WHOI History During War Years

1941 - 1950

By
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Projects - Personnel - Inventions -
Bibliography of Unpublished Reports

After fifteen years I am attempting to write a brief outline of the work done at the Woods Hole Oceanographic Institution, more or less in conjunction with other research laboratories, during the war years. Because of the lapse of time, I am sure some problems will be overlooked and many persons' names unintentionally omitted - for this I apologize.

When the contract work was started it was quickly broken down into small projects and given numbers for inter-office use. Therefore each project will be listed chronologically.

(Eventually reports, both published and unpublished, will follow each section.)

In the event of war the Woods Hole Oceanographic Institution realized that their basic research activities would be drastically curtailed by shortage of manpower, by the restrictions of the vessels and by the fact that "Copenhagen Standard Water", the standard water by which all sea water samples are compared, would become impossible to obtain. In cooperation with Mr. Floyd M. Soule and Dr. Clifford A. Barnes of the U. S. Coast Guard, a large amount of such water was prepared. Large quantities of water were collected from the Gulf Stream. It was filtered, stored in large glass-stoppered carboys for 9 months, then mixed and sealed into pyrex glass tubes. 1941

On July 1, 1940 Woods Hole Oceanographic Institution began its first contract with the Navy WHOI, Proj. #1) towards the defense effort of the United States.

An aggregate staff of about 20 persons were busy throughout the war period in studies designed to improve the understanding of the performance of antifouling paints, and to increase knowledge concerning the distribution and rate of growth of the fouling organisms. Dr. Ketchum and Dr. Ferry worked primarily on the physical chemistry of paint systems while Dr. Hutchins and Dr. Deevey were concerned with the biological aspects of fouling.

A 1940- #1 PROJECT According to Al Vine

On the technical side the main objective was to develop a quicker and more reliable method of testing the antifouling characteristics of paints. First, one had to learn how the paints prevent fouling. From this study it became possible to develop chemical methods of measuring the leaching rate of antifouling paints in the laboratory, independently of the availability of fouling organisms.

Once the importance of the rate of dissolution of paint was demonstrated, the next step was to examine the physical and chemical properties of the toxics, and organic matrix ingredients, and of the complete paint system so as to be able to control the process.

The need for detailed information on the tendency for various naval installations to foul led to the collection of many samples of the growth from navigation buoys and their mooring chains from all parts of the coast of the United States. The study of this material provided much new information on the depth and distance from shore at which fouling is to be expected, the relation of temperature to its rate of growth, and the geographical limits of the occurrence of the various species.

At this time, with the exception of the officers of the U.S.S. SEMMES, there was practically no liaison between oceanographers and the Navy department or its facilities. The meaning of the words "ocean" and "atmosphere" seemed to be little more than "water" and "air". Realizing the general lack of understanding of physical oceanography and its possible relation to wartime problems, Dr. C. O'D. Iselin, the Director, prepared a memorandum (enclosed) for the National Defense Research Committee of the Office of Scientific Research and Development, pointing out many of the practical applications that oceanography held for the

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Memorandum written by Dr. C. O'D. Iselin on August 5, 1940 to the National Defense Research Committee entitled "Memorandum concerning the research facilities available at the Woods Hole Oceanographic Institution."

"The Woods Hole Oceanographic Institution, an endowed corporation, has been engaged in oceanographic research since 1931. This memorandum sets forth some suggestions as to how the personnel and equipment of this laboratory can better be utilized for the national defense, for it seems likely that the training and experience of oceanographers will enable them to attack successfully various problems having a naval consequence.

During the last ten years oceanography has become a highly developed field of science, due largely to the efforts of a few specialized institutions in Germany and Scandanavia, but the knowledge gained is not readily available to American naval officers. While expanding so rapidly oceanography in this country has not had as close a contact with the Navy as might have been desirable. Not only is the Navy unaware of the modern developments in this field of science, but the handful of oceanographers only very imperfectly understand the naval problems for which their specialized knowledge might prove valuable. This does not seem to have been the case in Germany where for the last five years a relatively large group of oceanographers, as far as we can tell, have been working on a number of naval problems.

The staff of the Woods Hole Oceanographic Institution at present consists of some 21 investigators and technicians. The majority of these people also hold teaching positions in various universities. It is only during the summer months that the whole staff is at Woods Hole; at which time, including their assistants, about 50 people are at work. Only three staff members and four technicians have been employed by the institution on a full time basis. However, as a team this staff is able to bring to bear a very wide range of knowledge on marine problems, both biological and physical.

The laboratory has not been entirely without contacts with naval research. In 1937 we cooperated with the officers of the destroyer "Semmes" in an investigation of the stratification of the surface waters near Guantanamo, Cuba, and off New London, Connecticut. This was in connection with supersonic methods of detecting submarines. As a result of our very limited experience with this problem, we developed an instrument for measuring the stratification of the superficial layers from a moving vessel.

More recently we have had a contract with the Bureau of Construction and Repairs for work on certain phases of the fouling of ships' bottoms. At the present time the Navy is financing our bacteriological department which is almost entirely engaged in this very practical research.

The facilities for marine research at Woods Hole are unique in this country. Ample laboratory space and living accomodations are available throughout the year. The library, which specializes in all branches of science connected with the sea, is the best in the world. In addition, a fully equipped ocean going research vessel is maintained. Indeed one of the best arguments which can be advanced to support our plea for a part in the movement towards increased national defense is that the staff of the Woods Hole Oceanographic Institution includes a number of men fully trained in practical work at sea. Several members of the staff have for some time been in the Naval Reserve and others are applying for admission.

It is most difficult for one who has not been trained as a naval officer to make specific suggestions as to just how oceanographic knowledge can be utilized in naval research, but the following general considerations seem suggestive.

1) Through its director, increased use could be made of the Woods Hole Oceanographic Institution as a consultive body. It is hoped that the Navy will feel free to seek our advice on any matter involving geographical, physical, chemical, biological or meteorological considerations. Our staff includes specialists in all the major fields of science connected with the ocean. In problems where several fields of science are involved only an oceanographer is able to correlate the different factors.

2) Naval officers engaged in special research or requiring training for research might profitably spend some time at Woods Hole. Not only are laboratory facilities and a library available, but by working at Woods Hole the officers would gain some idea of what oceanographic methods and knowledge the Navy could utilize. The U. S. Coast Guard has for a number of years had such a policy and it has worked very well.

3) There are not doubt several problems on which an immense

amount of work has been done by the Navy, but the knowledge gained has never been critically analyzed by scientists. The fouling problem provides a good example of this. No Naval officer could digest in a few years' time the file in the Bureau of Construction and Repairs dealing with the thousands of investigations and observations which have been made. It is suggested that this whole mass of material might be critically studied by a small group of qualified scientists and a manual be prepared on the subject. In this way the chaff could be separated from the wheat and the future problem of research could rest on a firmer foundation of truth. Such an undertaking would require, it is true, several years, yet in the end some order could be brought out of a great mass of haphazard observations. Other handbooks for the use of naval officers could in the same way be prepared under the editorship of the staff of the Woods Hole Oceanographic Institution in close cooperation with the competent naval officers.

4) We have good evidence that German oceanographers made detailed studies long before the outbreak of war of the currents in certain critical areas. If it seems advisable, the men and the instruments are also available in this country for such an undertaking.

Besides the currents, the thermal structure of the uppermost 300 feet of the ocean seems to be an important factor in submarine-detecting methods. The stability of the surface layers changes seasonally and even from hour to hour, nevertheless it would be possible to make a detailed study of a number of typical areas and thus develop a better understanding of the principal factors governing these phenomena.

5) There are many improvements which can be made in instruments useful to the Navy. Such companies as the Submarine Signal Company are doing excellent work, yet their business does not warrant oceanographic research. We have cooperated unofficially with the Submarine Signal Company and have taken their men to sea and have helped test and develop certain instruments, yet both from our point of view and from theirs the necessity for secrecy sets up barriers. They feel that they cannot tell us the whole story and we feel that we should not make too many suggestions. If we could learn what sorts of instruments are needed, there is no doubt that for the experimental phase in their development the Woods Hole Oceanographic Institution could do useful work. We have at least two extremely able instrument men. Just by chance we have suggested the Bathythermograph and the Barochronograph to the Submarine Signal Company, but no doubt other useful instruments could be devised, if our physicists understood the needs.

6) Meteorology at sea presents many special problems to the Navy. Fog seems to be a good example. The prediction of fog at sea is not well handled in any meteorological textbook or course of instruction because few meteorologists have been at sea. We have three meteorologists on our staff who would be glad to look into this or any other problem from the Navy's standpoint.

7) Finally, it is suggested that the research vessel "Atlantis"

is available for exploratory work in any part of the world. There may well be questions in distant regions which the Navy would like to look into without attracting attention and in some cases a scientific vessel can be successful in such missions.

It seems unnecessary to go into further detail at the present time. Enough has been written to indicate the sort of work which could be handled by the Woods Hole Oceanographic Institution. The following members on our staff seem to be particularly well qualified for what might be termed Naval research in oceanography:

Meteorology:

C.-G. Rossby
Athelstan F. Spilhaus

Physical Oceanography:

R. B. Montgomery
C. O'D. Iselin

Chemistry:

Norris W. Rakestraw

Bacteriology:

Selman A. Waksman
C. E. Renn

Physiology and Marine Biology

George L. Clarke
Alfred C. Redfield
Gordon A. Riley

Instruments:

Maurice Ewing.

If the technicians and the essential men on the "Atlantis" be included, the list would become much longer. Depending on the sort of problems we are assigned, some of the men listed above may have to be relieved of teaching duties. It seems best that each case should be handled individually, if and when the need arises. However, should the various universities involved not be willing to continue teaching salaries, the Woods Hole Oceanographic Institution will have to be provided with additional funds.

For the most part the staff of this institution is made up of men who are young and all are keen to get started on research which has a practical goal. It is for this reason that a number of them have sought commissions in the Naval and Army Reserve. However, if used as a research team, it is believed that they will be much more productive than as individuals, especially as there is good reason to believe that modern oceanography is a field of science of no little importance to naval strategy.

C. O'D. Iselin
Director
Woods Hole Oceanographic Institution"

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Navy. In response to this memorandum, on August 5, 1940, the NDRC awarded to the institution Contract NDCrc-40 which, although having been taken over by Navy sponsorship, remains in existence today under cognizance of Office of Naval Research and the Bureau of Ships.

Proj. 2. Sound Transmission. This contract began in October of 1940. By February of 1941 the first major report "Sound Transmission in Sea Water" written by C. O'D. Iselin and Maurice Ewing was published and served as the framework for much of the ensuing work. In this, they discussed: development of the art of submarine signalling, physics of sound in sea water, oceanography of the surface layer, range and intensity of the direct beam, and variations in the thickness of wind stirred layer.

B
1940-

As a result of the earlier work of the R/V ATLANTIS and U.S.S. SEMMES near Guantanamo in 1937, Dr. A. F. Spilhaus invented the bathythermograph, an instrument designed to graph temperature against depth on a grid while being towed from a ship underway. Although this instrument was impractical at the time, Dr. Ewing, with his assistants Allyn C. Vine and J. Lamar Worzel, perfected it, and by 1942 it became standard equipment on all research vessels and on many escort ships. About 200 bathythermographs were made and calibrated at Woods Hole before they were manufactured commercially. In the first four years of its use, over 60,000 records were accumulated and processed. From data collected by these, and later by the submarine bathythermographs, new fields of sound transmission phenomena were opened.

Submarines and surface ships alike were playing tricks on detection and evasion that baffled the Navy. From the basic research data accumulated at the laboratory since its beginning, from the studies made of this phase of sonar at Guantanamo, and with the aid of the BT supplemented by a WHOI refraction slide rule, WHOI personnel began to instruct Naval officers at the Sound School at Key West, Florida, and in the Caribbean area. Robert J. McCurdy was the leader in instruction aboard ships, while Gordon A. Riley and T. A. Austin spent many months as instructors at the Sound School. From 1941 through 1944 more than 600 ASWIS officers were given 1 to 4 week courses in oceanographic aspects of antisubmarine warfare at Woods Hole by Dr. G. P. Woollard and Mr. Richard Geyer. In the meantime WHOI personnel were making cruises on escort ships, making reverberation records and studying the variations in the structure of the water; also cruises covered areas from Key West south to Trinidad, west to the Mississippi River and north off the coast of Maine.

Measurements were made on the sound field of standard echo-ranging equipment under many operating conditions and studies carried out to evaluate the relative importance of the various oceanographic factors that influence maximum sonar range gear.

The bathythermograph and newly developed refraction slide rule made it possible to construct ray diagrams so that 1943 one could better understand the refraction effects. It was also found that the operational range limit of echo ranging equipment could be reasonably well predicted from these records. Then an effort was made to correlate this with types of bottom.

C. O'D. Iselin and A. H. Woodcock worked on the range prediction of diurnal heating which occurs near the sea surface causing a serious reduction in the range of submarine detection, 1943 which is called "afternoon effect". Mr. Phil Church and Dr. C.-G. Rossby of the University of Chicago made additional observations in Lake Michigan. Again Mr. Woodcock made a short study of solar heating in surface sea water in order to obtain a series of measurements which would indicate whether or not it would be possible to predict the reduction of range on a given day in terms of heat exchange across the sea surface.

Many cruises were made for the study of reverberation to help determine the causes and magnitude of reverberation in the open ocean.

To help in the prediction of ranges by submarines on surface ships a submarine model temperature-depth recorder was made. This instrument evolved into the submarine bathythermograph and was 1942 installed on all submarines. Six such instruments were built here prior to commercial manufacture. The SBT served two practical purposes: (1) in the predictions of listening and echo ranging conditions, and (2) as a guide for maintaining proper trim during a dive. Starting in 1943, WHOI representatives gave submarine bathythermograph instruction in all major U.S. Submarine bases, also instructing the crews of the submarines during operations. In the spring of 1944 this training was extended to advanced submarine bases in the Pacific.

Using photographs and actual bottom samples, Mr. Henry C. Stetson, head of the Geology Department at WHOI, was able to construct sediment charts for the continental shelf off the Atlantic and Gulf coasts of the United States. These charts were made showing the acoustic effect of the bottom character in water less than 100 fathoms. For most of the shallow water areas in the Atlantic theater of operations charts were completed at Woods Hole and then published by the U. S. Hydrographic Office and the U. S. Coast and Geodetic Survey.

1942

In 1943 Mr. Wm. E. Schevill made a trip to England to secure data on bottom sediments from the files of the British Admiralty and to obtain a picture of the scope and purposes of oceanographic research in British war activities. While there he also obtained data to supplement and further our work on submarine and surface ship operation and performance. This included the geographic aspects of submarine warfare.

After Dr. Redfield's initial start with the Bay of Biscay, submarine supplements to the sailing directions for the west coasts of Spain, Portugal, northwest Africa and off-lying islands, the Japanese Empire area, western tropical Pacific and South China Sea were made from data compiled in England, at WHOI, and SIO, under the supervision of Mr. Wm. E. Schevill. These supplements became the primary means of explaining to the submarine operating forces how, on the average, refraction due to near surface temperature gradients would influence the assured range of detection; as did the sonar charts in terms of surface tactics. 1943-44

Realizing that oceanographic conditions had important effects on diving operations, Dr. Alfred C. Redfield, Dean F. Bumpus, Allyn C. Vine, and Wm. E. Schevill made intensive studies of the factors affecting the buoyancy of submarines, due to the major influences of density changes as shown on a bathythermograph grid. A density meter was devised as an aid to diving. Some time later hundreds of hull compression tests were made and recorded. 1942 1944 (Cont'd Proj. 23, p. 27)

Mr. F. C. Fuglister supervised the compilation of data and made charts of the hydrography of the Western Atlantic west of the 60th meridian showing the average subsurface and surface temperatures and salinity in that area. At that time the data were unevenly distributed, both in time and in the geographical sense; however, by combining observations from somewhat larger areas it was possible to follow the seasonal changes in considerable detail. 1945

During 1944 Dr. R. B. Montgomery and Mr. Richard A. Geyer made soundings in the lowest 100 feet of the atmosphere over Buzzards Bay. The primary purpose of this phase of work was to assist in the studies of the effects of vertical gradients of temperature and humidity on the propagation of short radio waves in the atmosphere.

From the many oceanographic observations made before the war, charts were prepared at WHOI showing sound ranging 1943 conditions in the following areas: North Atlantic, North Pacific, South Atlantic, South Pacific, Indian Ocean and Mediterranean Sea.

The maximum range of sonic detection in sea water, both by echo ranging or by listening, depends upon many factors. Demonstrating some aspects of this, many examples of sound beam patterns were constructed from the standpoint of the average vessel and of a submarine at periscope depth.

Later about 400 ray diagrams, showing the extent of the sound field and the sound intensity distribution for the common 1944 temperature-depth patterns encountered in the ocean were constructed and made available to the Navy for practical estimation of sound conditions. These diagrams covered the upper 300 ft. of the water column. This work was prosecuted under the supervision of Dr. George P. Woollard.

"A Manual of Ocean Waves, of Surf and of Beaches" was written by Dr. Henry B. Bigelow and Mr. Henry C. Stetson, which was later published by the U. S. Government Printing Office. 1944

Dr. G. L. Clarke made observations and measurements of waves, surf, and shore conditions on beaches of Martha's Vineyard and Cape Cod, studying the characteristics of waves as they approach the shore. The possibility of employing changes in wave characteristics to determine water depth from aerial photographs was explored. 1944 Photographs were made simultaneously from the ground and from the air. Martha's Vineyard Naval Air Station, Army Air Force Proving Ground Command, Eglin Field, Florida, and Photographic Interpretation Center, Anacostia, D. C. cooperated in this study, as later did SIO.

Dr. Kenneth C. Reynolds extended this study by making laboratory experiments of wave characteristics as they approached beaches.

A report entitled "Trial Forecasts of Breaker Height on the East Coast of the U. S." was prepared by Gardner Emmons and 1945 G. L. Clarke, using data obtained between Cape Hatteras and northern Massachusetts.

From these studies here, and at other marine laboratories, fairly accurate predictions of sea and swell conditions in the open ocean, and the characteristics of surf on given beaches, could be predicted.

B 1941-45 Proj. 3. Explosive Method. (A. P. Crary and R. W. King) (Harbor protection)

B 1941-45 Proj. 4. Signal Corps. (Crecelius)

Observations with QC gear on range and reverberation were made at the mouths of harbors in order to determine the effects of turbulence on bottom hydrophones used in harbor defense.

Carlyle Crecelius, in cooperation with the Signal Corps, worked on the problem of sound detection in waters near the coast, as oceanographers had found that many variable factors play a much more important part in shallow water than they do in deep water. A current meter was developed to help in this undertaking.

Montgomery?

B 1941-45 **Proj. 5. Submarine Temperature-Depth Recorder.**

A suitable submarine bathythermograph was developed by Dr. Maurice Ewing and A. C. Vine through a series of seven models made at Woods Hole and tested at Key West and New London. The final model was put into production by the Bristol Company. ~~This instrument became the~~ This SBT became ~~the~~ a standard instrument on all submarines and was useful ~~for both~~ to both the diving officer and the sonar officer.

B 1941-45 **Proj. 6. Underwater Camera.**

Dr. Maurice Ewing, Allyn C. Vine and J. L. Worzel designed and constructed a series of cameras to take pictures underwater. A hydrofoil was then adapted for carrying ~~this~~ one of these instruments. By lowering it on cables to any desired depth, or by towing it near the bottom, it was possible to identify sunken ships and mines. For oceanographers this gave them their first view of the ocean floor. Where before they had believed that the ocean depths were stagnant, they now saw ripple marks indicating that there were currents present.

Dr. Edw. M. Thorndike developed a transparency meter to be used in conjunction with the camera. This meter enabled one to 1943
make quick measurements to determine the maximum distance at which successful photography could be used.

Tests were made by Dr. Kirkpatrick on the use of underwater television (orthicon) as a means of observing submerged mines and wrecks. Although by no means a failure, in that stage of development, too much work was needed to justify further experiments at that time.

Two models of underwater periscopes were made and tested at the laboratory.

c 1942- Proj. 7. Underwater Explosives.

This project was started at Harvard University under the direction of Dr. E. Bright Wilson, but because of inadequate ocean facilities nearby it was transferred to the Woods Hole Oceanographic Institution in 1942. Although at the beginning it was entirely divorced from the normal scientific activities of WHOI, long before its termination in 1948 it was found that oceanography and underwater explosives had much in common. Dr. Arnold Arons of Amherst College and WHOI continues to investigate these phenomena.

Here the great concern was developing gauges for measuring the pressure wave produced by an explosion. Although small charges were sufficient for calibration and evaluation at the start, in a short time larger and larger amounts of explosive materials were needed.

At the termination of work here, all of the reports pertaining to this project were sent to the Princeton Library.

B 1942-45 Proj. 8. Bubbles.

In order to study ship wakes for echo ranging and listening purposes it was important to understand the role of bubbles in the acoustic properties of wakes. Dr. Jeffries Wyman, first with Dr. Redfield and later with David Barnes and Wendel Lehmann, studied the acoustic properties of the scattering and absorption of sound by the wake of a small propeller and then by the direct role of bubbles. These experiments lasted for about three years, the results indicating that bubbles were formed in sufficient abundance in surface wakes and last a sufficient length of time to explain qualitatively the observed acoustic properties of such wakes.

Scholander, Edwards + Irving?

B 1942-45 Proj. 9. Wake Visibility and its Suppression.

This project was undertaken by Dr. A. C. Redfield and G. L. Clarke. Using 2 DUKWs, observations and measurements were made both in Woods Hole and Florida waters to ascertain the ability to suppress wakes.

B 1943-45 Proj. 10. Underwater Camera Construction. From Dr. Ewing's prototype, about 15 cameras were constructed at WHOI for the Bureau of Ordnance before they were manufactured commercially. A few non-magnetic cameras were also made for close-up work on mines.

? 1943-45 Proj. 11. Fouling of Mines and Buoys.

Inasmuch as Dr. Louis H. Hutchins was working on the biological aspects of fouling on Project 1, it seemed quite natural that his interest should also include the fouling of mines. Hundreds of samples of the growth of barnacles from navigation buoys and their mooring chains from all parts of the coast of the United States were collected and examined.

Here the concern was the practical importance of fouling in relation to ship resistance, the functioning of underwater sound equipment, mines, nets, and salt water pipe systems. A description was given of the common fouling organisms, their methods of development and reproduction, their geographical distribution and seasonal incidence, and relevant aspects of their physiology including their sensitivity to toxic substances.

B 1943-45

Proj. 12. Smoke Screens.

From his studies of air turbulence and convection over the air, Mr. Alfred H. Woodcock became interested in the performance of smoke screens over the water. As the program progressed Dr. Jeffries Wyman became supervisor of the project.

Extensive studies were made to help determine the scale of the convective motions under various conditions of wind and air-water temperature differences. L. Irving "Joe" Baker

With the aid of the air thermograph and other standard instruments, analysis of smoke screen behavior could be placed upon a physical basis furthering an understanding of lower air motion, which gave a much more complete physical picture of the air-sea interrelationship. Following this, new recording instruments were devised to be used on low flying aeroplanes. It was believed that in this way studies of the lower atmosphere in the course of long flights over the ocean could be studied; also, with the cooperation of a plane and surface ship, heat exchange could be more fully understood.

After studying the behavior of smoke near a coast and over the open ocean with great success, assistance was sought by 1944 the Navy in the behavior of smoke munitions as used in landing operations. Tests of this nature were made in Florida, Puerto Rico, and Pearl Harbor area, using field equipment under actual operating conditions.

Smoke generators, when used by oceanographers, provided the first clear picture of convection over a water surface.

The scope of the work in connection with this project had grown beyond that originally anticipated, and in 1944 a new contract was awarded for that project alone.

B 1943-45

Proj. 13. BT Instruction.

Because of the time and number of personnel involved, and also the amount of traveling required, a special project was set up to expedite these needs.

B 1943-45

Proj. 14. Current Gradients. Dr. J. L. Hough and P. Osborn, using Dr. E. E. Watson's bathyclinograph, made many records of water velocity versus depth.

B 1943-45

Studies were made to determine the drift of the moored type mine under various wind and current conditions, both by the movement of the water and by the wind. The first consideration was of the pattern of drift bottles, as they are of the same order of magnitude as that of a mine, at the same time bringing all existing knowledge of the general circulation to bear on the problem. Observations made relating the leeway of the mine studies to the movement of a standard 15 ft. current pole as a function of wind drift established the minor complications.

Otis Barton

Dr. Clarke and Mr. Henry D. Russell made a library study of the transparency and color of ocean waters around the Japanese Islands and East Indian regions to determine the feasibility of making photographic surveys of the water in that area.

Butler ?

Proj. 15. Drifting.

About 45 series of tests on the wind drift of four types of Navy rubber rafts and two types of Army rafts were made. These were made in Buzzards Bay, off Gasparilla Island near Boca Grande, Florida and in the northeastern Bahama area.

B 1944 Proj. 16. Short Range Sound Transmission.

Having made successful seismic measurements in Chesapeake Bay, off Barbados, off the Orinoco River, and in the Gulf of Pari ., Dr. Maurice Ewing and J. L. Worzel obtained definite evidence as to the thickness of the unconsolidated sediments. These records clarified many problems of the transmission of sound waves both in the water and through the bottom.

Using these data, Dr. C. L. Pekeris completed a theoretical study which established a definitive and detailed explanation of the observed dispersion in terms of bottom structure and the depth of water.

Since it is very important in sound field measurements in shallow water to know the exact role played by the bottom, Dr. G. P. Woollard studied samples of mud bottoms in the Gulf of Maine, the Mississippi Delta region, the Gulf of Panama, the area north of Trinidad, the Baltic Sea, the Black Sea, the Adriatic Sea, the Ionian Sea, and the Aegean Sea.

Dr. Leonard N. Liebermann perfected an instrument for recording reverberation (at 12 and 24 kc) at sea.

A memorandum was submitted entitled "Sound Transmission at 12 and 24 kc in Shallow Water". The observations used were obtained under the supervision of Dr. Maurice assisted by D. E. Kirkpatrick, and L. N. Liebermann assisted by D. A. Wilson and M. W. Arsove.

Dr. L. N. Liebermann and Dr. D. A. Wilson studied the attenuation of sound in water by the decay method at frequencies between 16 and 22 kc; extended by Dr. Liebermann to the study of the reflection of sound from the sea surface.

RAFOS

B 1944 Proj. 17. Long Range Sound Transmission (SOFAR)

This project was generally considered to cover sound transmission problems involving path lengths of hundreds of miles.

Dr. Ewing realized that at mid-depths over large areas of the ocean there exists a layer where the speed of sound is at a minimum, forming a so-called sound channel. Over most of the North Atlantic the minimum velocity layer is at a depth of about 1300 meters. Because of refraction effects, signals emitted in this layer can travel very long distances without having to undergo either bottom or surface reflection. Thus acoustical transmission in this layer is relatively efficient and a receiver located at similar depth can record signals originating several thousand miles away. A small bomb, devised by Dr. J. L. Worzel, was fired and the differences in the arrival time of that signal at three widely spaced receiving stations established a fix. In order to study the feasibility of this means of communication a receiving station was established on Eleuthera Island, and was in operation for nearly a year, having received signals with a maximum range of 3200 miles. Dr. Wm. S. von Arx, from the U. S. S. MUIR, found that Bermuda and the surrounding shoal area created a "shadow zone", obstructing transmission of sound through the

E.E. Watanko Cable?

Great Circle route.

Studies, from available information, were made on the nature of the bottom of the ocean off the coasts of California and Hawaii adjacent to the proposed SOFAR stations in the Pacific Ocean, the best probable locations for the hydrophones, the probable arcs of reception, the positions of fixed land control points, and other information that would facilitate the establishment of an efficient monitoring system on the west coast.

Dr. Woollard and Mr. Barbour prepared a report and manual on SOFAR theory, setting up stations, and preparing maps. Dr. George P. Woollard carefully analyzed earlier data obtained by the USC&GS on transmission of explosive sound, attempting to determine some of the influencing factors of underwater sound transmission by seasonal variations in temperature and salinity. Later he wrote the manual "A Summary of Factors Governing Sound Ranges". This was prepared in cooperation with the Anti-Submarine Warfare Instruction School at Boston, and supplemented manuals already published by the Bureau of Ships and the Hydrographic Office.

D 1944-45 <u>Proj. 18. Smoke</u>. (Transferred to a project of its own.)

Tests were made by Mr. F. deW. Pingree on the performance of life rafts used by U.S. ocean flyers to provide a more comprehensive coverage of raft problems than had as yet been made. He also made observations for the prediction of the drift of life rafts and other objects having various amounts of freeboard and drift under the combined action of wind and current.

E 1944-45 Proj. 19. Scouring of Mines.

Henry C. Stetson, with Jack L. Hough, George D. Kellogg, Jr., Kenneth C. Reynolds, and David B. Ericson, made tests during 1944 and 1945 to discover the behavior of ground mines under sea conditions on different types of bottom and to determine the effect of currents on the scouring of them. Work was done in the waters around Provincetown, Vineyard Sound, and Buzzards Bay.

To study this more closely scale models of the Mark 25 and Mark 12 mines were observed in a flume 8 feet long, 2 feet wide, and 2 feet deep. A window was set in the side of the tank so that the movement of the models could be observed under water.

B 1944-45 Proj. 20. Services of Expediting BTs and SBTs.

Having designed and constructed over 200 bathythermographs and 6 submarine bathythermographs in a shop barely capable of producing one such instrument, the Navy decided to have them manufactured commercially. A great amount of time and effort was spent in selecting a suitable manufacturer, because of the great amount of precision required. The Bristol Company of Waterbury, Connecticut was chosen, and work on specifications and development continued for many months, under the supervision of A. C. Vine.

B 1945-46 Proj. 21. Chlorine toxicity pipes

This was an outgrowth of Project 2, to find means of preventing the fouling of salt water lines in ships pipe systems. Experiments were made on the toxicity of chlorine and pentachlorphenate on marine organisms including a series of tests of the effectiveness of injections of these poisons into pipe systems in which sea water was flowing. These latter tests were conducted by Harry Turner at The Ethyl Dow Company plant at Kure Beach, North Carolina in cooperation with the International Nickel Company and Wallace and Tiernan, Inc. The work is described in Contribution 380 of the WHOI. Later experiments were made at Woods Hole and Kure Beach using chlorine generated electrolytically from the flowing sea water. The biological results were encouraging but such chlorine proved to induce corrosion in the piping.

β 1945-46

Proj. 22. Construction of 3 air thermographs

This mechanical instrument, which can be raised by a kite or balloon, greatly facilitated measurements of vertical temperature gradients at low elevations of the atmosphere. It was designed primarily to be used in the smoke screen operations and meteorological work, under supervision of Mr. David Barnes.

β 1945.

Proj. 23. Diving Characteristics

A concentrated study was made on the diving characteristics of submarines as to the compressibility, the components of the dynamic forces at different speeds, and the rate of thermal expansion or contraction under different conditions.

Wm. E. Schevill and A. C. Vine made quantitative tests on the east coast and at Pearl Harbor in an effort to determine the effect of rudder and speed changes on trim and depth control of submarines.

By adding a simple instrument to record temperature as a function of depth, diving officers were shown how to move more rapidly, more safely and more quietly, from one depth to another. They were also shown how to balance on density layers, and where and when these would be available. By explaining the refraction of sound due to vertical gradients of temperature and salinity it became clear that in many circumstances there was a best depth for evasion.

B 1945

Proj. 24. Underwater Sound Instrumentation (Develop. of Density Recorder.

Work was intensified on developing and perfecting instruments to be used by both surface vessels and submarines. Of prime importance was an instrument to measure and record density and sound velocity versus depth.

Dr. A. C. Redfield, Dr. Wm. L. Ford, John F. Holmes, A. C. Vine, and Wyman C. Rutledge spent considerable time on this problem. The deck mounted temperature-salinity recorder was developed and a special salinity corrected BT was built by the Bristol Company along lines initiated at Woods Hole.

B 1945

Proj. 25. Marine Meteorology

Upon completion of studies of the behavior of smoke screens, Dr. Wyman, Mr. Woodcock, Mr. Barnes and Mr. McCasland turned to the study of vertical air motion over the sea. Insofar as it was bound to involve studies of the vertical distribution of temperature, it was also expected to yield results relevant to the problem of radar transmission.

Although the first problem undertaken was the study of the relatively small scale convective motions thought to be characteristic of the lowest thousand feet of atmosphere in the Trade Wind area, attention quickly turned to the problem of the convective motion taking place on a large scale, involving the genesis and decay of the large masses of cumulus clouds which are a characteristic feature of the Trade Wind area. For these studies, many instruments were adapted for use on ships and on relatively slow aeroplanes.

B
1945-48

Proj. 26. Modification of Tidal Currents

Dr. W. T. Edmondson studied the available current pole measurements secured by the U.S.C.&G.S. in order to determine the average tidal cycle at each station as a factor in air-sea rescue operations.

B
1945-46

Proj. 27. Photomicrographic Techniques

This work was done by subcontract to Western Electric Company to permit us to supervise the work of a man at the Research Laboratory of the General Electric Company in New York who had developed a technique for sectioning and photographing paint coatings adhering to steel as an aid to determining the structure of such coatings.

B 1945-50 Proj. 28. Assistance to Government Laboratories - USNUSL

The U.S. government requested WHOI to provide assistance, facilities and personnel, in oceanographic problems of mutual interest, to U.S. Navy activities and to contractors of the Navy Department which had been approved by the Hydrographic Office.

B 1945-46 Proj. 29. Shallow water locating

Late in the war there was a heavy loss of ships in training carrier borne night fighters. In order to help locate downed aviators the feasibility of an acoustic detection system to locate small explosive charges in a local area of some 10,000 square miles was attempted. Such a system was determined to be feasible, but no operating system was set up.

B 1945-46 Proj. 30. Smoke Screen Data Analysis

With the great amount of data obtained from the smoke screen tests, personnel had to be trained to process them, in order to evaluate and make them ready for oceanographic use.

B 1945-46 Proj. 31. Training in Use of Smoke

At the request of the Commander-in-Chief, U.S. Fleet, a group of officers representing the Bureau of Ships, Bureau of

Ordnance, and Bureau of Yards and Docks came to Woods Hole to formulate a working digest of the material on smoke screens available here for use in the field.

B 1945-46 Proj. 32. Wave Characteristics

During the study of waves it was found that proper devices to measure and record tides, swell and waves were lacking. This project combined the continued study of waves with the adaptation of the necessary tools to make this work practicable.

B 1945-46 Proj. 33. Development of Wave Meters

Arthur A. Klebba developed the Woods Hole shore recording wave meter which was used in the wave observations in Vineyard Sound. He also constructed a wave period analyzer to take the record from his swell recorder and resolve the frequencies of the various wave trains making up the swell. Experimental wave recorder stations were set up at Cuttyhunk Island and at Bermuda. Special tide gauges were also made for wave research. These were light in weight so that underwater swimmers could put them on the bottom of the ocean. 1945

The wave period analyzer is a photo-electric scanning device which automatically gives the wave periods, combining to cause the observed sea conditions. The associated wave recorder presents the bottom pressure fluctuations caused by the swell. One can read this record directly for wave height and for the more pronounced wave periods. The period analysis is then quickly carried out in detail by the wave period analyzer.

By observing the change in wave velocity or wave height off an unknown beach, by means of aerial reconnaissance, it became possible to calculate the underwater topography with surprising accuracy.

B 1945-46 Proj. 34. Surface Vessel BT Field Engineers.

A great deal of time was spent preparing a "text book" for persons using the BT. Old reports, memos and manuals were revised and combined into one set of instruction, to help personnel interpret the effects of water conditions and factors on sonar performance.

B 1945-46 Proj. 35. SBT Engineering. The same work as on Proj. 34 was done for SBTs.

Although A. C. Vine and Wm. E. Schevill directed the work here, both of these projects were under the auspices of the Bureau of Ships, Code 940; later being integrated with the writing group at UCDWR in San Diego.

1945-46 **Proj. 36. Technicians on NOrd-9500.**

(Coles - Germany) Scheivell?

1945-46 **Proj. 37. Plankton Feeding.**

Dr. George L. Clarke made experiments on the use of marine plankton as a possible food for men under emergency conditions at sea.

B 1945-

Proj. 38. Submarine Supplement Western North Atlantic and North Atlantic Oceanography.

While many submarine supplement charts of the western North Atlantic were prepared during the war there were some sections, where, before the war, observations were too scarce to make charting practicable. With the accumulation of war data this, to a degree, was corrected.

D.F. Bumpus

B 1945-46

Proj. 39. Development of STD Recorder.

In order to determine the feasibility of a salinity corrected submarine bathythermograph, the Bristol Company in cooperation with ~~Dr. A. C. Redfield and~~ A. C. Vine, constructed an experimental model for deck use on a ship, which continuously recorded temperature, depth, and salinity at a remote, cable connected probe. The testing of this instrument was done by Dr. Wm. L. Ford, who also made many oceanographic studies with the instrument. Mr. John Holmes worked on design of the equipment and from these efforts the CXJC salinity corrected submarine bathythermograph was made.

1945-46 B Proj. 40. Sonar Analysis.

New york - Empire State
Brown Univ.

1945 In preparation for the oceanographic research activities at Bikini Atoll, Dr. Wm. S. von Arx constructed and operated a hydro-kinematic model of the atoll at this laboratory. Here the circulation due to wind, tides and oceanic flow was studied. Dr. von Arx also devised a current meter that was used at Bikini.

From these studies a whole new branch of physical oceanography emerged - experimental oceanography.

End of year 1945

~~PERSONNEL~~

Director

C. O'D. Iselin

Associate Director

Alfred C. Redfield

Scientists

R. F. Arentzen
A. B. Arons
Melvin Arsove
T. S. Austin
J. C. Ayers
David Barnes
Peter S. Bergmann
Wm. C. Bohn
R. M. Brown
D. F. Bumpus
Wm. S. Butcher
H. R. Cattley
George L. Clarke
Robert H. Cole
J. Stacey Coles
Robert D. Cotell
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C. A. Crecelius
Paul C. Cross
W. E. Curtis
J. C. Decius
E. S. Deevey, Jr.
W. T. Edmondson
J. E. Eldridge
Gardner Emmons
D. B. Ericson
Maurice Ewing
J. D. Ferry
W. L. Ford
George Fraenkel
Frederick Fuglister
P. M. Fye
Gabriel Gever
R. A. Geyer
Wm. E. Gordon
E. J. Groth
R. R. Halverson
D. F. Hornig
J. L. Hough
J. F. Holmes
O. E. Hunt
L. H. Hutchins
Lawrence Irving
D. B. Johnstone
W. D. Kennedy
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R. W. King
D. E. Kirkpatrick
M. S. Klapper
A. A. Klebba
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L. N. Liebermann
Nelson Marshall
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Harry McCurdy
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Sterling McNees
F. J. Mather, III
Milton Miller
R. B. Montgomery
Emmeline Moore
I. M. Newell
Philip Newmark
Charles Niffenegger
Palmer Osborn
Ernest Patterson
Roger Patterson
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M. J. Pollak
C. M. Pomerat
R. S. Price
C. E. Renn
D. M. Reynolds
Kenneth Reynolds
G. A. Riley
H. H. Robinson
H. D. Russell
W. C. Rutledge
Marshall Schalk
W. E. Schevill
W. G. Schneider
G. T. Scott
P. S. Shafer
A. M. Shanes
Nathaniel Shear
R. F. Shropshire
W. S. Shultz

C. P. Slichter
J. P. Slifko
Eastman Smith
F. G. W. Smith
Aaron Spector
R. W. Spitzer
D. S. Stacey
Nelson Steenland
H. C. Stetson
H. M. Stommel
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C. W. Tait
H. A. Templin
E. M. Thorndike
David Todd
H. J. Turner, Jr.
A. C. Vine
W. S. von Arx
C. M. Weiss
G. N. White, Jr.
Rupert Wildt
D. A. Wilson
W. W. Wood
E. E. Watson
A. H. Woodcock
G. P. Woollard
L. V. Worthington
J. L. Worzel
Jeffries Wyman
A. J. Yaspan
Thomas Zandstra
D. J. Zinn

Administration

Wm. C. Schroeder
John McGilvray
N. T. Allen
John Churchill

	Inventions	Inventors
1.	Methods of Sea water Form Suppression and Apparatus	Alfred C. Redfield and Allyn C. Vine
2.	Propellor Wake Cover (abandoned)	Alfred C. Redfield
3.	Bow Wave Spray Curtain (abandoned)	Alfred C. Redfield
4.	Bathythermograph	Maurice Ewing and Allyn C. Vine
5.	Submarine Bathythermograph	Maurice Ewing and Allyn C. Vine
6.	Method and Apparatus for Controlling Hydrofoil Depth	Maurice Ewing and John L. Ewing
7.	Method and Apparatus for making Grids (abandoned)	Maurice Ewing
8.	Wet Englarger (abandoned)	D. E. Kirkpatrick
9.	Transparency Meter for Fluids (abandoned)	E. M. Thorndike and D. E. Kirkpatrick
10.	Density Meter (abandoned)	A. C. Redfield
11.	Bottom Hardness Measuring Device (trans. to Sub. Signal Co.)	Ralph F. Shropshire
12.	Underwater Camera Housing and Rig (abandoned)	Maurice Ewing, A. C. Vine and J. L. Worzel
13.	Bottom Identifying Devise (trans. to Sub. Signal Co.)	Ralph F. Shropshire
14.	Refraction Slide Rule (abandoned*	Maurice Ewing and A. C. Vine
15.	Method of Sound Transmission	Maurice Ewing
16.	Tide Gauge	Arthur A. Klebba, A. C. Vine and Maurice Ewing
17.	Carbon Paper	Maurice Ewing
18.	Improved Submarine Bathythermograph	A. C. Vine, A. C. Redfield, A. W. Jacobson, J. L. Russell

	Inventions	Inventors
19.	Method and Apparatus for Detonating Explosive Charge.	Maurice Ewing, J. L. Worzel
20.	Wave Meter	Arthur A. Klebba
21.	Electronic Voltage Step Function Generator (abandoned)	Richard M. Brown
22.	Coulomb Calibration Circuit	Robert H. Cole
23.	Use of Air Bubbles as an Antifouling Device (abandonment advised)	F. G. Walton Smith
24.	Device for Integrating Functions	James S. Coles and Richard M. Brown
25.	Free Piston Impulse Gauge	William E. Gordon
26.	Square Integrator	Allyn C. Vine
27.	Cable Compensation Network	Robert H. Cole
28.	Amplifier without Phase Reversal	David S. Stacey and A. C. Redfield
29.	Electronic Time Delay	Robert H. Cole and David S. Stacey
30.	High Resistance Meter	David S. Stacey and Donald F. Hornig
31.	Linear Diode Voltmeter	David S. Stacey
32.	Regulated High Voltage Supply (abandoned)	Robert H. Cole
33.	Coupling Circuit for Electrostatic Pickup	Robert H. Cole
34.	Displacement Gauge	Robert H. Cole
35.	Spherical Sector Flash Charge (abandoned)	E. Bright Wilson, Jr., Paul M. Fye and John M. Eldridge
36.	Depth Indicator	William S. Butcher
37.	Ocean Bottom Hardness Tester	William S. Butcher
38.	Momentum Gauge Piston Stop	William S. Shultz
39.	Timer for High Speed Movie Camera	Roger S. Kuhn and George K. Fraenkel

Inventions	Inventors
40. Underwater Flare (abandoned)	Ernest L. Patterson, Paul M. Fye, James S. Coles
41. Bottom Sampler	J. L. Worzel
42. Tidal Current Meter	William S. von Arx
43. Air Thermograph	Jeffries Wyman and David F. Barnes
44. Accelerometer	A. C. Vine
45. Implosion Noise Source	J. L. Worzel
46. Bottom Firing Detonator	J. L. Worzel
47. Bomb Arming Devise	J. L. Worzel
48. Pressure Measuring Devise	J. L. Worzel
49. Piezoelectric Pressure Gauge	Arnold Arons and Clifford Frondel
50. Current Profile Recorder	Edmond E. Watson
51. Tool for applying Wire Clamp	James R. Sullivan
52. Chart Drive for Long Time Interval	Arthur A. Klebba
53. Optical System for Wave Recording on Photographic Paper	Arthur A. Klebba
54. Method of Solving Fundamental Relationships of Sea Water Variables	A. C. Vine
55. Conductivity Cell	A. C. Redfield
56. Geomagnetic Electrokinetograph	William S. von Arx
57. Method of Recording Buoyancy	Allyn C. Vine
58. Simplified Buoyancy Recorder	A. C. Vine, John F. Holmes, Wyman C. Rutledge
59. Temperature Measuring Device (abandoned)	A. W. Jacobson

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