THE OFFSHORE CIRCULAR ARRAY

Techniques For The Mid-Water Support And Mooring
Of Oceanographic Instrumentation In Shallow Water

W. J. Bunton And I. E. Davies • Research And Development Report • 19 January 1965
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THE PROBLEM

Investigate and report on factors in physical oceanography which pertain to underwater sound and develop techniques to expedite these investigations. Specifically, install on the shallow ocean floor adjacent to the NEL oceanographic research tower a circular array of stanchions capable of supporting transducers at prescribed positions in the water column over a long period of time for the study of internal waves.

RESULTS

1. Forty-eight stanchions have been accurately placed by NEL divers on the sea floor off Mission Beach, California, in 62 to 64 feet of water. Spaced 29 feet apart, they form a circle with a circumference of 1395 feet. Each stanchion consists of three telescoping sections of galvanized pipe. The base sections, with three vertical fins welded to them, were injected approximately 4-1/2 feet into the sediments by high-pressure water directed through the pipe and into the bottom. The stanchions are used to support thermistor beads at 30-foot depths. The array is presently in use in conjunction with the internal-wave and underwater-sound studies being conducted by the NEL Marine Environment Division.

2. Over a 15-month period, the vertical and horizontal positioning of these stanchions has remained virtually unchanged, attesting to the stability of this type of installation. Other successful applications of this technique have been made. The equipment and diving procedures developed for this job are applicable to other underwater engineering problems.

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RECOMMENDATIONS

1. Further test the horizontal and vertical stability of these stanchions in different types of sediments.
2. Correlate results with sediment classification and shear strength.
3. Experiment with various designs of pipe section in order to optimize mooring capabilities and minimize installation time and expense.

ADMINISTRATIVE INFORMATION

The work covered in this report was performed under SR 004 03 01, Task 0586 (NEL L40551). Installation of the vertical array was accomplished during the period 6 June 1963 through 16 July 1963.

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INTRODUCTION

Critical placement of underwater equipment on the sea floor for long-term studies has traditionally been a source of concern for scientists and engineers engaged in investigation of the marine environment. Mooring techniques have been unable to satisfy the needs created by the complex instrumentation presently in use. For example, large tripods with legs imbedded in clumps of concrete, weighing as much as 2000 pounds, have been used to position thermistor beads, acoustic equipment, and other oceanographic devices at relatively stable points above the sea floor. Positioning of these tripods at desired locations has proved to be a tedious, expensive operation, requiring the services of a large vessel equipped with winches and booms. Once emplaced, the concrete clumps are susceptible to wave scouring which, in short periods of time, changes the position of the equipment relative to the sea floor. Thus, any job requiring a large number of these installations becomes virtually impossible.

An alternate method of anchoring small equipment to the bottom which has been in use by NEL for some time, is to physically inject sections of pipe into the sediments using high-pressure water. This method, commonly referred to as "jetting," is performed by divers using SCUBA or shallow-water diving equipment. When several feet of pipe are buried in the sea floor in this manner, scouring action is considerably reduced, if not entirely avoided, and the protruding pipe becomes a stable, relatively permanent mooring to which a variety of instruments can be mounted or tethered.

The Marine Environment Division of NEL is charged with the responsibility to study oceanographic factors that contribute to the use of underwater sound in naval operations. Internal waves are known to alter sound fields in the sea. Consequently, many studies conducted on the NEL oceanographic tower depend on adequate field measurements of naturally occurring internal waves. Ideal

controls on temperature and sound measurements can be obtained in model studies conducted under laboratory conditions, but the question remains: how well do laboratory measurements apply to natural conditions in the sea? The NEL oceanographic tower offers the scientist some of the controls that can be obtained in model studies -- a power supply that does not change in potential or frequency and a stable support for transducers and recorders. These laboratory-like controls are lost if an attempt is made to buoy transducers from surface floats and lay power and signal cables to the tower. A more desirable procedure is to eliminate surface floats and fix transducers to rigid supports that are jetted into the bottom and cannot move.

Motion of transducers, or lack of it, is important from several standpoints. Motion of sound transducers introduces fluctuation in sound level at the receiver which completely defeats the purpose of certain experiments. In the measurement of internal waves in shallow water, both vertical and horizontal motion of transducers (usually thermistors) can contaminate the results if the vertical gradient of temperature is high. Surface swell introduces vertical motion of a float and transducers attached to it by an amount approximately twice the amplitude of the swell. The thermistors pass through the temperature gradient periodically, the frequency depending on surface waves. Surface-wave frequencies are introduced into the temperature record and this is undesirable when only motion of internal origin is of interest. Attempts to study any temperature fluctuation at frequencies higher than swell frequencies, using this arrangement, would be seriously inhibited.

Internal waves cause horizontal temperature gradients in the sea. Horizontal motion of thermistors caused by swell again introduces frequencies equal to surface-wave

frequencies into the temperature record. This contamination can be reduced somewhat by thermal lagging of the thermistors, but it cannot be completely eliminated. A high thermal gradient corresponds to a high stability frequency and internal waves can progress at a high frequency. If internal waves are to be passed at full amplitude, then surface-wave frequencies cannot be completely eliminated from the record by thermal lagging.

An important advantage to jetting transducer supports into the bottom is that relative accuracy approaching laboratory accuracy can be obtained. Transducer placement for measuring internal waves is analogous to the design of a directional radio antenna or a directional sound transducer; that is, with a certain placement, a certain response can be obtained. An array of transducers can be installed, depending on the requirements, as an antenna with a given response. Transducer spacing can be controlled by the diver, and the scientist can be assured of the accuracy he desires.

In May 1963 the Marine Environment Division of NEL requested the installation of a circular array of thermistor beads on the shallow ocean floor adjacent to the existing NEL oceanographic tower. The array was to be used in a study of internal-wave vectors and was to consist of forty-eight vertical stanchions, 29 feet apart, forming a circle with a 1395-foot circumference (fig. 1). Each stanchion was to rise 31 feet off the bottom and be capable of supporting the necessary thermistors and cables. The tripod method of installation was deemed unfeasible for a job of this magnitude and rejected in favor of the jetting method.

This report describes the devices used to carry out this installation and the method of placement as well as the diving procedures involved, with further applications of these techniques.

Figure 1. Model of the offshore circular array showing relation to the NEL oceanographic tower.

DESIGN AND CONSTRUCTION OF STANCHIONS (FIGURES 2A THROUGH 2C)

Figure 2(A). The base pipe section of each stanchion is designed to facilitate insertion into the sediments as well as to withstand the horizontal strain of wave surge. Three vertical fins, welded to the pipe at intervals of 120°, add to the horizontal stability of the installation. The tapered nozzle has holes strategically placed to best utilize the effect of the high-pressure water during the jetting operation. The upper end is threaded for coupling to the water hose.

Figure 2 (Continued)

(B) Telescoping stanchion sections, drilled for coupling.

(C) Complete stanchion assembly, with base pipe section in place and telescoping sections installed.*

*Drawings of construction details are available upon request; write the Commanding Officer and Director, Navy Electronics Laboratory, San Diego, California 92152, Attention Code 3119.

VERTICAL ORIENTATION OF BASE PIPE (FIGURES 3 AND 4)

Figure 3. Tripod with leveling and holding device, designed to enable divers to position pipe during the jetting operation. Tripod is shown with base pipe section in place.

Figure 4. Leveling device. With tripod in place on sea floor and base pipe section positioned within tripod rim, leveling device is lowered over base pipe section and clamped to rim. Pipe is raised a few inches and secured by T-screws near top of holding sleeve. Diver plumbs pipe by manipulating thumb screws and observing bubble levels on hinged sleeve. Hinged sleeve is unfastened and allowed to drop out of the way. Chain prevents loss. T-screws on holding sleeve are released, and pipe drops to sea floor. The L-screw which clamps the holding sleeve in the raised position is loosened, and holding sleeve falls through leveling device until it is stopped by T-screws. Pipe is now ready for jetting into the sea floor.

JETTING-IN BASE PIPE SECTIONS

Divers attach $1\frac{1}{2}$ -inch fire hose to the top of the base pipe, using a bell reducer to fit the larger diameter of the pipe. Communication is maintained between divers and the support boat by a signal line. On signal, the crewmen start the high-pressure water pump, which forces 60 gallons of water per minute through the welded nozzle of the pipe at 100 psi. The water pressure displaces the sediments and allows the pipe to settle under its own weight into the sea floor (fig. 5). After the downward movement of the holding sleeve is arrested by the two T-screws and the bell reducer reaches the top of the sleeve, the diver diverts the water by means of a Y-gate valve located between the fire hose and the bell reducer, and signals the support boat to stop the pump. At this point the pipe has settled $4\frac{1}{2}$ feet into the bottom, the fins are covered, and the jetting-in is completed. Approximately 90 seconds is required to jet in one base section.

The fire hose is disconnected and the tripod and leveling device are lifted over the protruding pipe section. The tripod is relocated at the next position. An air-filled lifting bag attached to the tripod during relocation facilitates movement by the divers.

Figure 5. Diver jetting-in a pipe section. Displacement of sediment is evident at bottom of pipe. Signal line runs from leg of tripod.

POSITIONING STANCHIONS IN THE ARRAY

A center reference stanchion was jetted into the bottom 735 feet from the oceanographic tower. A 222-foot length of $\frac{1}{8}$ -inch-diameter cable (radius cable) was tethered to this center stanchion by means of a 3-inch ring which permitted free movement of the cable around the center point. Station 1 was established by stretching this cable along a magnetic north course and jetting-in the base pipe section. Surveying of stations 1 through 13 is depicted in figure 6.

With the completion of station 13, a full quarter of the circle had been formed. At this point, station 13 was considered to be station 1 for the next quarter circle and the process was repeated. In order to obtain the greatest possible accuracy, the divers swam the entire length of cables such as the radius cable and the longer chord cables each time they were used. This process expended a great deal of time, but it assured that the cables were not snagged on rocks, debris, or marine organisms.

It has been estimated that each station can be surveyed to an accuracy of less than 1 percent error by following these procedures.

Figure 6(A). Succeeding stations are positioned by means of cables of lengths corresponding to chords of the circle. To position station 2, a cable 29 feet in length, corresponding to the chord subtended by an angle of $7\frac{1}{2}^{\circ}$, is stretched from station 1 in counterclockwise direction until it transects the radius cable stretched from the center reference stanchion by another diver. A temporary stake is inserted at the junction, the tripod placed over it, and stanchion 2 jettied into the bottom. The 29-foot chord cable is transferred from station 1 to station 2 and the procedure repeated to establish station 3, and so on. All cables are terminated with rings which fit over base pipes. ►

(B) So that gross errors are not caused by improper stretching of the cables, snagging, etc., a system of checks is imposed on every third position. At station 4 a chord cable 86 feet 6 inches in length, corresponding to the chord subtended by an angle of $22\frac{1}{2}^{\circ}$, is stretched from station 1. The junction of the three cables -- the 29-foot chord cable from station 3, the radius cable, and the chord cable from station 1 -- constitutes station 4.

(C) The junction of cables from stations 1, 4, and 6 and the center stanchion confirms the accuracy of location of station 7.

(D) Check of location of station 10.

(E) Check of location of station 13.

ADDING TELESCOPING SECTIONS TO THE BASE PIPE

After the forty-eight base pipes were emplaced, each third pipe was buoyed to provide the support boat with a visual guide of the array. The telescoping sections which form the upper part of the stanchions were bolted together and a float attached at the top of the upper section so they would settle to the bottom in a vertical position. The size of the float permitted a slight negative buoyancy to the sections which facilitated handling by the divers. These sections were dropped as close as possible to the surface-buoyed base pipes and the divers guided them down and inserted them in the base sections. The divers removed the float, surfaced, and moved to the next position, repeating this operation until the array was completed.

DIVING PROCEDURES

Because of the long, strenuous bottom time required during the installation of the base sections, a surface-supplied air source was utilized. A low-pressure compressor with two 300-foot diving hoses, located on the stern of the support boat (a 50-foot Navy utility boat), provided two divers with a wide working radius. Ninety minutes' bottom time was considered optimum for the project, since it eliminated the necessity of two decompression stops. On one dive of this duration, two divers could install three base pipes and measure a fourth. Divers completing a tour on the bottom would ascend to a stage suspended at a 10-foot depth from the support boat, and after proper decompression, surface to become tenders for the next pair to go down. After six or seven pipe installations, all work on the bottom ceased as the support boat moved to a new position. A buoy attached to the tripod served as a permanent guide to the area in work.

For the second phase of the operation (adding the telescoping sections), SCUBA equipment was utilized. This gave the divers mobility for the constant ascending and descending required for this task. Freed from the restriction of the air hose, a team could complete an assembly in 5 to 7 minutes. To avoid decompression stops, divers were replaced after telescoping four sections. During this phase, the support boat was not moored.

DIVING TIME REQUIRED

Diving man-hours were logged for each phase of the operation to facilitate accurate estimation of further work of this type. The first phase, surveying and inserting base sections, was completed in 18 working days once the procedures and equipment were standardized. Total diving time for this phase was 81 hours and 27 minutes. Phase two, installation of telescoping sections, was performed in 4 working days with a total of 16 hours and 15 minutes of bottom time. Total diving man-hours required for the completion of the array, therefore, was 97 hours and 42 minutes.

OTHER APPLICATIONS

Several other applications of this principle have been successfully used at NEL and many more are in formula-tive stages (fig. 7).

Figure 7(A). Offshore radar target at San Clemente Island, California. Guy lines stabilize the stanchion in 30 feet of water and presence of strong wave action.

Figure 7 (Continued)

(B) Pipe sections used to anchor guys are equipped with circular plates to resist vertical and horizontal pull. "Deadmen" can be utilized in any depth workable by divers.

Figure 7. (Continued)

(C) Sonar target tethered to deadman, and hydrophone mounted on pipe similar to base sections of thermistor array. Similar installations off San Diego, California, have proved completely satisfactory.

(D) Time-lapse camera and photographic light mounted on jettied-in pipes. Projected installation will be used in studies of wave scouring associated with mines.

Tests of the resistance of these stanchions to various forces have been initiated and some results are available. The base sections used in the array have been subjected to preliminary tests adjacent to the NEL pier. A base pipe was jettied into the bottom and a pipe cap with a welded eye was screwed onto the threaded end so that a cable could be attached. A cable was run from this eye through a pulley fastened to a pier piling and up to a walking crane on the pier. Various degrees of upward pull on this cable were measured by a dynamometer placed between the cable and the hook on the crane. Simultaneously, the angular displacement of the pipe was measured by a diver (fig. 8).

Figure 8. Angular displacement of base pipe section subjected to horizontal stress.

Preliminary tests were also carried out on two deadmen jettied into the bottom in 60 feet of water adjacent to the vertical array. A vertical strain was taken by a winch aboard a modified landing craft (LCU 45) and the dynamometer was once again placed in the system to measure the force necessary to pull the deadmen from the sediment. Because of surface wave action it was difficult to maintain a steady strain, and the deadmen were worked back and forth in the bottom. The force required to wrench each deadman from the bottom was approximately 2250 pounds. During most of this operation, the ship was anchored to these pipes. Since this vessel was in excess of 100 tons, it has been speculated that larger, more sophisticated deadmen could be used for permanent moorings for large vessels.

Further tests are planned using more powerful pumps to facilitate deeper penetration of the deadmen and greatly increase their anchoring capabilities. Also under consideration is the use of high-pressure air as the power source. If feasible, this would eliminate the water pump, hose, signal line, and also the tedious task of mooring the support vessel over the work area.

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