M.A. in 1939. Dr. Wakelin received his Ph.D. (physics) from Yale University in 1940 where he specialized in the field of ferro-magnetism.

During 1939-43 Dr. Wakelin was a senior physicist in the Physical Research Department of the B. F. Goodrich Company, Akron, Ohio, where he was concerned with the structure and physical properties of natural and synthetic rubber, and with x-ray diffraction and electron microscope studies of high polymers.

From 1943-45 he was Ordnance Staff Officer to the Coordinator of Research and Development, Navy Department. During 1945-46 as a Lieutenant Commander, USNR, he was Head of the Chemistry, Mathematics, Mechanics, and Materials Sections of the Planning Division, Office of Research and Inventions, and was active in the planning and organization of the Navy's program to sponsor basic scientific research, now under the direction of the Office of

Naval Research. Following World War II, Dr. Wakelin helped establish the Engineering Research Associates, Inc., as Director of Research, and as Director of the Field Survey Group of PROJECT SQUID under ONR contract to Princeton University.

In 1948 he became Associate Director of Research of the Textile Research Institute in Princeton, and in 1951 was appointed Director of Research. In 1954 Dr. Wakelin established his own consulting business as a consultant on research planning and organization to General Electric Company, Stanford Research Institute, American Radiator and Standard Sanitary Corporation, J. P. Stevens and Company, Inc., Frenchtown Porcelain Company, and Star Porcelain Company. He helped found the Chesapeake Instrument Corporation in 1954, established to conduct research and development for the Navy in the fields of underwater sound and acoustical devices. He was also a Research Associate with Textile Research Institute working on the structure and physical properties of high polymers under a program sponsored by the Office of Naval Research.

On July 8, 1959, Dr. Wakelin became the first to hold the office of Assistant Secretary of the Navy for Research and Development. On July 16, 1959, he was designated Chairman of the subcommittee of the Federal Council for Science and Technology formed to look into plans for meeting the Nation's needs in oceanography. This subcommittee, on 22 January 1960, was made a permanent part of the Council and redesignated as the Interagency Committee on Oceanography. Dr. Wakelin has remained Chairman. In July 1960, he was Head of the United States Delegation to the Intergovernmental Conference on Oceanographic Research which met in Copenhagen, Denmark. The Conference recommended the establishment, under UNESCO, of an Intergovernmental Oceanographic Commission (IOC) to promote scientific investigations of the oceans. Dr. Wakelin was also Head of the United States Delegation to the First Session of the IOC held in October 1961 in Paris, France.

Dr. Wakelin is a member of Sigma Xi, the American Physical Society, American Association for the Advancement of Science, Textile Research Institute, Textile Institute of Great Britain, and has been a contributor of scientific papers to the Journal of Applied Physics, the Industrial and Engineering Chemistry, and Textile Research Journal in the field of high polymer physics. He is co-author, with C. B. Tompkins and W. W. Stifler, Jr., of "High-Speed Computing Devices," published by McGraw-Hill Book Company in 1950.

DR. I. EUGENE WALLEN, Marine Biologist, Environmental Sciences Branch, Division of Biology and Medicine, Atomic Energy Commission, Washington 25, D. C.

Dr. Wallen was born in Afton, Oklahoma, October 4, 1921, obtained his B.S. in 1941, his M.S. (zoology) in 1946, both at Oklahoma Agricultural and Mechanical College, and his Ph.D. (limnology) at the University of Michigan in 1950.

He served as a Navy Flier in World War II and is now a LCDR, active in the Naval Research Reserve. At Oklahoma Agricultural and Mechanical College he was an instructor from 1948-49, Assistant Professor from 1949-53, Associate Professor in zoology and Chairman of biological sciences from 1953-56. From 1956-57 he was Assistant Director of Science Teaching Improvement Program of the American Association for the Advancement of Science and from 1957-59, a Training Officer for the U. S. Atomic Energy Commission. In 1959 he joined the Division of Biology and Medicine in his present capacity.

In this capacity he has the technical responsibility for research projects at Woods Hole, Scripps Institution of Oceanography, Bureau of Commercial Fisheries at Beaufort, Bermuda Biological Station, etc., as well as at university campuses to encourage establishment of research programs, and to evaluate existing research projects. He arranged Commission support for the International Conference in Oceanography and has primary responsibility for the scientific work at Eniwetok Marine Biology Laboratory.

He is alternate member for AEC of the Interagency Committee on Oceanography of the Federal Council of Science and Technology. He is a Fellow of the American Association for the Advancement of Science and of the Oklahoma Academy of Science (Chairman, Scientific Section, 1954-56), and a member of the American Institute of Biological Sciences, the National Science Teaching Association, Phi Kappa Phi, the American Fisheries Society (Member, Water Pollution Committee, 1954-56), the American Society for Limnology and Oceanography, Sigma Xi (Local Treasurer, 1951-54), and the Wildlife Society.

He has 27 published articles and many more Congressional Hearing reports and mimeographed articles. His fields of interest are pond and lake limnology, water pollution, science education, and oceanography.

THEODORE J. WEHE, Program Manager for Oceanography, Martin Company, Electronic Systems and Products Division, Baltimore 3, Maryland.

Mr. Wehe was born in Berwyn, Illinois, on December 3, 1927. He attended Massachusetts Institute of Technology, was graduated from Brown University with an A.B. in geology, and took graduate courses at the United States Department of Agriculture Graduate School, George Washington University, and at American University.

He began his oceanographic career in 1946 at Woods Hole Oceanographic Institution and participated as an oceanographic technician in Radiological Safety Section of JTF-1 during Able and Baker atomic tests at Bikini. After working at the Mount Washington Observatory as an icing observer, he returned to WHOI to execute oceanographic surveys off the coast of North Carolina and in the Persian Gulf. From 1951-53 he was an assistant oceanographer at Narragansett Marine Laboratory and active in various surveys of Narragansett Bay and approaches. He joined the U. S. Navy Hydrographic Office in 1955 as an oceanographer and held positions of increasing responsibility from analyst of tides and currents, to Project Coordinator for Special Projects, and Special Assistant to the Special Projects Officer. In the latter capacity, he participated in and contributed to various programs, including the Government-Industry Oceanographic Instrumentation Symposium, and the proposed U. S. National Oceanwide Survey Program.

He recently accepted a position as Program Manager for Oceanography, Martin Company, a division of the Martin Marietta Corporation. As such, he is responsible for developing and managing oceanographic research, systems, and instrumentation in and for the Electronic Systems and Products Division, and, additionally, for seeing that existing talents, capabilities, and experience in ASW and underwater acoustics at Martin are used to best advantage in the program.

He is a member of AGU, AMS, and NSIA, and an associate member of ORSA. He has authored and co-authored a number of reports and has been editor of and/or contributor to others including "Mathematical Applications of Operations Research" by Dr. T. L. Saaty (McGraw-Hill, 1959).

DR. J. LAMAR WORZEL, Assistant Director, Lamont Geological Observatory, Columbia University, Palisades, New York.

Dr. Worzel was born in West Brighton, Staten Island, New York, February 21, 1919. He received his B.S. in engineering physics in 1940 from Lehigh University. Upon graduation he joined the Woods Hole Oceanographic Institution as a Research Associate where he was engaged in research on underwater sound and photography.

He was made a Research Associate in Geophysics at the Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, in 1946. He came to Columbia University in 1946 as a geodesist where he received his M.A. in 1948 and his Ph.D. in 1949. In 1948-49 he worked as Research Associate in Geology at Columbia University. He became Instructor in the Department of Geology, Columbia University in 1949, Assistant Professor in 1951, Associate Professor in 1952, and Professor in 1957. In 1950 he became Geophysical Consultant for the Office of Naval Research. In 1951 he was made Assistant Director of the Lamont Geological Observatory of Columbia University.

He is Chairman, Special Study Group 20, International Union of Geodesy and Geophysics, and a member of the Panel of the Indian Ocean Expedition of the U. S. National Committee for SCOR.

He is a member of the American Association for the Advancement of Science, the Geological Society of America, the American Physical Society, the Seismological Society of America, the Society of Exploration Geophysics, and the American Geophysical Union.

His principal research has involved gravity at sea, seismic refraction at sea, underwater photography, sound transmission of sea water, and oceanography.

CHARLES S. YENTSCH, Research Associate in Marine Biology, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts.

Mr. Yentsch **was born in** Louisville, Kentucky, on September 13, 1927. He obtained his B.S. at the University of Louisville in 1950 and his M.S. at Florida State University in 1953. He was a Marine Biologist, Florida State University, from 1952-53, and a Biological Oceanographer at the University of Washington (Seattle) from 1953-55. He joined the Woods Hole Oceanographic Institution in 1955 where he has been acting in his present capacity in the study of marine phytoplankton ecology. He served in the U. S. Navy from 1945-46.

He is a member of the American Society of Limnology and Oceanography and the American Phycological Society.

Mr. Yentsch has published a number of articles in national and international journals on marine productivity and is well known in his field. He is also an authority on the instrumentation required for the study of the biological processes in the sea.

APPENDIX L

SOME ABBREVIATIONS AND ACRONYMS USED IN OCEANOGRAPHY

AEC: Atomic Energy Commission.

ART: Airborne Radiation Thermometer.

ASTM: American Society for Testing Materials.

ASW: Anti-Submarine Warfare.

ASWEPS: Anti-Submarine Warfare Environmental Prediction System.

BCF: Bureau of Commercial Fisheries.

BT: Bathythermograph.

BUSHIPS: Bureau of Ships.

BUWEPS: Bureau of Naval Weapons.

CMR: Common Mode Rejection.

CNO: Chief of Naval Operations.

CSIRO: Commonwealth Scientific and Industrial Research Organization (Australia).

DECCA: A continous-wave, hyperbolic radio aid to navigation in which a receiver measures and indicates the relative phase differences between signals received from two or more synchronized ground stations.

DOD: Department of Defense.

DOO: Director, Office of Oceanography. The proposed office to be established within the Natural Sciences Department of UNESCO.

DRAI: Dead Reckoning Analog Indicator.

DRT: Dead Reckoning Tracer.

EQUALANT I & II: Tropical Atlantic Investigation.

FAO: Food and Agriculture Organization of the UN. Established 1945 at Quebec. Headquarters in Rome. Supported by the dues of member countries.

FLIP: Floating Instrument Platform.

FM: Frequency modulation.

HO: Hydrographic Office.

HUK: Hunter-Killer.

HYDRO: Hydrographic Office.

IACOMS: International Advisory Committee on Marine Sciences. Organized November 1955 as part of UNESCO Natural Sciences program; also advisory to FAO.

IAEA: International Atomic Energy Agency. Organized 1956 in New Yord. Headquarters in Vienna.

IAPO: International Association of Physical Oceanography. One of the associations constituting the IUGG. Established 1919. No salaried employees or headquarters. Supported by UNESCO through IUGG. Meets concurrently with IUGG.

IBM: International Business Machines.

ICES: International Council for the Exploration of the Sea. Founded 1899/1902 as an association of fishing nations of northwest Europe. Headquarters at Charlottenlund, Copenhagen. Supported by dues of member countries.

ICO: Interagency Committee on Oceanography.

ICSU: International Council of Scientific Unions. Founded 1919 in Brussels. Headquarters at The Hague. Membership composed of national academies of science of 43 countries. Supported by dues of members and by UNESCO.

IGY: International Geophysical Year.

IIOE: International Indian Ocean Expedition.

IOC: The Intergovernmental Oceanographic Commission. Established by UNESCO.

IRE: Institute of Radio Engineers.

ISA: Instrument Society of America.

IUGG: International Union of Geodesy and Geophysics. Founded 1919 in Brussels. One of the constituent Unions of ICSU. Membership composed of geophysical organs of national academdies of science of various countries. Headquarters (secretary's address) in Paris, but meets every three years in various parts of the world. 1963 meeting to be in Berkeley. Supported by dues and by UNESCO.

I. T. & T.: International Telephone and Telegraph.

LGO: Lamont Geological Observatory.

LORAN: Long Range Navigation.

MAD: Magnetic Anomaly Detection.

Mil-E-Con: Military Electronic Conference (Sponsored by IRE).

MOHO: The Mohorovicic discontinuity.

MSTS: Military Sea Transport Service.

NASA: National Aeronautics and Space Administration.

NASCO: National Academy of Sciences Committee on Oceanography.

NEL: United States Navy Electronics Laboratory.

NODC: National Oceanographic Data Center.

NSIA: National Security Industrial Association.

OMEGA: A long-range navigation system originally developed for totally submerged submarines, giving worldwide coverage with six to ten ground stations.

ONR: Office of Naval Research.

ORSA: Operations Research Society of America.

RCA: Radio Corporation of America.

RF: Radiofrequency.

R/V: Research Vessel.

SCOR: Special Committee on Oceanic Research. Set up by ICSU in August 1957 as a means of coordinating the oceanographic interests of IUGG (IAPO) and the various other ICSU unions, such as those for biology, geography, chemistry, and physics. Committees of national academies of science have been set up to adhere to SCOR, and its support comes from these committees.

SCUBA: Self Contained Underwater Breathing Apparatus.

SINS: Ships Internal Navigation System.

SIO: Scripps Institution of Oceanography.

SNAP: Systems for Nuclear Auxiliary Power.

SMPTE: Society of Motion Picture and Television Engineers.

SVTP: Sound Velocity, Temperature, and Pressure unit.

TENOC: Ten-year oceanographic program (Navy).

TNT: Trinitrotolulene - an explosive.

TRANSIT: Program to develop and establish in being a system of near-earth satellites to provide a means for establishing locations (navigating) anywhere on the surface of the earth (Kershner).

TV: Television.

UHF: Ultrahigh frequency.

UN: The United Nations. A political organization of most of the nations of the world. It has set up specialized agencies such as UNESCO, FAO, and IAEA, open for membership to UN member nations desiring to cooperate in these special fields and also to non-UN members (such as Switzerland).

UNESCO: The United Nations Educational, Scientific, and Cultural Organization. Established 1945 in London. Headquarters in Paris. Supported by dues from member countries. Established IACOMS and IOC.

USCG: United States Coast Guard.

USC&GS: United States Coast and Geodetic Survey.

USN: United States Navy.

USWB: United States Weather Bureau.

VHF: Very high frequency.

WHOI: Woods Hole Oceanographic Institution.

WMO: World Meteorological Organization. Established as IMO in 1947 and became WMO in 1951. Headquarters in Geneva. Supported by dues from member countries.

Photograph by R. Baylor
Woods Hole, Massachusetts