TIDAL CURRENTS SURVEY — NEW FIELD TECHNIQUES

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Note on author. — Lieutenant WESTBROOK was graduated from Worcester Polytechnic Institute in 1953 with a B.S. in Civil Engineering, and the same year was commissioned in the U.S. Coast & Geodetic Survey.

During his nine years in the C&GS, Lieutenant WESTBROOK has seen service aboard six ships engaged in hydrographic and tidal current surveys along the Atlantic Coast of the U.S., Alaska and Puerto Rico.

Shore-duty tours include steel tower triangulation and gravimetric surveys in the interior of the U.S., and duty with the U.S. Navy as an instructor at the U.S. Naval Amphibious School, Norfolk, Virginia.

Material for this article was gathered in 1959 when Lieutenant WESTBROOK was Executive Officer aboard the USC&GS Ship *Marmer*. The *Marmer* was engaged in making an extensive tidal current survey of New York Harbor.

INTRODUCTION

Much too often, experience gained by field personnel is lost to others, generally due to a lack of written records concerning small but important details. In many instances, there is necessarily a lack of sufficient personnel overlap in assignments to provide continuity with respect to experience. New personnel must carry on the same type of work on new projects, and should, if at all possible, reap the benefits which come with a knowledge of previous techniques used. In the following article it is the author's intent to help provide that knowledge.

In 1958, the U.S. Coast & Geodetic Survey Ship *Marmer* began a current survey in New York Harbor that was to last two years. During that time, it was to become one of the most extensive and complete surveys of that type ever attempted in an area by one vessel. In addition, the project was completed in a minimum of time, with exceptional accuracy, few break-downs, and very little loss of equipment. Much of the credit for the success of the survey goes to the *Marmer's* Commanding Officers, Cdr. Philip A. WEBER (1958) and Cdr. Raymond M. STONE (1959), who both worked tirelessly to perfect many of the new techniques that will be mentioned.

The figures for lost equipment are surprisingly small, as New York Harbor is one of the busiest in the world. Many current buoys were placed in locations exposed to all sizes and types of shipping. Why more equipment was not lost or damaged may have been due partially to good fortune, but proper rigging, inspection on station, and rapid completion of each series no doubt insured the project's success. The dissemination of station locations to all interested parties, along with the excellent seamanship on the part of New York skippers, pilots, and tug boat men, were major contributing factors in the prevention of losses.

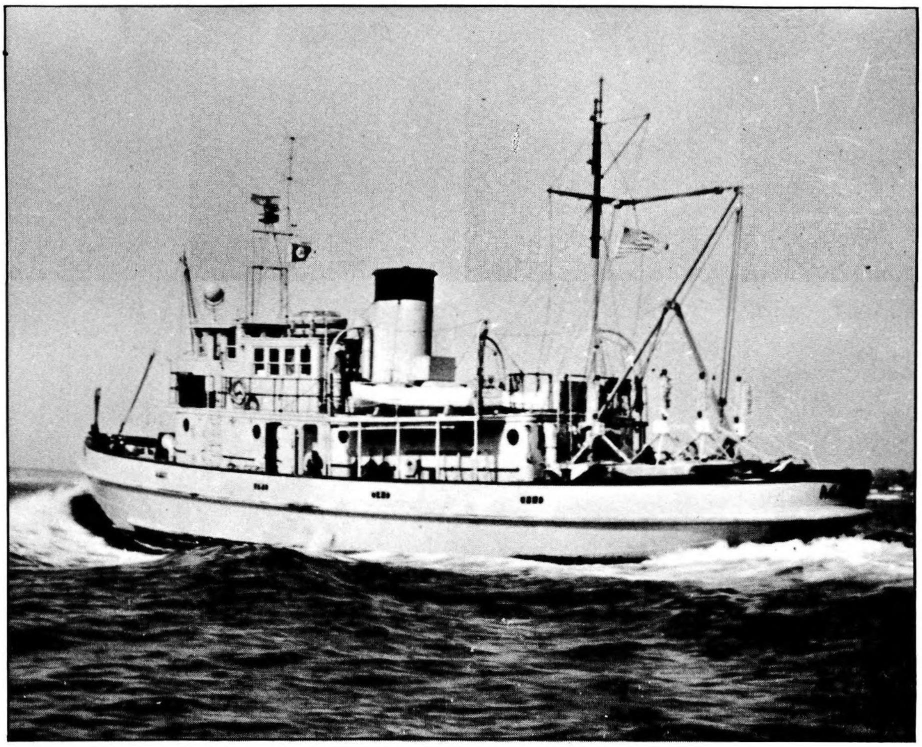

FIG. 1. — USC & GS Ship *Marmer*.

SCOPE

In the article that follows, some of the changes that have come about recently in current surveying employing Roberts Radio Current Meters will be pointed out. Techniques involved in the configuration of current buoys and buoy anchor and meter suspension systems, the planting of buoys by ship or launch, the keying, receiving, and recording of data, and the processing of records are included here.

While there may be numerous differences between methods and equipment as discussed in this article and those in C&GS Special Publication No. 215, Manual of Current Observations, and in the Roberts Radio Current Meter Mod. II Operating Manual, it is not the author's intention to supersede material in those publications; only to augment them and add some new developments.

CONFIGURATION OF CURRENT BUOYS

Current buoys used on the New York Harbor survey were of the standard 120-inch type with certain modifications. A completely new superstructure was designed to handle a flashing light system of greater range, a stainless steel whip antenna, and a Swedish type radar reflector. Fig. 2 shows a new type buoy on station.

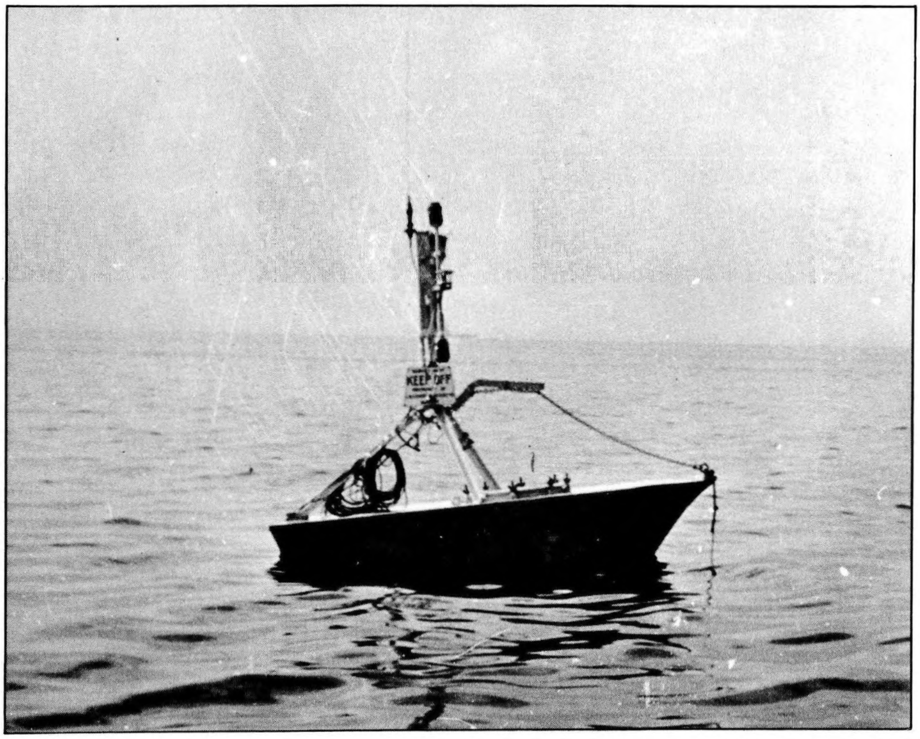

FIG. 2. — Current buoy on station.

Each buoy (the *Marmer* carried four) was painted overall with yellow chromate rust preventive paint. Superstructures were spray painted with international orange fluorescent paint, and the four corners of each buoy were given a coat of red fluorescent paint.

The resulting combination of paint and lights was so striking that a buoy could hardly be overlooked by an approaching ship by day or night. For periods of poor visibility or fog, the radar reflector proved to be quite efficient in providing a bright blip on a radar screen when approaching from any direction. In this manner, the buoys were well protected from collision under all conditions.

BUOY ANCHOR AND METER SUSPENSION SYSTEMS

Seventy-five-pound Danforth anchors were used to hold each buoy on station. They were found to be heavy enough to hold in strong currents, but if a buoy was struck by a passing vessel, it was found that the anchor would drag before the cable became strained enough to part. A number of buoys were saved in this way.

A thirty-foot length of galvanized chain was used next to the anchor in every case to provide additional weight on the bottom, and help prevent kinking and chafing of the cable. The remainder of the cable was made up of $\frac{1}{4}$-inch wire rope of sufficient length for a scope of approximately three to one. It is helpful to have 25 and 50 foot lengths of cable made up in advance so that the appropriate lengths can be bent together quickly while rigging buoys.

Since Modified Model II Roberts Radio Current Meters were used on the 1958-1959 project, new hangers were devised to provide for the larger dimensions of the meter fins and impellers. With the length of the hanger plus swivels known, the lengths of wire rope required for proper suspension of meters at various depths can easily be calculated. This is done for the convenience of the deck force.

A fifteen-pound lead fish weight shackled to the bottom hanger provided stability and helped maintain the meters at the desired depth.

Hoisting the meter system for inspection and maintenance after the buoy was on station was accomplished by using a length of knotted tiller rope of the type used for lead lines. One end of this line was secured to the top of the swivel on the first hanger; the other end was brought up and attached to the buoy superstructure.

Instead of securing it directly to the ring in the buoy's keel, the meter suspension cable was secured to the after leg of the superstructure tripod. When making up the cable, this additional distance must be provided for.

An additional length of cable was used to draw up the suspension cable to the buoy's keel ring. This cable prevented chafing and held the suspension cable close to the keel ring, but it facilitated the raising of meters for inspection on station.

To prevent fouling of anchor cable with the meter suspension cable, a method was devised which worked quite well. A preventer cable was attached between the bull nose ring of the buoy and the free end of the yoke. Its length was such that the yoke, hanging free, could lead at any angle forward of 30° from the vertical. The yoke thus was prevented from leading any further aft, keeping the anchor cable at a safe distance from the meters.

After the buoys were rigged, a responsible person checked the meter suspension for correct lengths and proper rigging, with close attention to swivels.

The following data was recorded for each station : buoy number, meter depths, frequency used, meter numbers, sequence switch number, and length of anchor cable.

Fig. 3 shows a typical buoy with meters on station.

PLANTING OF BUOY BY SHIP OR LAUNCH

Planting by ship

While the first buoy was being checked out, the ship steamed toward the location of the first station.

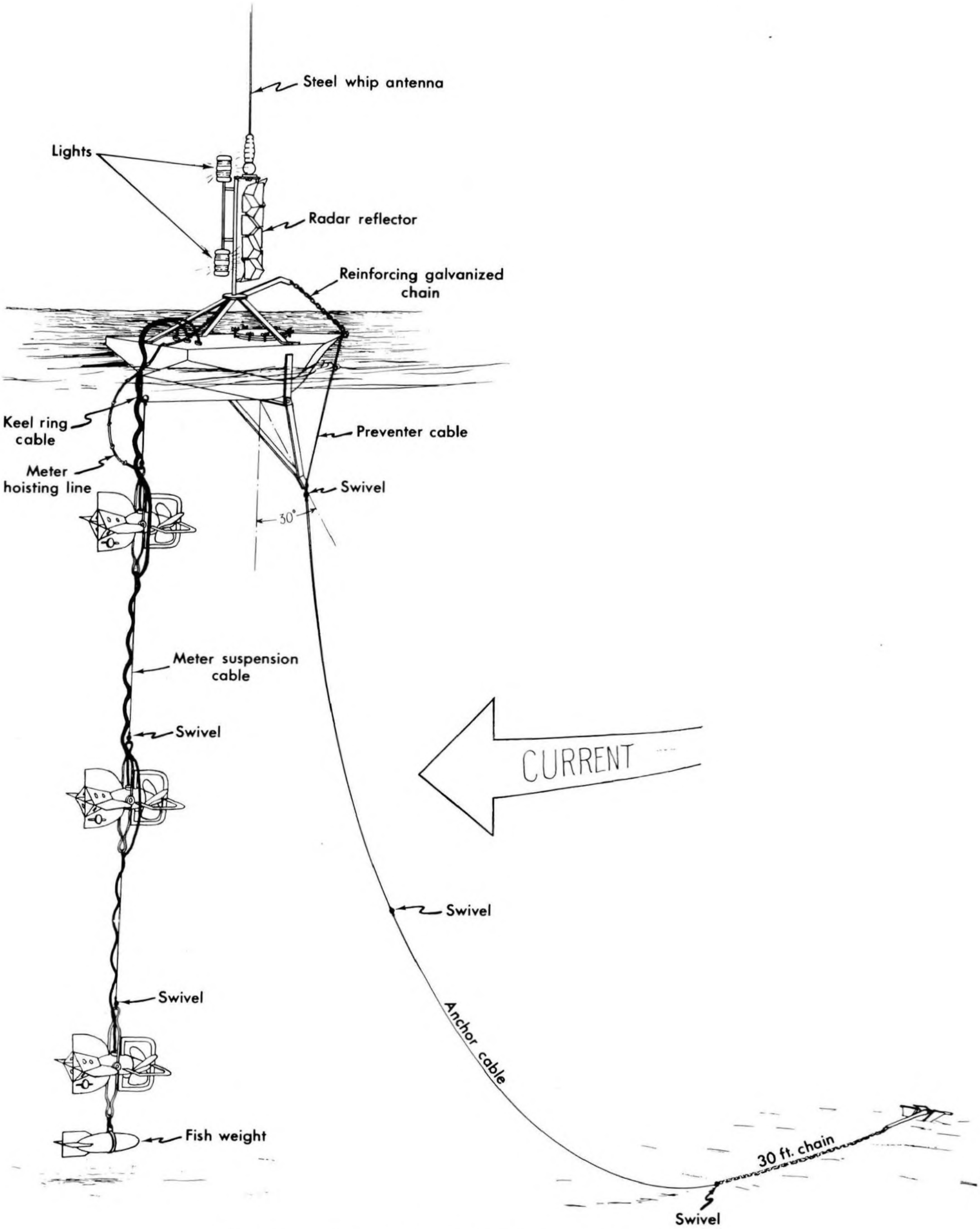

FIG. 3. — Typical buoy with meters on station.

Suitable landmarks that appear on the chart of the area were chosen for a strong sextant fix and check angle at the station. When the ship reached the station area, and if plenty of manœuvring room was available, a few trial fixes were taken, and cross ranges sighted which would place the ship over the desired spot when the buoy was planted.

As soon as the buoy and meters were checked out, the bridge was signalled. The ship was then stopped dead about one-quarter of a mile from the station, and approximately on-range with the two objects to be sighted on when towing the buoys into position.

With the buoy at the rail, the meters were placed in the water. To lower the meters quickly, a minimum of four men were required. The procedure was as follows :

Long lengths of 1-inch manila line (approx. 25-30 feet each) were reeved through the tops of each hanger in the suspension, and were used to lower each meter separately and gently. One man raised the bottom meter and fish weight and carefully lowered them over the side. The man tending the line on that hanger took up the strain, and lowered slowly, keeping the meter away from the ship's side. A pause was made at or near the surface of the water for the tail to fill with water, and a check was made to see that it was balanced horizontally. As the slack between meters was let out, the first man picked up the middle meter and lowered it in turn over the side. The line tender on this meter took up the strain on both middle and bottom meters. The first line then was unreeved and hauled aboard. The same process was followed in lowering all three meters.

After the meters were lowered, the meter hoisting line and the keel ring cable were both secured to the centre of the superstructure tripod with spring clips to take up the slack in each.

Next, the short strap holding the yoke close to the bow of the buoy was unsnapped, and the yoke lowered gently by holding a strain on the buoy's anchor cable. The buoy then was lowered into the water, the lowering hook brought aboard, and the buoy fended astern of the ship with boathooks. After the buoy cleared the region of the screw, the bridge was notified, and the run to the station was begun, while towing the buoy at slow speed. While the ship was in the process of towing, men on deck let out the anchor cable slowly until most of the cable and chain were in the water. The anchor itself was held over the side by means of a pelican hook which was let go as soon as the correct anchor position was reached.

When the ship crossed the range, and the anchor was dropped, a sextant fix and quick check angle were taken and recorded, the time noted, and the fix plotted. The buoy had been planted with a minimum of guesswork, and right on station.

An activating signal was sent immediately after the buoy settled down as a further check on the working condition of the equipment. If the tape appeared good, it was saved, and the series (usually 100 continuous hours) was begun. If the meters seemed to be working properly, the ship steamed toward the next station location, and the buoy or buoys already planted were keyed at their appropriate times every half hour.

On deck, the checking out process began all over again, and, on the bridge, landmarks were chosen for a new fix as the next station was approached.

The planting process is complicated and tiresome. However, if each man knows his job, and does it with care at the right time, great speed and efficiency are possible. Normal planting time for four buoys with three meters each on the *Marmer* was about four or five hours, and sometimes less in exceptional instances.

Planting with launch

There are some buoy locations at which it is practically impossible to use the ship for planting due to shoal water or lack manœuvring room. At these locations it is preferable to use a launch. Let us now assume that one of our buoys was to be planted in this manner.

The launch used should be solidly constructed, and should have an open work-well or cockpit in the stern. It must have a flat transom with no part of the rudder above water. Speed is desirable, of course, but the other features mentioned are more important. For the *Marmer*'s launch, a woven rope fender was made to hang over the stern of the launch. This permitted the launch crew to tie up to the stern of the buoy for repairs or maintenance.

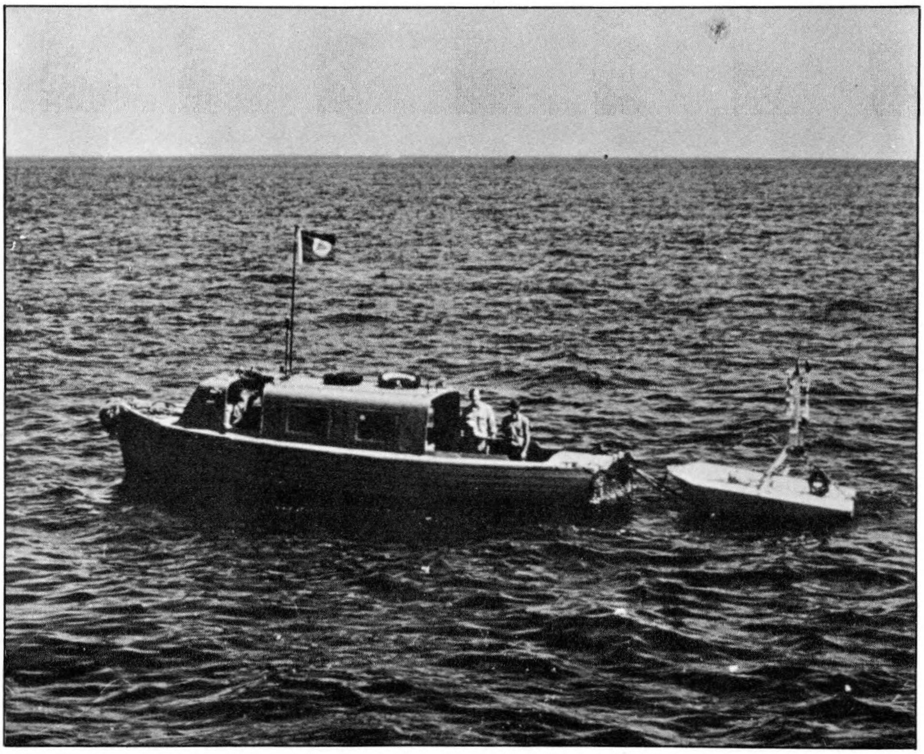

FIG. 4. — *Marmer's* launch and buoy.

Figure 4 shows the *Marmer*'s launch with a buoy in towing position. Note the square end of the launch, the open cockpit, and the fenders.

Following is the step-by-step procedure that was used in planting a buoy with the launch. The launch was brought alongside the ship, just forward of the position the buoy would take when lowered into the water. With the buoy at the rail, the buoy anchor and anchor cable were passed into the launch. The slack was taken in, and the cable temporarily secured to a cleat on the stern of the launch for towing.

In most cases, it was possible to rig the meters and fish weight on to the suspension cable aboard ship, and then the meters lowered. Then, when the buoy had been lowered into the water, the launch towed it on station. At times, however, there was a possibility that the meters or fish weight might drag on the bottom while being towed on station, and at such times, the buoy was planted in the following manner.

Before the buoy was lowered into the water, a check was made to see that the tirex cable glands had plastic bags fitted around them to keep out moisture. The meter suspension cable (without meters and fish weight) was then coiled and secured with marlin to the buoy superstructure (see fig. 5). The buoy yoke was placed in the down position for better towing.

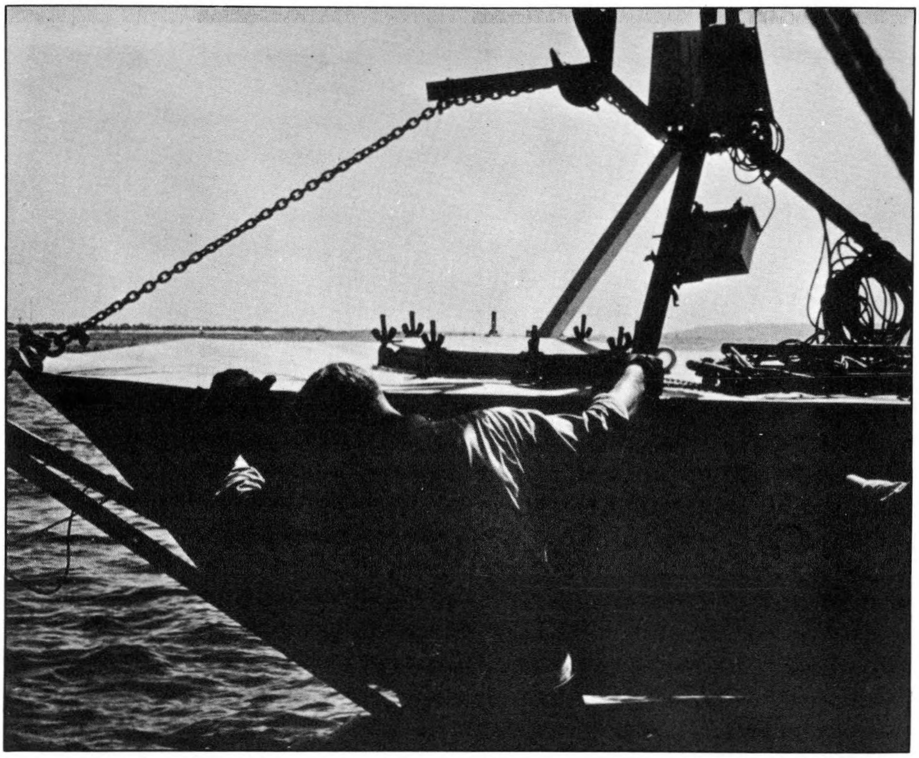

FIG. 5. — Current buoy lowered to the rail.

The fish weight, current meters, and the tools and equipment necessary to secure them to the suspension system were placed in the launch. Also necessary, as standard equipment, were two sextants, a chart showing the station location, and a three-arm protractor.

The launch crew consisted of the directing officer who observed one angle and plotted positions: another man who served as right angleman and lookout; a cockswain-engineer; an electronics technician; and two seamen.

After all necessary equipment was stowed, the crew boarded the launch, the buoy was lowered, and the launch got underway with the buoy in tow.

The buoy anchor was taken to the forward deck by one seaman who remained there to let go the anchor at the signalled time. The anchor chain was led along one side of the launch. The other seaman tended the chain and cable to see that they both cleared the launch without kinking when the anchor was dropped.

At this time, it might pay to mention the safety precautions used. Gloves were worn at all times while handling cable. Extreme care was constantly necessary that fingers did not become pinched throughout the entire planting operation, and that someone was not standing in a bight of chain or cable when planting took place. This type of work requires that safety be uppermost in the minds of all hands, not only for one's personal safety, but for the safety of others as well.

As the launch approached the station, it was normally brought on with a series of trial fixes, and the anchor dropped. However, when the current was strong, it generally proved best to get on station by trial fixes, select cross-ranges, and then make the run to the spot, paying out the cable on the approach, then signalling the seaman to drop the anchor when the cross-range was reached.

With the buoy planted, the launch was backed down to the stern of the buoy and secured. The securing line for this purpose was made up of a spring clip, a short section of flexible rubber, and a length of small manila line. The clip was secured to the buoy's after end, and the end of the manila secured to the launch's stern.

The meter suspension cable was then brought into the cockpit of the launch and the meters and fish weight were attached. The meters were tested and, if satisfactory, were put over the side. The meter hoisting line and keel ring cable then were secured in place to the superstructure tripod.

Before returning to the ship, the launch called on the radio to report that the buoy had been planted and was ready to be keyed. At the earliest opportunity, the ship keyed (activated) the buoy transmitter, and if the report returned from the ship that the meters were operating properly, the launch returned to the ship.

After all buoys were planted, the ship anchored as near the stations as conditions permitted throughout the 100-hour series, so that immediate repair (or recovery in case of collision) of the buoys was ensured.

KEYING, RECEIVING, AND RECORDING OF DATA

Watches set up to monitor the buoys during each 100-hour series were composed of three two-man teams with watches of eight hours apiece, 0000-0800, 0800-1600, and 1600-2400. Four-hour watches could easily be set up, but eight-hour watches were preferred by the crew and worked out very well.

Each team was made up of an officer or electronics technician as tape scaler, and a quartermaster or seaman as chronograph operator. Since tape scaling for eight hours can be a strain on eyes and nerves, it is a help if the seaman or quartermaster is checked out in scaling, to serve as a relief.

As experience is gained, however, tape scalers usually find some time to relax between tapes.

With four buoys planted, there is no time to check tapes from the preceding watch. With less than four buoys operating, some tapes can be checked. For example, with three buoys being monitored, the tapes of one station from the preceding watch could be re-scanned and checked.

The process of keying, receiving, and recording of data for four buoys will now be discussed.

The frequencies of the four buoys were marked on the dial of the audio oscillator in the order of keying. Stations 21, 22, 23, and 24, for example, had their audio frequencies established in ascending order, and were always keyed in that order.

The oscillator was set to the first frequency on the hour and half hour. Keying, or commanding, the buoy was accomplished by depressing the mike button for a count of ten, which placed the ship's transmitter on the air with the correct audio tone. Next, the chronograph mechanism was started. The chronograph tape then moved beneath the three styli : time, velocity, and direction. The time stylus, activated by the ship's chronometer, recorded one tick per second on the tape.

If the buoy was keyed properly, the sequence switch in the buoy was activated. The buoy's transmitter came on the air, and the identification signal (two long dashes) was received for the top meter. These dashes were ticked off on the tape by the velocity stylus. For approximately two minutes the velocity ticks (V's) and direction ticks (D's) from the top meter were recorded on the tape. As the first part of the tape was issued from the chronograph, the operator recorded on it : the station number; keying time; date; and tape number (consecutive from first to last tape in the series, each station's tapes numbered separately). Parentheses were marked around the top meter identification signal, and the word *top* written inside. From then on, the main duty of the chronograph operator was to make certain that the tapes were complete and accurate. He watched that all V's and D's were recorded. In some cases, the signals received were weak, or the relays were sticking, which necessitated the manual activation of the relays, as the V's and D's were heard over the loudspeaker. V's and D's were distinguished by two different tones, and each stylus was activated by a separate relay. The arrangement for manual recording was not entirely satisfactory, and perhaps more investigation will be made into this problem in the future.

After the top meter was recorded, the sequence switch in the buoy sent the identification signal for the middle meter. This was shown on the tape by three long dashes, which were marked *middle*. Two minutes later, the bottom meter began recording with four long dashes on the tape, marked *bottom* by the operator. When the bottom meter was finished, the sequence switch had completed its cycle, and the buoy may be commanded again at any time. After six minutes had elapsed, the oscillator was set to the second frequency and that station keyed. The tape-taking process continued until the V's and D's of each meter on all four buoys were recorded on tape.

Some of the duties of the chronograph operator included : care of the chronograph by routine cleaning; changing tape rolls before they ran out at a critical time; and notifying the tape scaler of any difficulties or loss of reception, to prevent loss of tapes.

Of great importance to the accuracy of the survey was the making of V and D comparisons by the chronograph operator on the first tape each watch on each station, every time the tape was changed, and every time the styli were adjusted. A "V & D comparison " was made by moving both V and D styli arms back and forth by hand with the chronograph mechanism stopped, to see that the marks were coincident on the tape. If they did not coincide, the styli were adjusted accordingly. Fig. 6 is a diagram of the V & D comparison, showing the correct adjustment of the styli arms, and proper notations.

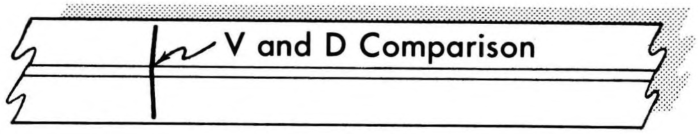

FIG. 6. — V and D comparison on tape.

As the first tape emerged from the chronograph, it was coiled neatly, and given to the tape scaler. The tape scaler laid out the tape on a desk, checked the record book with the tape time and number, and began the scaling process.

When possible, ten intervals between V_1's were scaled and the resulting number of seconds elapsed during those ten intervals were divided by ten to obtain the average interval time. When the current was slow and ten intervals were not available, the whole tape was scaled for the maximum possible intervals down to one-half an interval. A small V was marked beside each V_1 used. Fig. 7 shows a typical chronograph tape with ten intervals scaled.

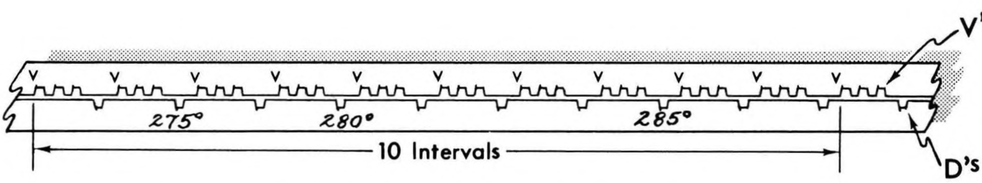

FIG. 7. — Typical chronograph tape.

In the record book, opposite the time, the number of intervals scaled was entered. In the next two columns were written the total seconds elapsed, and the average time interval, respectively. The rating table that changes average time interval to velocity for the modified Model II Roberts meter was referred to, and the velocity of the current in knots was entered in the next column.

The celluloid direction scaling template was then placed on the tape and, if possible, at least three directions were scaled and averaged. The average direction was entered in the record book. Each D used for averaging was marked with its direction, i.e. 045°, to simplify averaging and checking.

Directions were scaled more accurately by holding the template on the V's on either side of the D used. To do this more readily, the 90°, 180°, and 270° lines on the template were made to stand out with red ink, or made into dashed lines.

The scaling continued until the tapes from all four buoys had been scaled. By this time, the half-hour was nearly over. On the half-hour, the first buoy was keyed again, repeating the cycle.

The chronograph tapes were rolled, pressed, and neatly bound together with rubber bands. Two different methods have been used to roll tapes. One device is a wooden apparatus containing a wheel about 3 inches in diameter with a slot in the wheel for engaging the tape. The tape is rolled on the perimeter of the wheel. The other device is an ordinary piece of plexiglass (see fig. 8) which is less complicated, and works well enough.

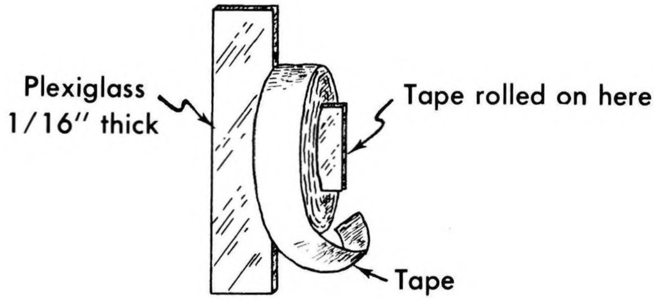

Fig. 8. — Device used for rolling chronograph tapes.

Covers made of thin pieces of cardboard were cut to the shape of the folded tapes and were placed at each end of a tape bundle. Bundles were made up for each station at the end of each eight-hour watch. Before the bundles were secured, the tapes were counted to see that no tape had been misplaced or lost, and that the numbers on the tapes agreed with those in the record books. Fig. 9 shows a sample bundle of tapes, with the proper identification written on the cardboard.

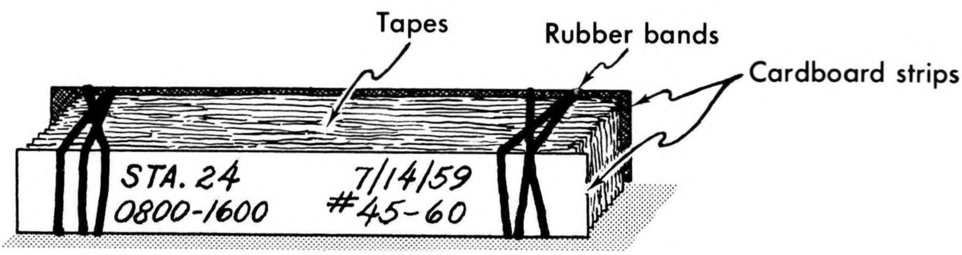

Fig. 9. — Sample bundle of tapes.

The wind direction and velocity were entered in the record book hourly only if the ship was nearby the buoy stations. The clock used for time must be compared with WWV and adjusted to the nearest minute at least once a day, preferably at 0800. A note to that effect was entered in the record book. Pole current observations were entered in the record book in ink alongside the corresponding meter values for comparison.

Each time a party inspected the buoys and meters, a note was entered in the record book at the correct time of occurrence, stating exactly what was done, and the conditions found. If one or more meters were changed, the exact time of the change was noted, along with the numbers of the new and replaced meters.

PROCESSING OF RECORDS

As soon as possible after the completion of a series, the records were submitted to the Washington Office. Before doing this, however, there were a number of things done to insure that the records were complete and understandable.

During the survey, running plots were maintained on each station for all meters. Any pole currents observed were also plotted on the curves for comparison purposes. Color coding was advantageous, using different colors for top, middle, and bottom meters.

The main purpose of a running velocity plot was to show the type of current in the area, and as a continuous check on the individual performance of each meter. The plots for each station were bound together and submitted with the other records of the survey. Since velocity plots do not give a check on the observed directions, the records must be watched continuously for erratic results.

After the stations in a 100-hour series were secured, additional information was entered in the record books.

First, the cover information was filled in. On long projects, such as in New York Harbor, it was necessary to have rubber stamps available for repetitive information.

Next, the data sheet was filled in completely, and included : buoy number; sequence switch number; type of meters used; meter numbers and change dates; and time corrections, if any.

The sextant fix and angles observed were written on the top of the first page of records. If the buoy was moved, dragged, or drifted off station during the series, the complete new fix was also recorded.

A section of chart was made up for each station. A red circle was used to indicate the station's position, and light lines were drawn to the landmarks used for the sextant fix and check angle. Each station's chart was rubber cemented inside the front cover of the first record book in that series.

Lastly, the record books were checked for completeness concerning notes, with special attention directed to meter changes and inspections.

Before submitting the records to the ship's Commanding Officer for approval, the tapes for each station were checked for completeness. In addition, the record books and current curves were given a final inspection.

After the Commanding Officer approved the records, the tapes were placed in suitable containers, wrapped, and mailed. The record books and current curves were generally mailed at a different time than the tapes for maximum security of records. Each piece mailed was numbered, and contained a copy of the transmittal letter for quick identification in the Office.

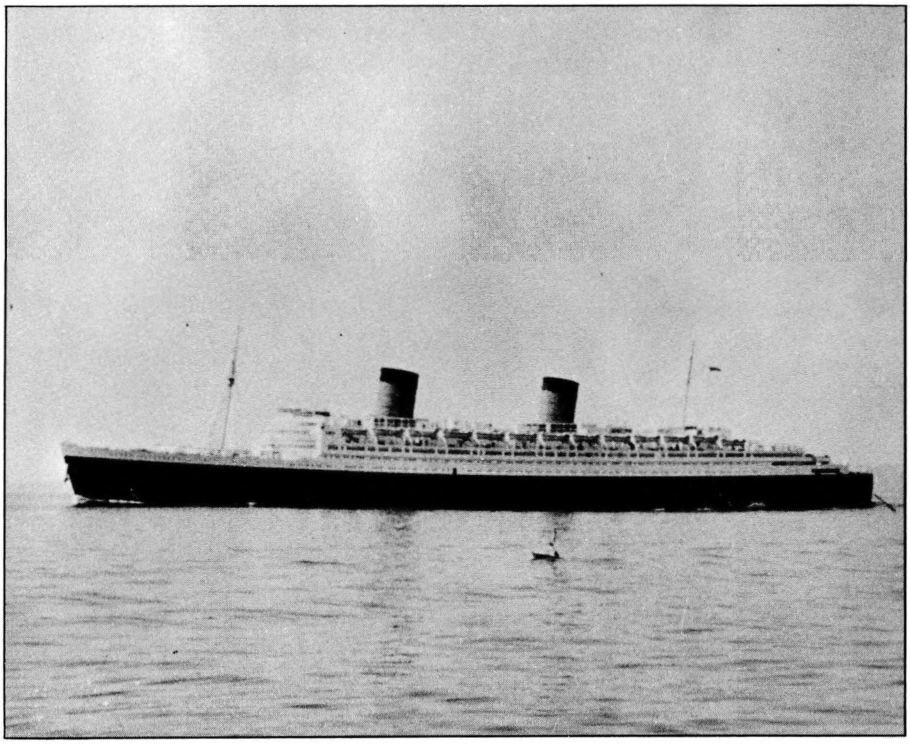

FIG. 10. — Cunard Line's *Queen Elizabeth* passing current buoy close aboard, New York Harbor.

CONCLUSION

With increased interest in oceanography and disposal of radioactive wastes at sea, including possible contamination of harbors by nuclear vessels, accurate current surveying has become tremendously important. Changes are, and will be, rapid in this field, making it difficult to keep abreast of new developments.

In all fields of exploraiton, there is, of necessity, a great amount of trial and error by which each new method or technique is tested and proved. A new trail should not have to be blazed which parallels the old. Steps previously trod should not have to be tediously retraced.

For the benefit of those who may be called upon to work on similar surveys, it is hoped that this article adequately records some of the latest methods and techniques devised up to this time in the field of current surveying, in order to form a basis for further advancement.