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PRELIMINARY REPORT OF THE U.S. NAVY UNDERWATER SOUND LABORATORY--ETC(U)
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FORT TRUMBULL, NEW LONDON, CONNECTICUT

USL PROBLEM
No. 1-610-05-00

PRELIMINARY REPORT OF THE U. S. NAVY UNDERWATER SOUND LABORATORY PORTION OF THE EXPERIMENTAL PROGRAM CONDUCTED ABOARD THE BATHYSCAPH TRIESTE JUNE THROUGH OCTOBER 1957,

by
R. V. Lewis

USL Technical Memorandum No. 1210-140-57
9 December 1957
12 P.

The following paragraphs contain a preliminary description of the U. S. Navy Underwater Sound Laboratory's part of the ONR-sponsored experimental program conducted aboard the Bathyscaph TRIESTE during the summer period of June through October 1957. Some background material is presented, the types of experiments and experimental equipment are described, some of the operational problems are discussed, preliminary results and conclusions are stated, and recommendations for future work are indicated. It is emphasized that this is a preliminary report, and final results and conclusions cannot be stated until calibrations are made and data analysis has been completed.

BACKGROUND

The purpose of the experimental program conducted aboard the Bathyscaph TRIESTE during the summer of 1957 was to determine the suitability of that vessel as a research tool. The method used to accomplish this purpose was to attempt to conduct a program of limited scope, and the measure of success was to be determined from a broad evaluation of all the problems encountered as well as from the evaluation of the scientific data accumulated.

It had been recommended that emphasis be placed on experiments in underwater acoustics including biology as it related to acoustics. The choice of experiments to be conducted was limited by the physical and operational characteristics of the Bathyscaph and by the very short time available in which to prepare for the summer's program.

The Underwater Sound Laboratory's part of the program consisted of three parts; viz., providing the Bathyscaph with underwater telephone communication, studying the directional characteristics of background noise versus depth, and determining the correlation pattern of the noise field occurring during any one diving period. Initial planning indicated five dives for the above purposes out of a total of 19 dives for the entire ONR program with the possibility of additional dives late in the season

(reference (a)). Actually four dives out of a total of 18 made for scientific purposes were available to USN/USL. Reference (a) also indicated that additional dives dependent on work to be done and the weather encountered would be made late in the season. USN/USL was to have been allotted one of these. The dives as planned in reference (a) were to be of the following type:

(1) Dive to 50 meters to calibrate and check USN/USL equipment and make self-noise measurements.

(2) Dive to 3000 meters to investigate directional properties of the noise field.

(3) Dive to 500 meters (3000 meter water depth) for four hours' work in the sound channel.

(4) Dive to 500 meters to investigate directional properties of the noise field.

(5) Dive to 3000 meters to investigate directional properties of the noise field.

The dives actually conducted were:

(1) Dive to 1100 meters to test communications and make observations.

(2) Dive to 1100 meters to investigate the directional properties of background noise.

(3) Dive to 2800 meters to investigate the directional properties of background noise.

(4) Dive to 300 meters (2800 meter water depth) for work in the sound channel.

The discrepancies between the initially planned dives and those actually conducted were largely due to unpredictable circumstances which also affected the time schedule. It was originally planned to conduct the ONR program during the period of 24 June through 23 September; however, the period of 3 July to 25 October 1957 was required.

EXPERIMENTS AND EQUIPMENT

The main objective of the USN/USL program was to make a limited study of the ambient sound level versus operating depth; and, as indicated above, two dives for this purpose were made, one two miles south of Capri on 2 September to a depth of 1100 meters and another 25 miles south of Ponza on 9 September to a depth of 2800 meters. Four receiving transducers were installed on the TRIESTE for these tests; viz., an 11 1/2 foot line

hydrophone installed vertically, a similar line hydrophone installed horizontally, an omnidirectional reference hydrophone, and a pressure gradient type hydrophone responsive to sounds arriving from above the Bathyscaph but not to those arriving from below. The sound output of each of the four transducers was switched in turn through a common amplifier and the resulting output levels read from a Ballantine meter through a set of four one-octave band filters. The bands selected were 300 to 600, 600 to 1200, 1200 to 2400, and 2400 to 4800 cycles per second. Preliminary results are discussed in a later section.

USN/USL provided communications between the Bathyscaph and the surface by providing two special-purpose 15-watt battery-powered underwater telephones. One of these units was constructed in a rectangular box with a cushion on top and was used as a seat in the Bathyscaph. The transducer for this unit was a free-flooding scroll with no pressure release material and was mounted on top of the "conning tower" of the TRIESTE so that no part of the vessel's structure would be in the sound path. The other unit which was always operated from a motor launch accompanying the Bathyscaph was contained in its original cylindrical case and was provided with a smaller free-flooding scroll transducer.

It had been hoped that it would be possible to combine Bathyscaph self-noise measurements with the communications tests; however, the necessary instruments were delayed in shipment and arrived in a damaged condition the day before departure of the Bathyscaph to the diving area. Since the underwater telephone would effect a considerable increase in operational safety and facilitate all Bathyscaph operations, it was decided that a dive for testing communications was warranted.

The dive to a depth of 1100 meters was conducted from 1200 to 1450 on 18 July in a sea state 3 and is described in detail in reference (b). Telephone communication was established at frequent intervals during the descent, and communications were near perfect during the descent, on the bottom, and during most of the ascent; however, at the shallower depths with the horizontal range greater than a half mile or so, communications were poor. This performance was typical of all the subsequent operations conducted. During the ascent the communications were made less frequently to allow time for listening to natural and man-made noises at the great depths.

Sounds heard on the telephone during the dive were also of interest. Noises assumed to be of biological origin were loud whistling of porpoises, clicking noises similar to those attributed to the gerabaldi fish, and a frying sound like crackling shrimp but of only 30 seconds or so duration separated by random intervals. Various screw beats of ships were also heard in the depth range of 870 to 390 meters, but there was no surface reconnaissance, except at visual ranges, with which to check the listening log. It is of interest to note that no operational sounds from the Bathyscaph were heard except the dropping of the ballast and the clicking

of the fathometer which was used intermittently when landing on the bottom.

Another objective of USN/USL's participation in the Bathyscaph program was to determine the correlation pattern of the noise field at sound channel depth occurring during any one diving period. This was to be done by using the two halves of the horizontal line hydrophone to provide an input to a USN/USL correlation sonar equipment adapted for use in the TRIESTE. The hydrophone was to have been rotated in azimuth by rotating the Bathyscaph using three electric outboard motor units mounted athwart ships near one end of the vessel and powered by an outside pressure compensated battery box. The Bathyscaph was to be stabilized in depth by providing a small displacement float at the surface connected to the vessel by sufficient rope to permit operation in the sound channel and adjusting the ballast as necessary to keep the equilibrium within the limitations imposed by the bouyancy of the float.

An attempt was made to test the motors on the 2 September background noise dive, but the battery box pressure compensation system proved to be faulty. The system was hurridly changed, and the motors were successfully tested to depths as great as 2800 meters on the 9 September background noise dive; however, a new liquid used to separate the electrolyte from the sea water softened the battery cases causing an electrolyte leak which destroyed the battery box the evening of 10 September so that the motors could not be used for the 11 September dive.

The dive was made on schedule, however, and it was hoped that the TRIESTE's normal propulsion motors could be used intermittently to turn the Bathyscaph to accomplish the desired result, but it was not possible to turn the vessel more than a few degrees by that means.

The experiment of holding the Bathyscaph at one depth; viz., 300 meters, was a complete success. With a float of only 250 pounds displacement connected to the TRIESTE by a one-fourth inch diameter manila line, the 125 ton Bathyscaph was held at constant depth for a period of two hours with the exception of a brief period of 15 minutes when depth control was temporarily lost.

Although it was not possible to obtain correlation data, the sounds heard were logged and recorded on tape; and, since the directional pattern of the hydrophone is known, it will be possible to determine from surveillance information what ships were heard.

In addition to making the observations necessary to accomplish the intended purposes of the dives as discussed above, secondary observations were also made. In particular the azimuth rotation of the Bathyscaph, the nature of the bottom terrain, and the living creatures in the vicinity of the bottom.

OPERATIONAL PROBLEMS

Although the results of this summer's program have been very satisfactory, if certain operational problems encountered were removed or alleviated, a considerable increase in operational efficiency could be effected. The chief factors contributing to inefficient use of vessel were:

(1) Only one Bathyscaph pilot was available.

(2) The method of charging storage batteries was inefficient.

(3) The method of conducting shipyard work was inefficient.

(4) There was improper liaison between the Bathyscaph party and the Italian navy.

(5) Topside design of the TRIESTE was a limitation.

(6) Time was lost because of illness due to poor sanitation.

If additional Bathyscaph pilots were trained, dives could be made every day of an operating period rather than every other day. During the summer's program it was necessary for Mr. Piccard to perform a very large number of duties. In addition to being the source of Bathyscaph technology and transacting all the business required to operate the vessel, it was necessary for Mr. Piccard to oversee almost every detail of servicing and repairing of the Bathyscaph and to pilot it during every dive.

At least one week's time between Bathyscaph operations was normally required for the purpose of charging batteries which were of the silver-zinc variety and required very special handling. It was necessary to charge them at a low rate and to measure the terminal voltage to three-place accuracy to determine when they were fully charged; and if they were permitted to rise above this proper terminal voltage, they became useless. The method used to handle this situation was to have a capable, responsible individual continually check the batteries by hand with a precision voltmeter. This process required 60 to 80 man hours. And it had to be done by a college student hired for the purpose, a member of the Bathyscaph party, or Mr. Piccard himself.

Shipyard work was done by rather crude methods and each job was closely supervised by Mr. Piccard. A number of tasks conducted simultaneously would greatly shorten the total time required, but this was not done probably because of a lack of personnel of suitable qualifications and sense of responsibility. However, considerable time was lost in the month of August during ideal diving weather because the work could not be conducted more efficiently.

The fourth item refers to the situation in which all operations were

planned between Mr. Piccard and the Italian navy without a means for the Bathyscaph party to discuss operational factors affecting their experiments or understanding operational problems which they could have assisted in solving. This was partly a language barrier problem. It should be stated here that liaison at the top levels between the U. S. and Italian navies was excellent.

Although some dives were made in sea state No. 3 and the TRIESTE was towed once in sea state No. 5, operations under such conditions were quite unsatisfactory; since in the case of the dives personnel were thoroughly drenched before entering the sphere, and, when towing in heavy seas, some damage was sustained. If the Bathyscaph topside structure were modified, there would be less reluctance to tow it in heavy weather and to dive in higher sea states. It would probably also be necessary to provide a means of locking the ballast silos in position while towing and providing an easy means of unlocking them before diving. The present "fail safe" design inherently allows them to move slightly and thus "pound" in heavy seas.

Some time was lost this summer to illness caused by poor sanitation. Navy medical authorities inspected the hotel kitchen in Castellammarre, but could only express their sympathy and recommend abstaining from many types of food since the navy had no jurisdiction there. One member of the party, the college student hired to charge batteries, contracted hepititus and was hospitalized for a month, and all members of the party contracted illnesses directly attributable to poor sanitation.

It should be stated here that an improvement in efficiency in utilizing the Bathyscaph would also require increased support for the research team. For the program conducted this summer it was necessary for each scientist to perform all tasks required to get his equipment working. Some of these tasks should be performed by technicians, machinists, and some (typing and records) by secretaries.

PRELIMINARY TEST RESULTS

About three months' time will be required to analyze the data taken during the USN/USL dives, but certain statements can be made at this time.

On the background noise dives sound levels were read at frequent intervals on both the descent and ascent, and temperature readings and compass readings were also made. The sound level data on both dives indicates that the variation as a function of depth in the responses of the four hydrophones to the background noise field are different, and the significance of these differences is not apparent from a preliminary inspection of the data. On the 9 September dive to 2800 meters an unusual and unexplained rise in band levels occurred during the descent at a depth of 1400 meters as observed by the hydrophone which is directional in the vertical plane; and there was a similar but not as pronounced a level rise

in the omnidirectional hydrophone response, but the responses of neither the horizontally mounted line hydrophone nor the pressure gradient hydrophone showed this change. Since the beam width of the vertical line was only about 6.25 degrees at 3600 cps, the apparent source of the noise must have been in the same plane as the receiver.

The telephones provided reliable communications for the entire Bathyscaph season and provided a means of obtaining approximate ranges between the TRIESTE and the accompanying motor launch by timing a "round trip" transmission with a stop watch. The distance to the bottom at ranges greater than those provided by the fathometer could also be attained to a rough approximation by timing the interval between the transmission of a tone and the return echo. An unexpected dividend was that the proper functioning of the ballast release mechanisms could be checked by listening to the telephone. Previously it had been necessary to do this visually by turning on the outside lights and observing the ballast flow.

The dive intended for obtaining correlation information from the sound field existing at that time was of limited success because of last minute equipment failure. However, the ability to hold the Bathyscaph at constant depth with the aid of a small float (250 pounds displacement) attached to the vessel by a light cord (one-fourth inch diameter manila line) was demonstrated, and sounds heard in the deep channel were logged and tape recorded and will be checked against surveillance information in the near future.

Azimuth rotation of the TRIESTE was observed on all dives, but preliminary observations have been concentrated on the Ponza dive of 9 September to 2800 meters. It appeared that a force acted on the vessel to rotate it in an increasing bearing direction during descent and a decreasing bearing direction during ascent, but superimposed on this force were rather amazing torques which caused erratic and sudden changes in direction of rotation with angular speeds as high as 50 degrees per minute. These changes could not be correlated with vertical velocity and must be due to strong underwater currents. A further evidence of underwater current observed on the bottom was the tendency of the guide rope to assume angles departing as much as 30 degrees from the vertical.

The bottom terrain was observed on the two dives at Capri on 18 July and 2 September at a depth of 1100 meters and at 2800 meters south of Ponza during the dive of 9 September 1957. Observations made on the former dives revealed that the bottom was quite flat, surfaced with a brownish grey mud, and indented by numerous small holes, perhaps one-fourth to one-half inch diameter which one might assume would be inhabited by animals or insects. On the first dive one group of five holes arranged in the manner of a dog's footprint was observed and was the same formation reported by previous Bathyscaph observers. On the second Capri dive a large hole of perhaps four-inch diameter was observed and photographed.

On the Ponza dive two landings were made revealing two different type bottoms a short distance apart (there was no means of determining the exact distance). Observations made on the first landing revealed that the bottom resembled that near Capri but sloped gently to the east. At the location of the second landing the bottom was undulated in character with a vertical distance of about one meter between the crests and valleys and perhaps three meters from crest to crest. The ridges and valleys followed a northwest-southwest trend.

The writer is not a trained biological observer but noted the life observed and reported it to Dr. A. B. Rechnitzer, Marine Biologist from NEL. On the dive of 18 July, as the TRIESTE landed on the bottom, a brown shell was observed which was about two inches long and resembled that of a clam except that one edge was scalloped. It was not possible to tell whether it was dead or alive. Shortly after the landing two brown bugs were seen walking on the bottom, then a white fish appeared. It had a large brown eye with a blue semicircle behind it. The tail had a V notch and was symmetrical, and there was a discontinuity on the underside that would remind one of the step on a high-speed motorboat. A number of these fish, perhaps eight or a dozen, eventually appeared. They would swim vigorously for a short distance and then lay on the bottom on their sides. The fact that the enveloping cloud of mud that resulted from dropping the ballast did not appear to disturb them would seem to suggest that they could not perceive the resulting change in light intensity.

Also on this dive a dark blue fish about one foot long with a thin white stripe across the end of its tail was observed. The tail of this fish was also symmetrical with a V notch indentation. It is believed to be of the same species as that observed by Dr. Deitz on his dive of 3 July and by Dr. Rechnitzer on his dive of 20 July.

On the dive of 2 September to 1100 meters in the same area, this observer saw one small greenish-brown fish about one inch long also with a symmetrical V notched tail. It was not possible to observe any other details, but Mr. Jacques Piccard saw one of these fish dive into a hole in the bottom.

On the dive of 9 July to 2800 meters this observer saw only one small fish near the bottom and could observe no details. During the ascent the flashing of large numbers of luminous fishes was observed at about 700 meters depth. On this dive Mr. Piccard observed several fishes near the bottom.

RECOMMENDATIONS FOR FUTURE WORK

In considering future acoustic work aboard the Bathyscaph, it is well to consider the manned vehicle versus lowering hydrophones from the surface or building an unmanned data-taking machine for research at great

depths. The advantages of the Bathyscaph are:

(1) It is in existance now and requires no development program.

(2) It provides a means of lowering and controlling large directional arrays at great depths. This is difficult to accomplish from the surface using cables.

(3) It provides "on-the-spot" human observation and judgment and the means to alter the conditions of an experiment as necessary to correct for changing environment.

(4) It provides a means of developing techniques for and getting experience with transducer arrays at depths and pressures greater than those conventionally encountered. This will be important in future submarine development.

In making recommendations for future Bathyscaph work it is necessary to consider organization and location as well as the technical program. This summer's program was a noteworthy event since it marks the beginning of naval research involving manned vehicles capable of operating through the entire range of depths of the sea, and the small scientific effort made this year can and should lead to a much larger future effort. It is the opinion of this observer that research involving the use of liquid-supported submarines should be pursued both on a short-term and long-term basis, and that tactical advantages could be gained by navigating the entire medium of the ocean.

The results of this summer's efforts have been most satisfactory; but it was not possible to conduct the program efficiently, and it is strongly felt that proper planning for a future season of Bathyscaph operations could effect a threefold increase in diving time available.

The greatest gains in increasing the efficiency of future Bathyscaph operations may be made by improving the organization, and this should begin at a high level. The creation of a committee for Bathyscaph research is suggested. This group would be charged with the duty of providing means of conducting acoustic and oceanographic research programs of scientific and tactical interest to the naval organization at depths greater than those which can be practicably or economically attained by other means.

Operations could be under the direction of a Field Operations Director utilizing to the fullest possible extent the advice of Mr. Piccard, who should serve as a Consultant for Bathyscaph Technology. At first the latter and the Pilot would be the same individual, but only until other pilots, preferably specially trained submarine officers, were available. Participating scientists should be chosen and suitable programs should be proposed by the respective laboratories but should be approved by the Bathyscaph Research Committee well in advance of the operating season.

The location of Bathyscaph operations is also important. It would be of considerable value to conduct operations in an ocean area more nearly representative of waters of tactical interest and one in which considerable oceanographic data has been accumulated in the past. The Bermuda area would be the first choice; but if logistic support proved to be too difficult in that location, the area off San Juan, Puerto Rico would be acceptable. Both areas have low average sea states and require only a short towing time to reach deep water. Also considerable oceanographic data has been taken in both areas.

The acoustic program for the immediate future should include an extention of the tests conducted during the past season, but with improved equipment which could easily be built if more time for preparation is made available, probably six months' advance notice would be sufficient. In addition to the above, the experiments suggested by Dr. F. N. Speiss of MPL involving investigation of the sound field as a function of depth using pulsed and CW sound sources on the accompanying surface vessel should be conducted (reference (c)).

The equipment envisioned for background noise measurements above 300 cycles would consist of three mutually perpendicular end-fire arrays with variable directivity (i.e., each array would have a main response pattern represented by the surface of a cone with an adjustable apex angle), the outputs of which would be fed to a switching box, thence through logit filters, and finally to a tape recorder especially adapted to the needs of the Bathyscaph. Such a system would permit acquiring many times more data per dive than was possible during the past season.

The hydrophone arrays would resemble the line hydrophones used in the past season's work except that transistor preamplifiers would be imbedded in the plastic between each element and leads from each preamplifier would be brought out to an externally mounted adjustable delay line controlled from within the sphere.

The switch box would provide for rapid selection of hydrophones and apex angles so that the selected signals could be fed to the tape recorder in a continuous succession.

A battery-operated tape recorder suitable for use in the Bathyscaph of at least the quality of the magnecorder model DT63 now used for much of the Laboratory's data collection at sea would be needed. The requirements are constant speed, moderately wide dynamic range, low power consumption, battery operation, and means for voice cues.

The equipment used for acquiring the correlation pattern of the noise field could be very similar to that provided for the past season's operation,

but a means of making the hydrophone unidirectional rather than bidirectional should be provided.

No doubt equipment used by other laboratories could also be improved if more preparation time were available so that more data could be collected for a given amount of diving time.

WORK BY OTHERS

The two other laboratories involved in the Bathyscaph program were the Naval Electronics Laboratory and the Hudson Laboratory of Columbia University. Dr. A. B. Rechnitzer, Marine Biologist of NEL, made three dives, one of which involved a skid down the side of a precipice with an estimated slope of 70 degrees. Mr. A. Lomask and Mr. Roberto Frasseto of Hudson Laboratories made a total of three dives to conduct background noise measurements in the 5 to 300 cycle range of frequencies. The method used was to obtain directional information from seven "spot" hydrophones by the use of correlation techniques. European scientists from Sweden, France, Switzerland, and Italy also made dives and two officers each of the United States and Italian navies made dives. Also three shallow water dives were made for the purpose of taking motion pictures of the Bathyscaph, both from above the water and beneath the surface. The former were taken by a Mr. Baume of MGM, Rome, and the latter by Dr. A. B. Rechnitzer of NEL.

CONCLUSION

The past season's activities aboard the Bathyscaph TRIESTE have been very much worth while, and a consideration of all phases of the program indicates that the Bathyscaph is a useful research tool and especially that it is useful for conducting acoustic research of interest to the navy at depths not economically or practicable attainable by other means. The Bathyscaph has an advantage over research conducted by lowering cables from the surface or an automatically controlled deep diving device in that it provides a means of lowering large directional arrays to great depths, it is available at the present time without development, it provides human judgment and the ability to adjust to conditions at the test location, and it provides a means of getting experience and developing techniques applicable to future deep submarine development. The utility of the Bathyscaph can be greatly improved by an improved organization for conducting the programs and by improving the Bathyscaph and the test equipment. Also, it would be desirable to conduct the tests in a location more representative of those of tactical interest such as the Bermuda or Puerto Rico areas.

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LIST OF REFERENCES

(a) ONR memo from Geophysics Branch to Participants in Project Bathyscaph of 22 May 1957 "Project Bathyscaph" (UNCLASSIFIED).

(b) R. V. Lewis, USL Tech Memo No. 1210-103-57 of 26 Aug 1957 "Deep Water Communication Tests Aboard the Bathyscaph TRIESTE" (UNCLASSIFIED).

(c) MPL ltr to CNO (Code 416) File 00b-U-88 of 31 May 1957 (UNCLASSIFIED).