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INSTRUMENTS ON A FIXED OCEANOGRAPHIC PLATFORM

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ABSTRACT

The U. S. Navy Electronics Laboratory Oceanographic Research Tower was constructed 6 years ago to conduct oceanographic studies in shallow water. During its operation over these years the tower has undergone modifications and additions. New equipment, new studies, and new techniques have been developed. These include studies and equipment used in the general fields of water motion, acoustics, electromagnetics, chemistry, biology and geology. Four systems for the measurement of thermal structure of the sea (vertical array, vertical logged array, horizontal array and isotherm followers) are discussed in detail.

INTRODUCTION

In recent years the technical requirements for fundamental and applied research in the sea have been increasing faster than present capacities can meet them. The result is that new technology is urgently sought and additional facilities are being developed. An example of a successful facility and its associated instruments for oceanographic research has been the U. S. Navy Electronics Laboratory (NEL) Oceanographic Research Tower (fig. 1), which was erected in 1959.[1] This tower is the first of its type to be designed and used specifically for shallow-water investigations. Through the use of this unique structure, a variety of studies have been made of the physical, biological, chemical, and geological features of the sea and their application to Naval problems. Modifications have been made to the tower and its instrumentation during the 6 years of its operation, and sufficient time has elapsed to establish the value of the facility and its use in making studies of the sea. This report presents descriptions of instruments and techniques used from this oceanographic facility.

OCEANOGRAPHIC TOWER ADVANTAGES

With the dearth of expensive oceanographic research vessels, it was believed that an economic solution to many oceanographic investigations could be resolved by a fixed platform in the sea, and, in fact, that some problems could be better solved by this means than from a surface ship. The advantages of a fixed platform would be stability, continuous measurements, economy, convenience and laboratory-like controls in a natural environment.

Stability A principal advantage is the tower's stability. A ship is constantly in motion due to the action of waves, wind and current, and it is frequently subjected to vibrations by these same elements or by its own power plant. The tower, on the other hand, is structurally rigid, firmly attached to the ocean bottom, and does not move. Instruments such as television cameras, motion-picture cameras, or sound transducers may be stabilized in depth and orientation, which is necessary for their successful use in many underwater studies. Stability is required for most accurate acoustic studies, and also for the photographing of sea-surface and sea-floor changes by time-lapse movies or underwater television used in the study of biological populations.

Long Period Measurement An important advantage of a tower is that it permits long-period, uninterrupted measurements to be made readily and economically. Tower instruments may be suspended in the water or mounted on the structure and allowed to record continuously in the instrument house. This makes possible the recording of oceanographic variables for periods of weeks or months. The firm footing of the tower (its supporting pins are embedded 63 feet in the ocean floor) permits it to operate efficiently even when the sea is high.

Superior numbers refer to similarly-numbered references at the end of this paper.

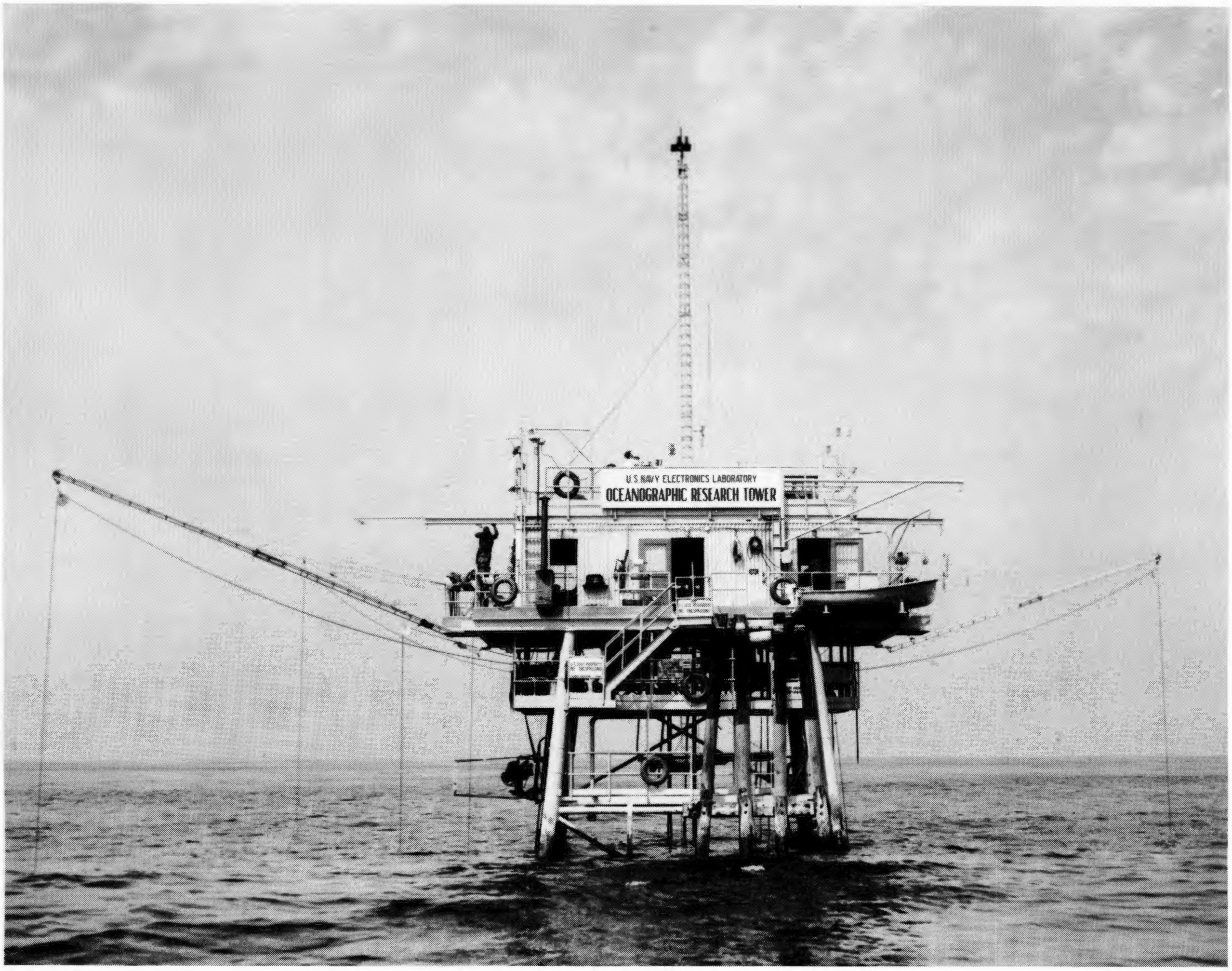

Fig. 1. U. S. Navy electronics laboratory oceanographic research tower.

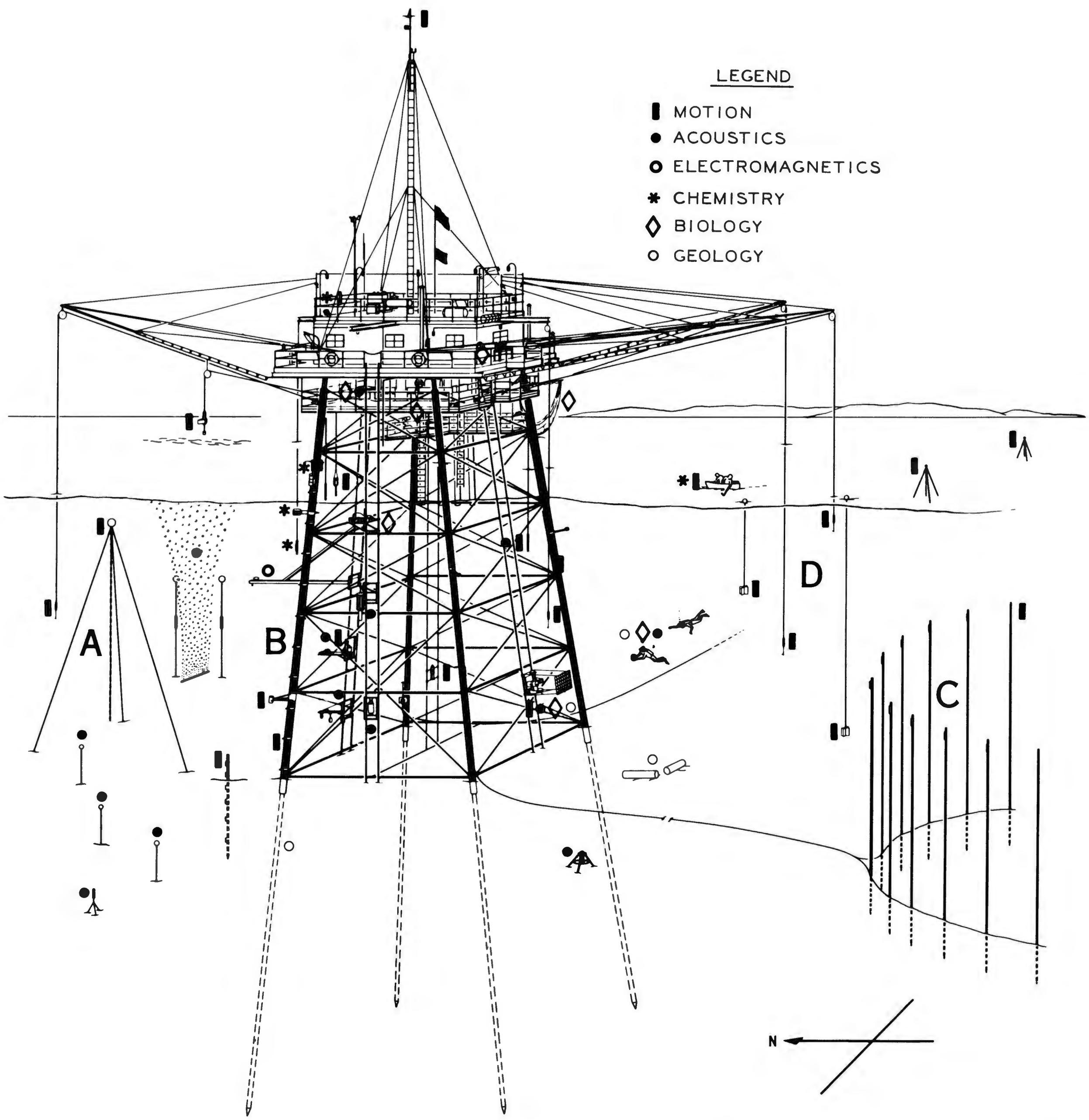

Fig. 2. Location of instruments (sensors) for various oceanographic studies. (A) Vertical temperature array; (B) vertical lagged array; (C) horizontal temperature array; (D) isotherm followers.

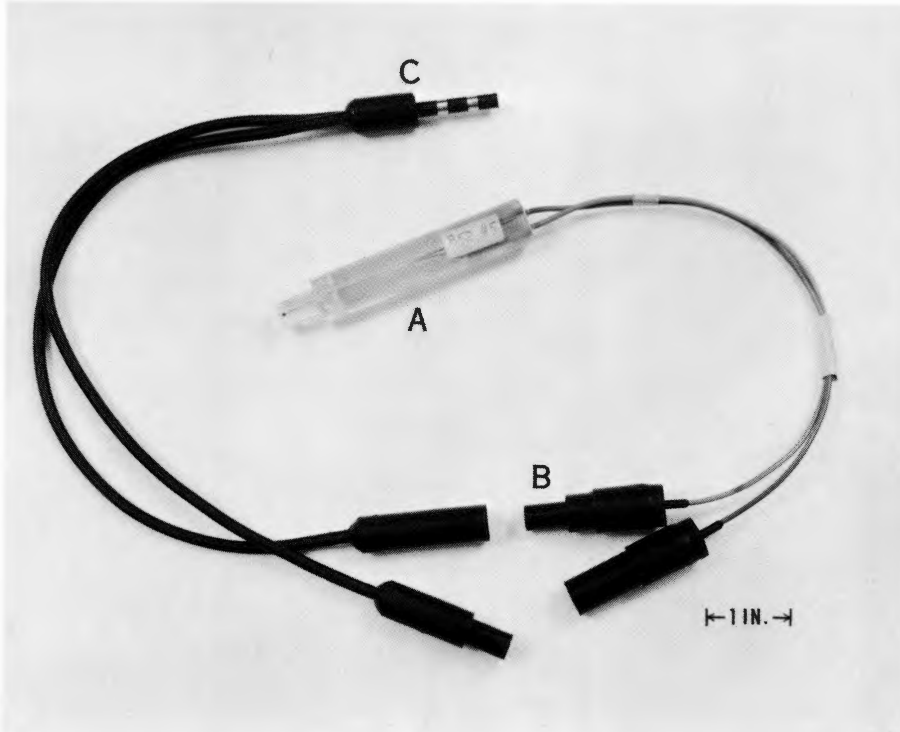

Fig. 3. Temperature sensor for vertical array. (A) Encapsulated thermistor; (B) connector; (C) underwater connector.

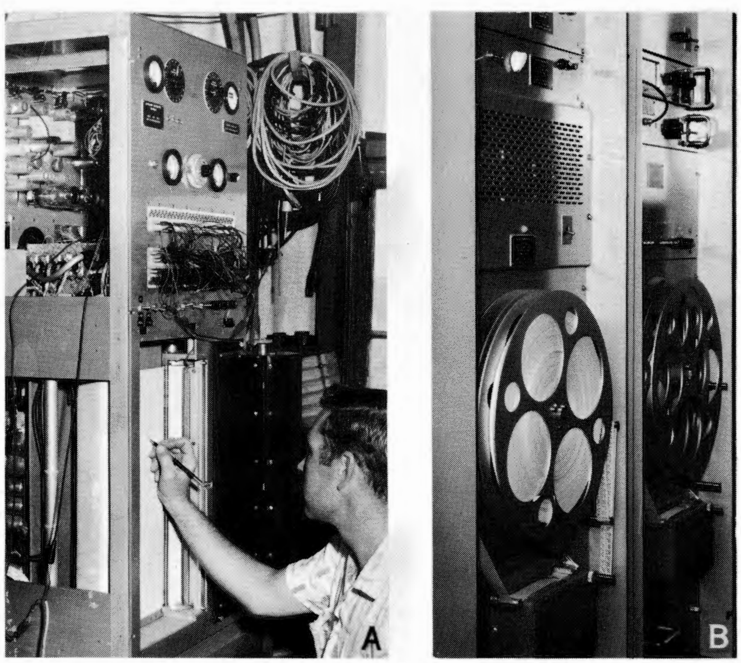

Fig. 4. Recorders for vertical and horizontal array. (A) Profiler; (B) digital.

Economy A further advantage of a tower is its economy of operation. The NEL tower, for example, can be operated for a number of studies by two or three technicians tending the recorders and maintaining instruments only periodically. Even when unattended, instruments can record many types of data for long periods.

Convenience Since the tower is located near the shore, personnel can "go-to-sea" in a matter of minutes, and the facility is available 24 hours a day. The time required to drive by car from any part of NEL to the Quivera Basin Landing in Mission Bay is 15 minutes. From there a 36-foot personnel boat makes the 14-minute run to the tower. Thus the sea operating area is only 30 minutes away, and a newly completed instrument may be tested quickly, or an urgent study conducted, without time-consuming travel to the operating area.

Laboratory Conditions Laboratory-like control of experiments, difficult or impossible on a ship, is an important advantage for certain oceanographic studies. Measuring devices or transducers can be held immobile at short distances from the tower by mounting them on diver-placed supports that have been jetted into the bottom. Cables can be laid from the tower to these instruments without risk of snapping the cable in bad weather. Electrical power is supplied from shore rather than motor generators, and municipal electrical power is stable in voltage and frequency. Thirty kilowatts are available at 440, 220, 110 volts AC and also 110 volts DC. In addition the tower is acoustically quiet and thus suitable for various sound studies.

TOWER LIMITATIONS

A limitation of the tower is its immobility, which renders it unadaptable to geographic oceanography, but additional area coverage can be obtained by the use of booms and the installation of sensors at relatively short distances from the structure. Another limitation is that it is restricted to relatively shallow water. These restrictions, however, have still allowed a wide variety of oceanographic investigations to be conducted from the tower.

LOCATION AND DESIGN

Location The location chosen for the tower installation is about one mile off Mission Beach, California, which is the closest site to NEL that can provide the necessary requirement of open sea conditions uninfluenced by man-made structures. The depth of water chosen was 60 feet, which represented a compromise between the maximum desired depth and the cost of installation. The sea floor at the tower site is a sandy, gradually sloping shelf devoid of rock and kelp. The surrounding area is free of commercial ship traffic, which makes it suitable for low noise level acoustic work and for undisturbed water motion measurements.

Design of Framework The tower is designed for a maximum of structural strength commensurate with the most natural marine environment possible. Four cylindrical pipe legs, 16 inches in diameter, support the framework. Long pipe pins, 12 3/4-inches in diameter, were driven through the four pipe legs to a depth of 63 feet below the sea floor. The welding of the inside pin to the four legs securely attached the framework to the sea floor. The instrument house and the main (cement) deck rest on top of this framework. The main deck of the tower is 22 by 38 feet and situated 27 feet above mean water level. The instrument house is 13 by 31 feet. The strong, flat roof of the instrument house, which is used for many studies, supports the electrical power transformers, meteorological instruments, air compressor, and a 40-foot vertical mast. Eight feet below the main cement deck is an expanded steel catwalk, around the four sides, for handling equipment. The main deck holds winches, electrical control boxes, storage bins, an aquarium, and racks for equipment used to collect live organisms.

TOWER CHARACTERISTICS

The instrument house consists of three rooms. The main room contains recorders, instrument racks, TV monitor, communication equipment and work benches.

Two guide cables extend up from the sea floor through a trap door in the main room. The cables provide known orientation and prevent swinging of suspended instruments. The north room houses the main recorders and electronic facility. The south room is for living and office functions.

TYPES OF STUDIES

To show the versatility of the tower, the various types of studies, and the

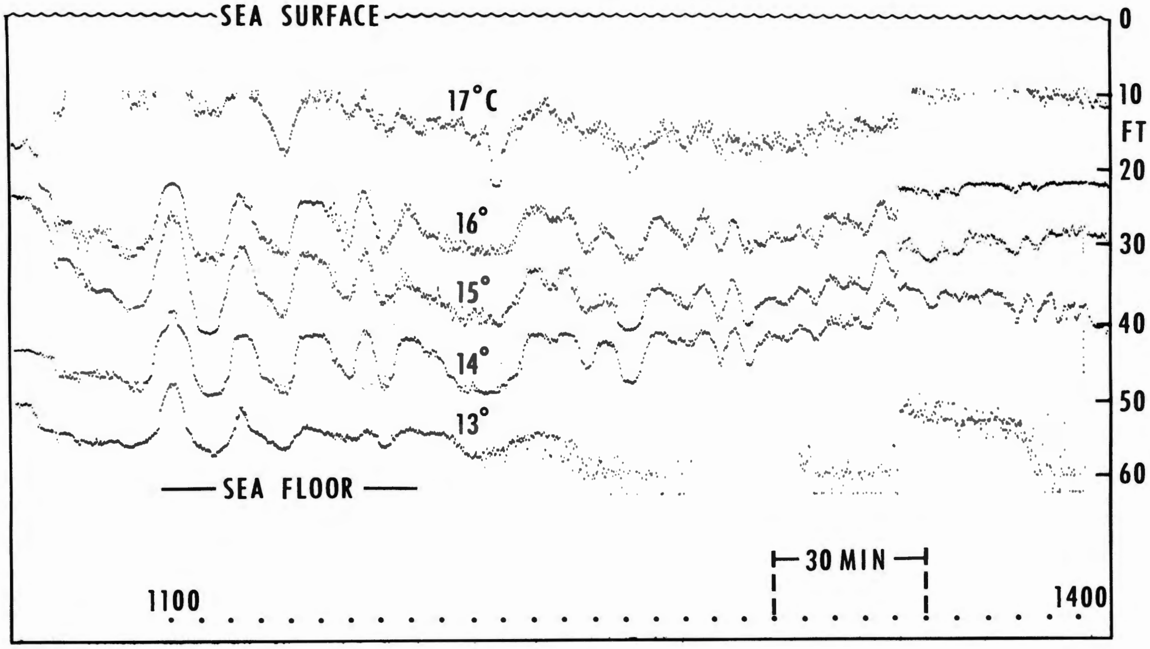

Fig. 5. Example of data from vertical array.

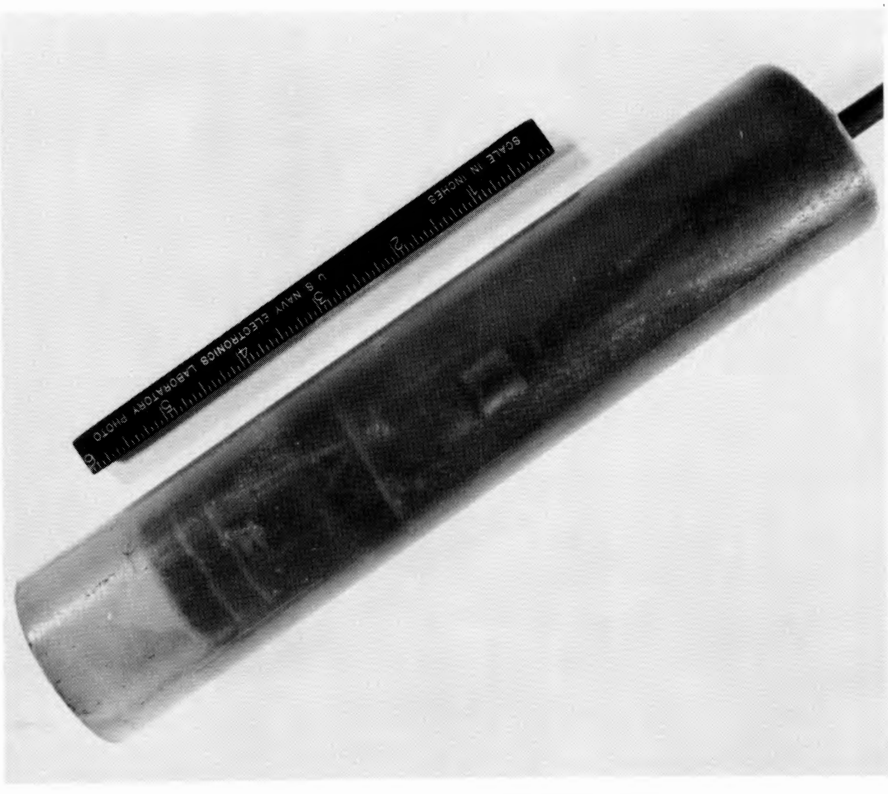

Fig. 6. Temperature sensor for vertical lagged array.

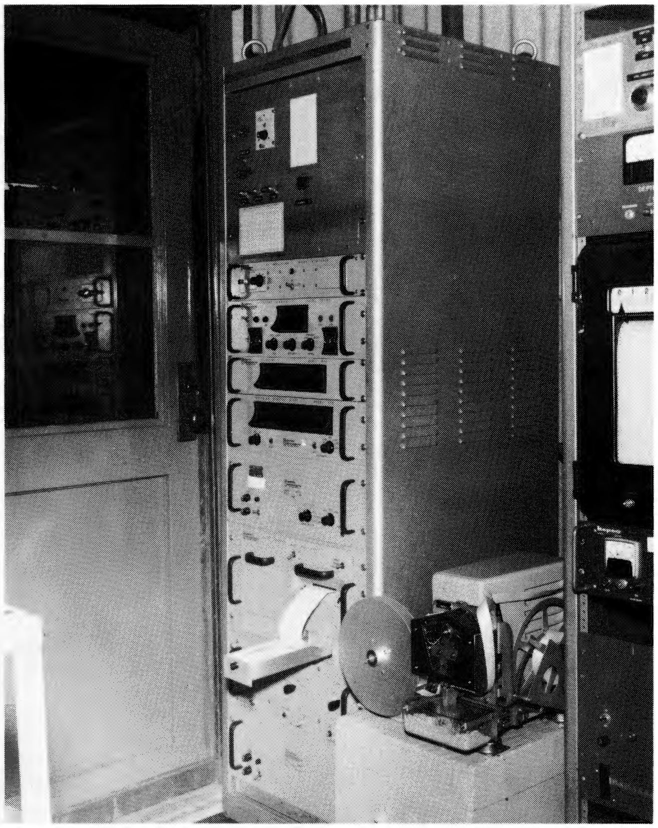

Fig. 7. Recorder for vertical lagged array.

Fig. 8. Model of horizontal temperature array.

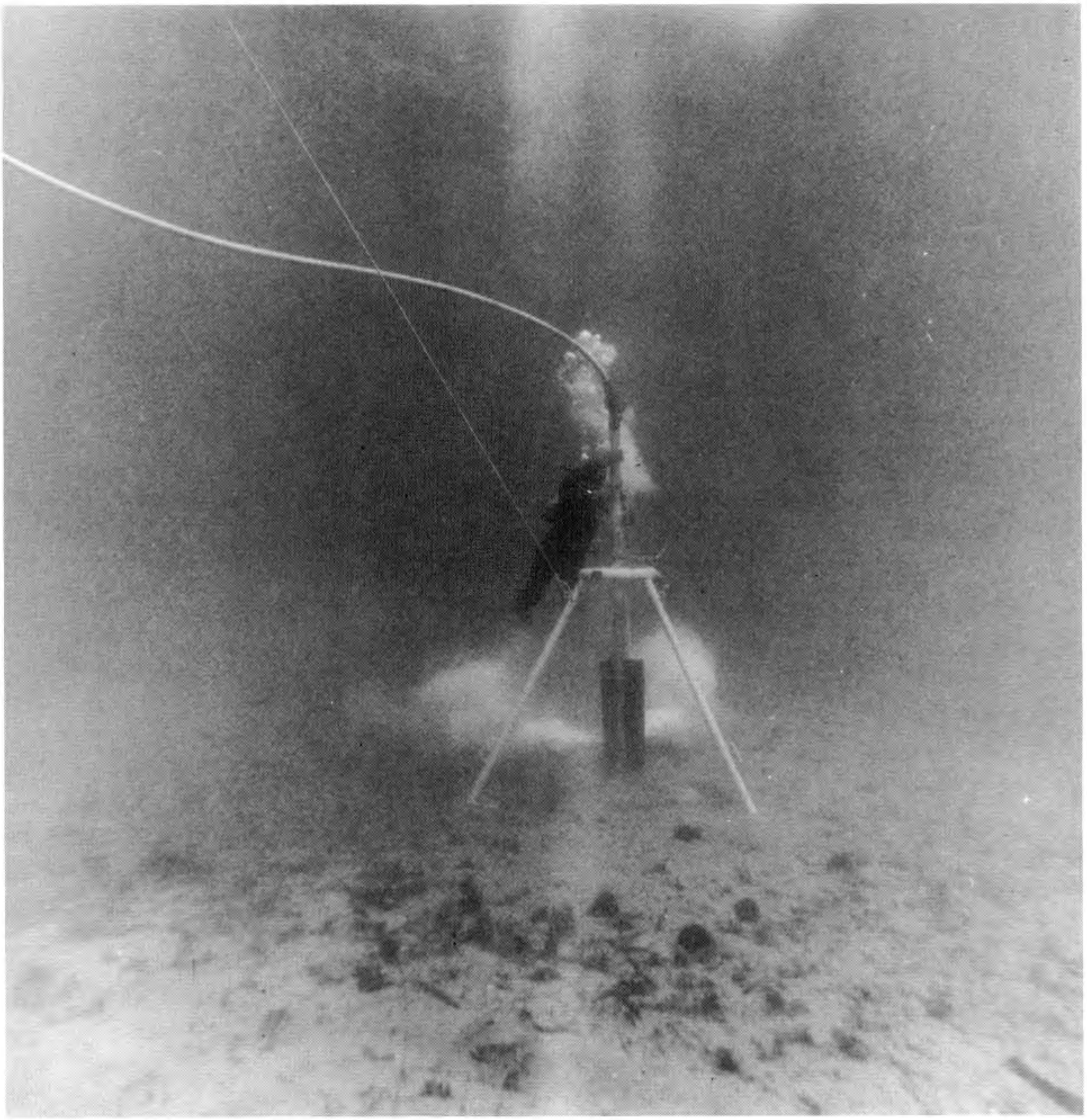

Fig. 9. Method of installation of vertical masts for horizontal temperature array.

instruments used, are tabulated below. The location of the instruments on the tower and their positions are shown in figure 2. In some studies several types of instruments, and different approaches are employed:

Studies	Instruments (Sensors)
Water Motion	Drogues suspended at various levels
	Current Meters on taut wires
	Current Meter suspended from boom
	TV with streamers
	TV with dye
	Convex mirror and camera on mast
	Temperature Sensors
Acoustics	Transducers on tower track
	Transducers on sea floor mounts
	Bubble Screens from sea floor
	Diver-held sonar
	Acoustic targets
Electromagnetics	VLF underwater antenna
Chemistry	Water sampling bottles to various depths
	Radioactive Sensors on tower legs
	Foam equipment on upper deck
Biology	Submersible pump on track
	Nets suspended in water and used with pump
	Hydrophotometer on track
	Plankton filtering equipment on main deck
	Closed-circuit TV
Geology	Visual observation and sampling by Soucoupe
	Burial of objects placed on sea floor
	Time-lapse photography system on sea floor

INSTRUMENTS FOR THERMAL STRUCTURE

The temperature structure of the ocean around the tower is studied because it provides information on the dynamic processes going on in the sea. Detailed data on thermal structure is required for the study of small internal waves and their influence on the transmission of high frequency sound.

VERTICAL (TEMPERATURE) ARRAY

For internal wave studies vertical strings of cable-connected thermistor beads have been floated from surface buoys, with the temperature recorded on the tower. More recently the sensors have been suspended at two-foot intervals, in a vertical array, by a taut-wire buoy system with the buoy submerged just below the surface (A in fig. 2). This arrangement permits temperature to be recorded with reference to the bottom rather than from the surface. More detail near the bottom is provided and the depth of sampling is less influenced by surface action.

The sensors used in the vertical temperature array are encapsulated thermistors (fig. 3). Since temperature oscillations with periods less than 30 seconds are not required in this study, the sensors are time-lagged to 30 seconds. The thermal lagging is accomplished by encapsulating with the following material:

Encapsulating (lagging) Material	
Epocast 202 (Furane Plastics)	10 parts
951 Hardner (Furane Plastics)	1 part
LP-33 (Thiokal)	7 parts

The thermistor bead with the electrical wires attached are placed in a lucite cylinder and the encapsulating liquid materials allowed to harden. The exact thermal lagging is

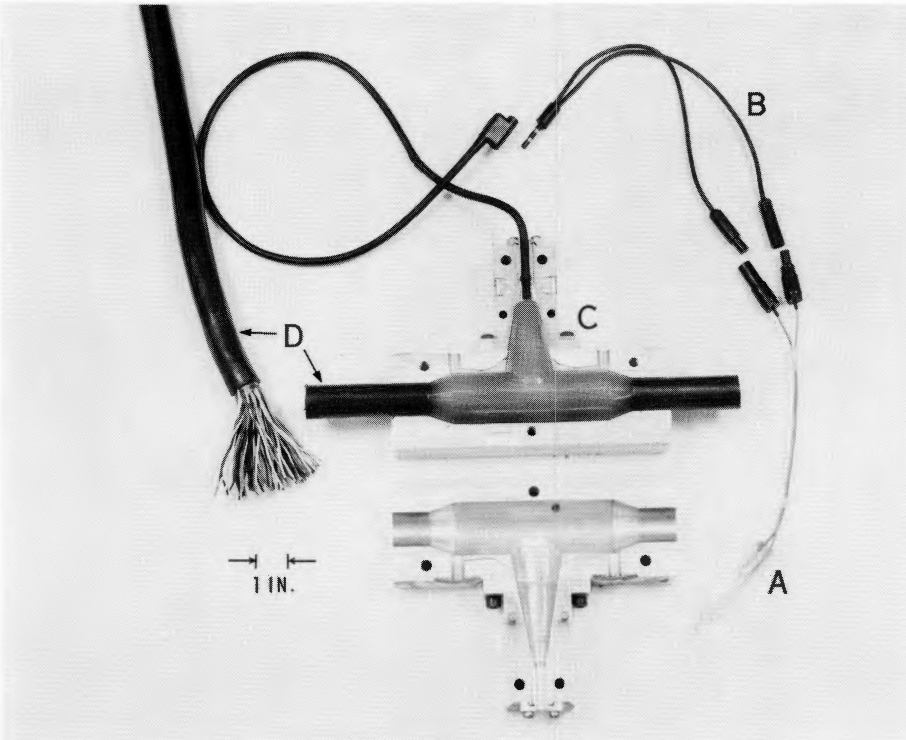

Fig. 10. Connectors for horizontal temperature array. (A) Encapsulated thermistor; (B) 35-foot leads; (C) mould; (D) trunk cable.

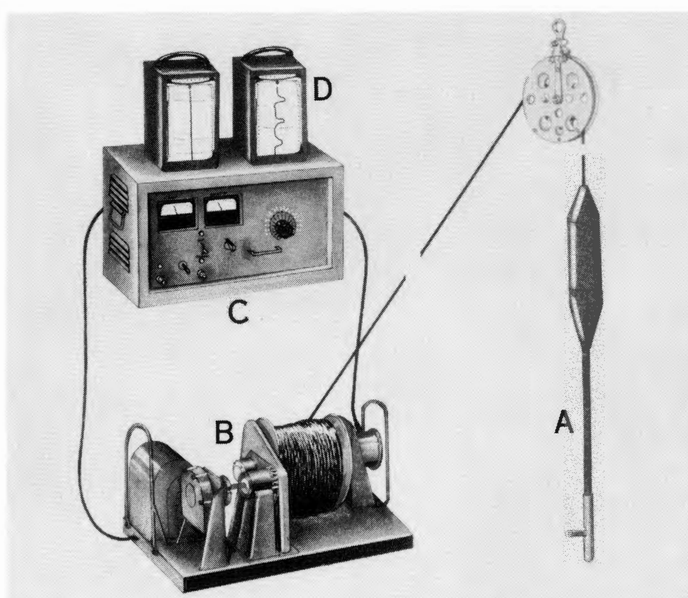

Fig. 11. Isotherm follower. (A) Sea-sensing unit; (B) winch; (C) electronics; (D) recorders.

accomplished by precisely trimming the thickness of material at the bead end of the casting.

The external electrical wires are attached to Electro Oceanic connectors type EO-300 (fig. 3B), which in turn lead to an underwater connector type EO-500 (fig. 3C). The mating half of the underwater connector is attached to the main cable which in turn leads into the instrument house. The EO-300 connector was chosen to permit the thermistors to be used interchangeably with the NEL thermistor chain sensors. The underwater connector is necessary to permit any given sensor to be disconnected and replaced by SCUBA divers. The present vertical array consists of 31 sensors. These all lead into the tower instrument house where temperatures are recorded in both analog and digital form.

The analog recorder (fig. 4A) sequentially samples and interpolates the output of the thermistor beads. The recorder prints the temperature data on 19-inch-wide electrosensitive paper in the form of a time-depth profile of isotherms.[2] An example of the data is given in figure 5. Here the horizontal scale is time, the vertical scale is depth, with reference to the sea floor, and the recordings are one degree (Centigrade) isotherms. Clearly shown is the nature of internal waves at the tower site during early spring.

The temperature data from the 31 beads can also be programmed, to be recorded on punch tape for convenience in machine analysis.

VERTICAL LAGGED (TEMPERATURE) ARRAY

In addition to short period (7-15 minute) internal waves, it is also necessary to study long period cycles in the thermal structure. This is accomplished by thermistors permanently fixed to the tower and lagged with longer time constants. The thermistors are mounted along the northwest leg of the tower and are held out from the leg by a protective bracket. The beads are spaced every 6 feet throughout the water column, and are used for long-term tidal, diurnal, and seasonal studies.

The thermistor beads are thermally lagged by potting in Polyurethene about 2 inches thick. (See fig. 6). The response time is adjusted to 20 minutes. The beads are moulded to an electrical cable that runs up the tower leg to a recorder in the instrument house, where temperature information is numerically printed as well as punched on paper tape for machine analysis (fig. 7). The data recording system is programmed to sample each bead once every 10 minutes.

HORIZONTAL (TEMPERATURE) ARRAY

Data on the horizontal thermal structure in two dimensions are needed to study the coherence and structure of internal waves as they propagate in a shoreward direction. Coherence studies are made possible by the installation near the tower of 48 thermistor sensors arranged in a circle 444 feet in diameter and 30 feet above the sea floor (C in fig. 2). The sensors are installed at the top of vertical masts jetted into the sea floor (fig. 9). The array is placed 700 feet southwest of the tower in order to avoid any possibility of unnatural influence which the tower might have on the thermal structure (fig. 8). The horizontal array of sensors at mid-depth detects changes in temperature as the internal wave passes the array. The first sensor activated indicates, by its position in the array, the direction from which the internal wave is approaching. From the subsequent space and time-temperature changes in other sensors, it is possible to obtain in detail the speed, direction, refraction and coherence of the internal waves. Normally, acoustic transmission studies are conducted at the same time, in order to establish the dependence of acoustic transmission on internal waves. The sensors in this horizontal array are the same as those used on the vertical array (fig. 10A). However, the electrical wires from the sensor to the underwater connector are 35 feet long (fig. 10B) so that they can extend to the top of the vertical masts (fig. 9). The end of the lead from the underwater connector is moulded (fig. 10C) into the multiple-conductor trunk cable (fig. 10D), which then leads 700 feet to the tower. The main trunk cable is internally pressurized with nitrogen at the tower terminal end. The pressure used is 35 pounds per square inch in order to overbalance the water pressure by 5 psi and thus avoid leakage.

Both analog and digital data are recorded from the horizontal array. Here the analog presentation is in the form of a time-horizontal space display of isotherms. Since the sensors are in a circle it is possible to establish direction, speed, and coherence of internal waves in a given plane at mid-depth.

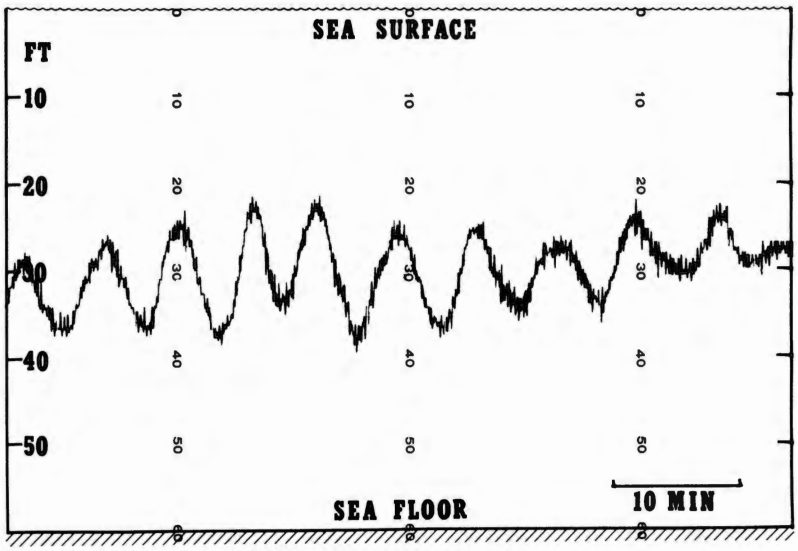

Fig. 12. Example of data from isotherm follower.

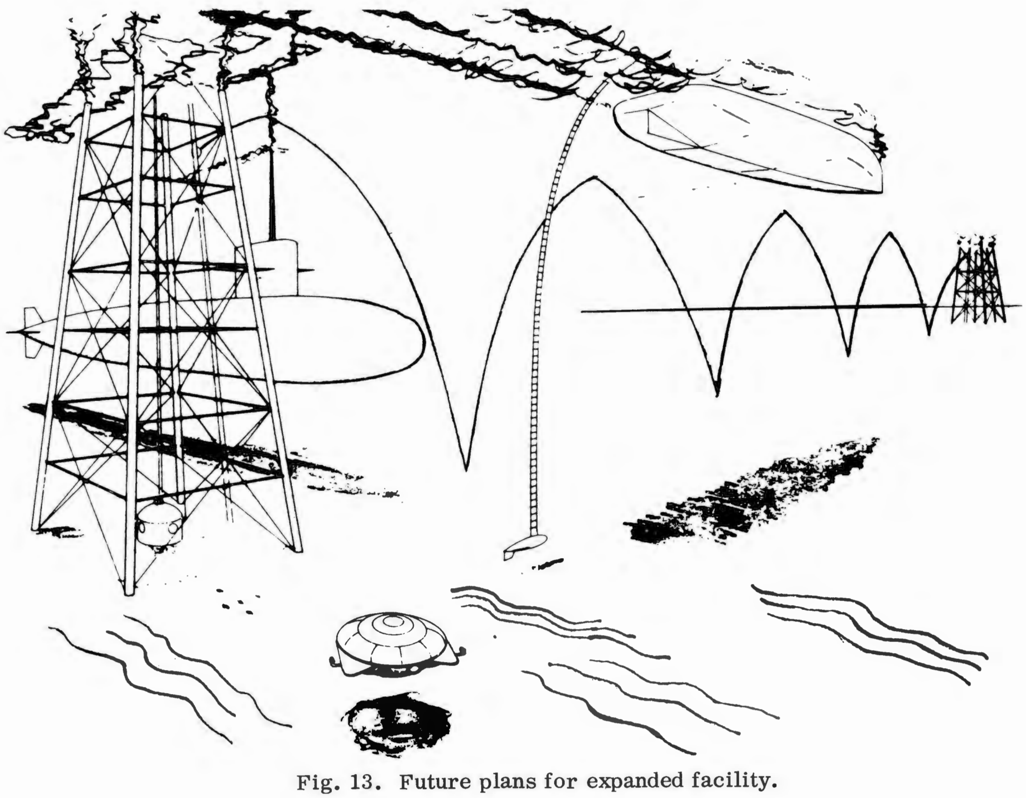
Fig. 13. Future plans for expanded facility.

The installation of the vertical masts, the electrical cables, and sensors for this array involved much SCUBA diving. For efficient operation and testing, it was necessary to develop an underwater communication system between divers, and between divers and tower personnel. Currently there are 91 thermistors, in various equipments, which require checking and maintenance. When leakage problems develop, the thermistors must be checked by divers. Prior to the development of a communication system, a diver had no way of knowing he had successfully corrected a defect until he had returned to the surface. The present communication system permits a diver to connect into the main cable at any thermistor station and, while working on a faulty station, receive instructions from personnel on the tower who are monitoring the defective circuit. This underwater communication system, called "TOWERCOM," has speeded up repair and maintenance of the underwater network of sensors.

ISOTHERM FOLLOWERS

For the measurement of the shape and depth of isotherms, which is needed in internal-wave motion and related acoustic studies, an instrument called an ISOTHERM FOLLOWER was developed at NEL to automatically measure the depth of a given isotherm.[3] The isotherm follower consists of 4 parts (fig. 11): A, the sea-sensing unit; B, the electric winch (containing a cable to which the sea-sensing unit is attached); C, an electronic unit (containing power supply, servo-mechanisms, and amplifiers, etc.); and D, the temperature-depth recorders. The temperature sensor in the sea unit is part of a bridge circuit. The output of the bridge circuit drives a servo system which in turn causes the winch to raise or lower the temperature-sensing unit as the depth of the isotherm changes. The depth of the given temperature is recorded with reference to time on the tower (fig. 12). By suspending isotherm followers from booms extending out 40 to 50 feet in length from three corners of the tower, and simultaneously recording the same isotherm, it has been possible to establish internal wave heights and shapes as well as speeds and directions of propagation near the tower.

SUMMARY AND DISCUSSION

The NEL Oceanographic Research Tower has proved extremely valuable in conducting many types of oceanographic investigations. The wide variety of studies and the diversity of equipment have shown the unique nature of the facility. The temperature structure of the sea, as measured by four different systems, has been subjected to extended study, and future plans call for several new systems. Among these are vertical, taut-line arrays deployed in the direction of propagation of internal waves to study their behavior with changing depths. Other systems call for a semicircular and checkerboard array to acquire data on three-dimensional thermal structures.

Projected plans also call for a larger oceanographic tower, in deeper water, to be used in conjunction with the present one for acoustic transmission between two towers throughout the year (fig. 13). The projected deeper water installation would have the advantage of operating with surface and subsurface vehicles. In addition it would be possible to follow the thermocline through a greater period of the year. Still other plans and studies will evolve as an understanding of the environment expands and instrumentation techniques develop.

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