SURVEY OF "GEORGES BANK"

(Extracts from the *Bulletin of the Association of Field Engineers, U. S. Coast & Geodetic Survey,* June 1931, and from *The Military Engineer,* N° 132, Nov.-Dec. 1931).

The hydrographic survey of Georges Bank was started by the Coast and Geodetic Survey in the spring of 1930 and will be completed in the fall of 1932. Four vessels are assigned to the project — two station and two mobile surveying ships.

This Bank, extending 200 miles off the New England coast and comprising about 15,000 square miles, is one of the most difficult areas to survey along the coast of the United States of America. The problems involved include remoteness from the base of the survey fleet; strong and erratic currents; prevalent fogs; heavy traffic of fishing craft and transatlantic liners; and numerous shoal areas.

The season is comparatively short because of unfavorable weather conditions during the late fall and winter months; it is not practicable to carry on survey operations from about the middle of October to the first part of May.

CONTROL FOR SURVEY OF GEORGES BANK.

The control for the survey is furnished by a chain of buoys anchored along the ridge of the Bank in about 200 feet of water, forming triangles with sides 10 to 15 miles in length. For the determination of the origin, a station ship, anchored near the buoy at the eastern end of the chain, located this buoy astronomically within a probable error of about 400 metres. The location of this buoy has been held fixed for the purposes of the survey.

From this origin the computation of the buoy triangulation scheme is based on lengths of lines obtained by radio acoustic ranging, with check sun, moon, or star azimuths over several of the lines, observed between two ships anchored at contiguous buoys. In determining the length of a line, a station ship, anchored near a buoy, has a hydrophone suspended under the keel and connected with the radio set. Another vessel drops a depth bomb, composed of a quantity of T. N. T., near one of the other buoys. The vibration from the explosion travels through the water to the hydrophone of the station ship and its receipt is automatically and instantly flashed back to the bombing vessel by radio. The elapsed time between the explosion and the receipt of the sound wave at the hydrophone of the station ship is recorded within one one-hundredth of a second on a speedily constructed chronograph on the bombing vessel. This procedure is followed in turn at all the buoys and, with a knowledge of the velocity of sound in the sea water of that region, the distance between all buoys in the chain are determined.

The positions of the buoys having been thus determined, two station ships are anchored at any two buoys and the mobile survey vessel steamed along a system of sounding lines, even through fog or at night, and depth bombs dropped at intervals of about ten minutes, furnishing locations of the vessel on the sounding lines in a manner similar to that used for locating the buoys. On this survey, bombs have "carried through" all the way from the edge of the Bank to the control buoys, which is a distance of 60 miles.

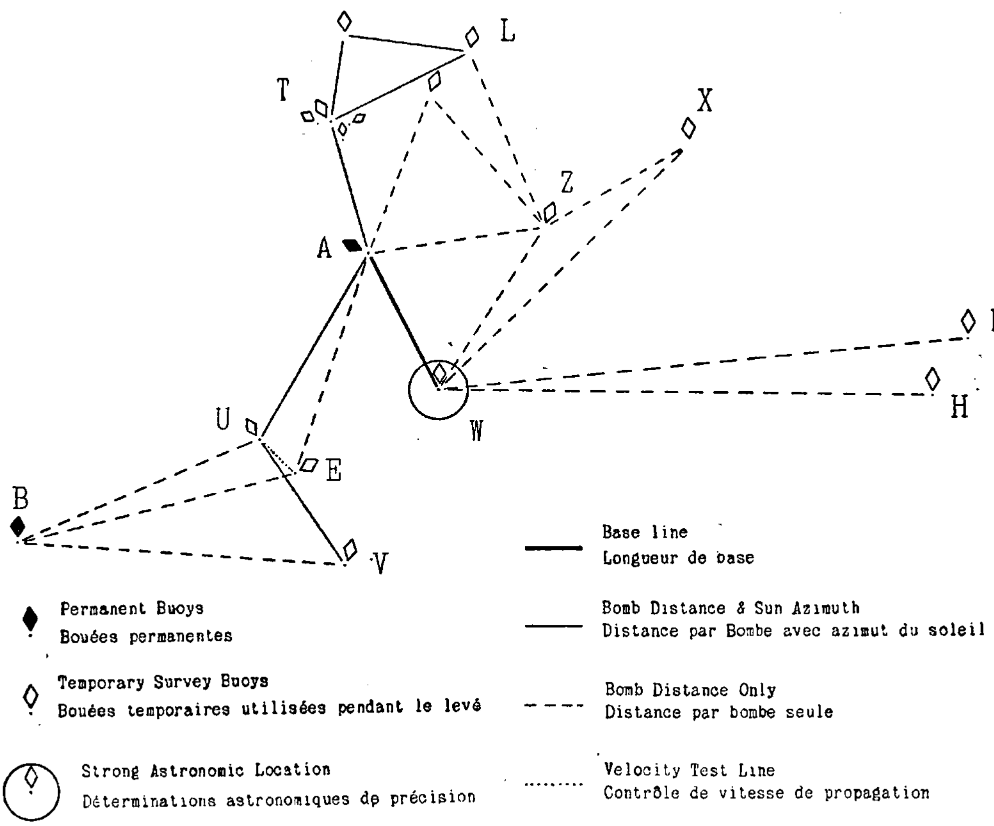
Soundings are taken on the survey vessel with the Fathometer every few seconds and every change in depth recorded, so that practically a continuous profile of the bottom can be drawn along any line of the system.

COMPUTATION AND ADJUSTMENT OF BUOY CONTROL NET.

I. — Office computation : The following method, adopted after analysis had been made of position, azimuth and distance determinations, was used in making the computations :

a) The astronomical position of buoy *W* was held fixed and positions of all other buoys were related to it by computed or measured azimuths and distances.

b) All sun azimuths were held fixed with the exception of *KT*, *UA* and *UV*.



F & H. Marker buoys; positions based on adjusted sounding line loops.

Fig. 1

c) The triangles *ZAL*, *ATL* and *KTL* were computed from two known sides and the included angle. All the remaining triangles were computed from three known sides.

Computation of the scheme by the above method gave double values of distances (metres) as follows:

Line	*Computed*	*R. A. R.*	*Discrepancy*
LA	35632	35596	36
LZ	30307	30331	24
KT	13891	13853	38

Three double values for azimuths of lines were also obtained. The discrepancy in the azimuth of the line *KT*, which is the only one entering into the positions of the buoys used on the season's work, is 13'.

No adjustment was necessary for positions of the buoys used for the control of the 1930 season's work since the discrepancies were small for this class of work and since what were considered to be the strongest values were in each case employed in computing the scheme.

II. — Field adjustment (Ship *Lydonia*) : In the office computation, the length *AW* and its observed azimuth were held fixed; also the astronomic position of *W*. Westward to Buoy *B* only the lengths were held; therefore, observed azimuths *UA*, *UB* and the compass azimuth of *EU* were rejected. As computed by the office all the observed azimuths lie to the left of their computed azimuths, indicating a chance for improvement by giving some weight to the observed azimuths.

Following a study in the field, computations were made as follows:

A mean between observed azimuth *UA* and the computed azimuth *UA* was taken. The triangle *UAW* was then computed with sides *AU* and *AW* held in length and azimuth. This threw all error on line *UW* which comes out as follows:

Observed length — 29531 metres; computed — 29426 metres. Since logarithm of *sine* Angle *A* changes 13 in 7th place and *sine* Angle *W* changes 14 in 7th place, it is proposed to change side *UA* by adding 60 to measured length, making *UA* become 34275 metres. Recomputing two sides and included angle gives lengths as follows:

UW (computed) = 29470; *UW* (observed) = 29531. The position of *U* was then computed with these data.

The office computation of triangle *UVB* was accepted. For the computation of the position of Buoy *B*, the observed azimuth and observed length of *UV* were held fixed. (Observed data: Azimuth 310°50'34"; length 20002 metres).

From data obtained in the computation of triangles *UVB* and *AWU* (and the true bearing and length of *EU*), the position of Buoy *E* was computed through each triangle. In these computations, two sides and the included angle of each triangle were used as follows:

1) *Triangle UAE*: The sides *UE* as observed, *UA* as assumed and the included angle at *U* as determined from the calculated azimuth of *UA* and the observed azimuth of *UE*.

2) *Triangle UEB*: The sides *UE* as observed and *UB* as computed and the included angle at *U* as determined from the calculated azimuth of *UB* and the observed azimuth of *UE*.

In this way all the closure error was thrown into the sides *AE* and *BE*, making differences as follows:

AE	(observed)	= 37448;	(computed)	= 37522 metres.
BE	»	= 45535;	»	= 45542 »

In the office method of computing the Triangle *KLT*, sides *LT* and *KL* and their azimuths were held fixed. This left discrepancies on the length and azimuth of *KT* of 38 metres and 12' 53" respectively.

It was felt in the field that both the length and azimuth of *KT* were likely to be as good as the lengths and azimuths of either other side. Accordingly, the azimuth closure was distributed between the azimuths of *KT* and *KL*, changing the angles at *L* and *T* by 6' 26" each, and the angle at *K* by 1". In the computation of this triangle, *KT* becomes 13852 metres, as compared with 13891 by office computation, and *KL* becomes 19623 metres, as compared with 19595 metres.

NEW APPLIANCES USED FOR SURVEY WORK. (a)

Portable R. A. R. Stations.

After definite failures of the shore stations on the North Carolina coast to receive the sound of bombs a sufficient distance to make the method practicable, experiments were started in which a hydrophone was suspended from a whaleboat; and with an amplifier, headphones and a note-book, an observer would listen while the ship carried out a pre-arranged schedule of operations. This generally occupied several hours during which the ship would fire bombs of T.N.T. at regular intervals while running away from the whaleboat which would be anchored at some position which was deemed a possible location for a hydrophone station.

Since there was no method of communication between the whaleboat and ship, very often it would be found that after from two to six hours of running out and back the ship, the whaleboat observer could only report that nothing was heard from the ship after the first ten minutes, although the ship had fired maybe 15 or 20 bombs after that and much time had been uselessly wasted. If communication could be had between the two, the total time could have been reduced to about 30 minutes.

The writer, after a few preliminary trials, made a transmitter of three coils of 9, 8 and 4 turns for plate, grid and antenna, respectively, some eleven centimetres in diame-

(a) *Information extracted from two articles relating to Portable Radio Acoustic Ranging Stations by* Dr. Herbert Grove Dorsey *&* O. W. Swainson, *appearing in the* Bulletin of the Association of Field Engineers, United States Coast & Geodetic Survey, *June* 1931, *pages 72 to 78.*

ter. Each coil was covered with a layer of rubber tape and the three then taped together and fastened to an odd piece of bakelite on which was placed a tube socket and five binding posts.

There was no grid leak, tuning condensers, chokes, or bias; almost nothing one ordinarily sees in a transmitter. The radio operator declared it "would not and could not oscillate", and was dumbfounded when, with a *UX* 210 tube and 225 volt *B* battery, the lamp of a wave meter would light up when at a distance of ten inches. It was, of course, not efficient, but it was waterproof. Its wave length was about 60 metres and communication was possible at a distance of ten miles. While it was not used to automatically transmit a signal on receipt of the sound of the bomb, it so simplified the experiments that tests could be made with the whaleboat in a dozen different places in a single day. Eventually this simple device was worked to a distance of some 40 miles.

Naturally, a small transmitter in which the tuning is dependent to a considerable extent upon the capacity of the antenna system will have its frequency vary with every motion of the boat. A dash may be broken into dots and dots completely lost so that, except in a calm sea, communication is difficult. The next step in advance is to use an independent oscillating tube and let it feed a radio frequency amplifier which is coupled to the antenna. This form of transmitter is far superior in that it is much steadier and little affected by rolling of the boat. This type was successfully used on the *Echo* in preliminary trials in the fall of 1929 and with the *Ranger* and the *Echo* off Florida in the spring of 1930. These latter transmitters were the first practical attempts in using a thyratron instead of a relay to close the *B* battery circuit of the transmitter so that there is no lag in the sending of the initial dash. During the summer of 1930 on Georges Bank, the transmitters on both the *Lydonia* and *Oceanographer* were changed to quartz crystal control so that no bomb signals were lost due to tuning itself, the frequency remaining absolutely steady so far as can be detected by the ordinary receiver.

During the fall of 1930 a report was sent in from the *Pioneer* that a launch had been temporarily equipped as a R. A. R. station and successfully used in determining distances between control buoys on an offshore bank, Discussion at the Washington office disclosed the usefulness of such methods and it was decided to build a compact arrangement for trial with the idea that it need not operate more than 10 or 15 miles to be extremely serviceable in many different cases of locating buoys, etc...

Before opportunity arrived for starting such an outfit, request came from the *Oceanographer* for practically the same apparatus which had been planned which was then built as quickly as possible during the press of regular work.

This apparatus is contained in a single cabinet of the same dimensions as the regular R. A. R. shore station amplifier (page 26, Special Publication N° 146 of the Coast & Geodetic Survey) and it is only necessary for the ship to furnish two *A* batteries, one *B* battery, one *C* battery, magnetophone, hand telegraph key, and necessary antenna wire to be used in a launch or whaleboat or wherever it is desired to make the tests.

A short wave radio receiver is also to be supplied by the ship, but it may be operated from the *B* battery and *A* battery N° 1, used with the transmitter.

Figure 2 shows the arrangement of the apparatus and gives the values of voltage to be used and location of the different controls.

With the exception of the antenna binding posts on the upper loft of the bakelite panel, all connections are made by means of cables passing through the back side of the box. A five conductor cable at the middle is connected to two *A* batteries, green to negative of N° 1 *A* battery, red to 4 volts positive, and black-white to 6 volts positive. N° 2 *A* battery may be 8 or 6 volts with white wire connected to the negative side and black connected to the positive terminal. The two *A* batteries are to be entirely separate and reasonably well insulated from each other by being placed on dry wood, for the difference in potential between them may be as high as the total *B* battery voltage.

A hand telegraph key should be connected between the positive terminals of the two *A* batteries and this key is to be used for regular telegraphic code between the boat and ship. Its operation will be to key the negative side of the *B* battery of the transmitter.

The *B* battery should consist of not less than 5 blocks of 45 volt dry batteries connected in series with negative end connected to the black wire in the cable next to N° 2 *A* battery, and positive wire to the red wire in this cable. Positive 45 volts and 180 volts of the *B* battery are to be connected to the black and red wires respectively in the cable next to N° 1 *A* battery terminals. A 45 volts *C* battery is to be connected to the left hand cable, negative to black and positive to red.

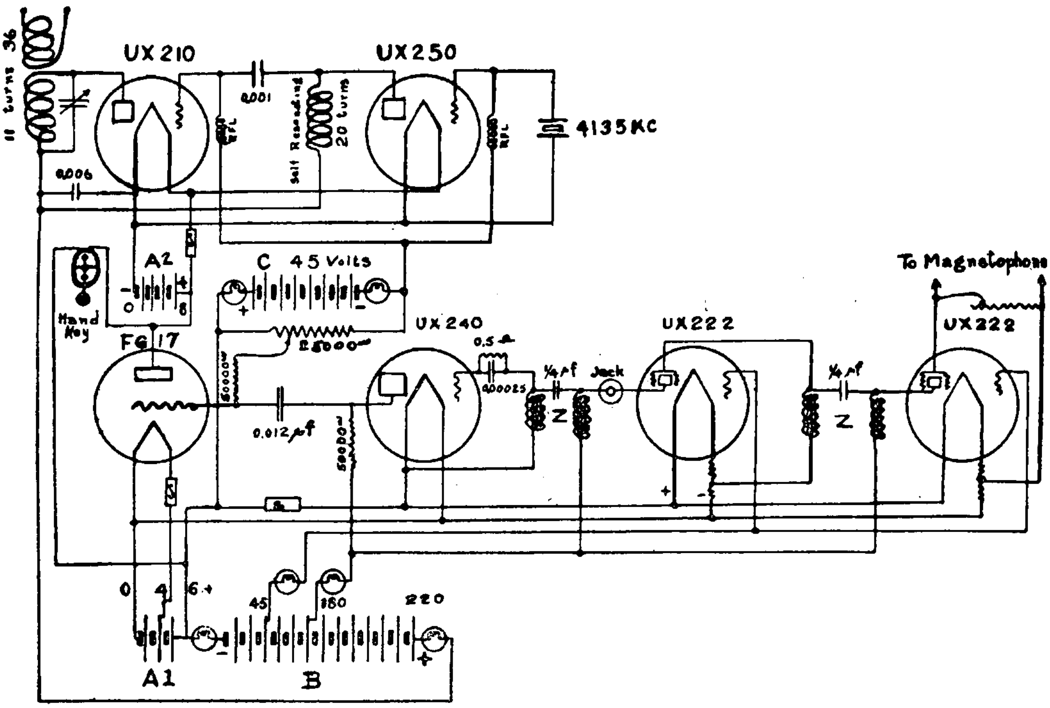


Fig. 2

It will be noted that the *B* and *C* battery terminals are all connected to miniature lamp sockets which should contain miniature lamps of about 0.3 ampere, and voltage 3 to 6. These lamps serve as fuses to protect the tubes and also act as current indicators. Moderate glowing of the lamps minus and plus *B* only mean that current of the order of 100 milliamperes is flowing through the transmitter tubes. The other four lamps will not glow unless something is wrong.

The magnetophone is connected to the cable at the right. No battery is needed with the magnetophone, as it is of the electromagnetic type of receiver generating its own electromotive force, which is applied directly to the variable input control resistance and thence to the space charge grid and negative return of the first amplifying *UX* 222 tube, which is connected to the second similar tube by impedance and condenser coupling. The screen-grid voltage is 45 volts and the plate voltage is 180 and a 1/4 microfarad condenser is used for coupling. Normally, these tubes and sockets are covered with aluminium shields, In the plate circuit of the second tube a telephone jack is connected in which may be plugged ear phones for listening to amplified sounds.

The second tube is connected to a *UX* 240 tube through a grid leak and condenser, making it act as rectifier. Its plate circuit is resistance coupled to a thyratron *F.G.* 17 and the grid return of the latter is connected to the arm of a 25000 ohm potentiometer connected across the *C* battery, the positive terminal of which is connected to N° 1 *A* battery. The plate of the thyratron is connected to positive terminal of *A* battery N° 2 so that the plate circuit of the thyratron is shunted across the telegraph key already mentioned.

In line with the thyratron is the oscillator tube inside a bakelite form on which is wound 20 turns of N° 18 wire serving as plate inductance for the oscillator. This inductance has sufficient distributed capacity so that the crystal oscillates freely without the use of a tuning condenser. The grid is connected to a radio frequency choke on which is impressed a negative bias of 45 volts by the *C* battery whenever the key or thyratron closes the circuit.

The oscillator tube may be a *UX* 171 *A* or *UX* 250. Either of these with 220 volts on plate oscillated better than a 112 or *UX* 210. However, with only 2 volts on *A* battery N° 2, a *UX* 245 makes a good oscillator.

The oscillator plate is connected to the grid of the power amplifier through a

0,001 microfarad condenser, the grid being biased by minus 45 volts through a choke, the same as the oscillator tube. A *UX* 210 tube serves best as an amplifier, although a *UX* 171 *A* will work and also a *UX* 245 with reduced voltage on the filament. The amplifier inductance of 11 turns of N° 12 wire is wound on a 2 3/16 inch bakelite form, mounted in a vertical position to the left of the amplifier. A 17 plate variable air condenser will tune this inductance to 4135 kilocycles, or to its second harmonic.

The antenna coil, of some 36 turns, is wound on the same bakelite form as the amplifier coil and the end terminals are connected to binding posts. In the laboratory two antennae wires about 10 feet long were connected to the binding posts and carried apart and slightly upwards to similate what might be had by using two oars as masts at the ends of a whale boat and connecting the antennae to their ends. A neon glow lamp gave indications of considerable voltage at their ends, but no actual tests were made. A flexible conductor is soldered near the middle of the coil, and taps are left at one end so that a ground wire may be tried, or different numbers of turns used to ascertain what may give best results in practice. With the close coupling between the antenna and plate coils, the condenser serves to tune both inductances.

In operation, the transmitter switch is closed and its circuits tuned until a good radio signal is received by the ship. This circuit is then opened and the receiver switch closed and input control adjusted so that the magnetophone seems quiet with no noise in the boat and the magnetophone hung about 6 fathoms deep. A slight pounding on the boat's side should be heard very plainly in the ear phones if all is working well. Next, the thyratron and transmitter switches should be closed and the potential of thyratron grid adjusted until the thyratron will not operate until some slight sound is produced in the water. The thyratron exhibits a blue glow when it operates and will not extinguish itself until its plate circuit or filament circuit is opened, or the filament circuit of the transmitter tubes. In the laboratory the amplifier was so sensitive to noises that the mere closing of the thyratron switch would cause sufficient noise to actuate itself and it was necessary to put an extra knife switch in the circuit but not mounted on the cabinet. This was connected between plus 4 volts of *A* battery N° 1 and the red wire. With this switch no trouble was experienced.

In practice, the thyratron will be used for only short intervals so that even though the filament requires 5 amperes, the *A* battery's charge will not be rapidly depleted. When the ship signals that the bomb has been dropped overboard, the circuit is closed through the thyratron and it should be opened again as soon as the noise of the bomb actuates the circuit which will send just one long dash. If the blue glow should persist in the thyratron as it sometimes does, due to the plate current heating the filament, it may be stopped by making a dot with the telegraph key which by shunting the thyratron plate circuit reduces its current to zero.

It should be noted that the signals made by the telegraph key will be slightly louder than those made by the thyratron, since the mercury vapor of the thyratron has an appreciable resistance. If this should make adjustment of the receiver and chronograph difficult, add a resistance of about 500 ohms in series with the key. This method is used on the *Gilbert* and the *Lydonia* so that the thyratron signal is slightly louder than the key signal. This makes adjustment on the ship easy for the thyratron signal is always somewhat stronger.

If the two stages of audio amplification are considerably more than necessary, a change to one stage may be readily made by simply removing the two shields and space charge grid terminals and placing the terminal normally on first tube on the second tube cap and just neglecting the second terminal. In this case it may be desirable to place a piece of paper under the control rheostat movable arm so as to open its circuit.

Since this portable set was built, experiments have been conducted with the new *UX* 232 screen grid tubes. These are far less microphonic than the *UX* 222 tube and give slightly greater amplification. Since they require only two volts on the filament and draw only about 1/8 ampere, they are more suitable than even the *UY* 224 tube which requires 1½ amperes.

If any more portable R. A. R. sets are built they should be planned for the *UX* 222 tube.

Portable R. A. R. Set.

A cage aerial was stretched between two 2"×3" poles 16 feet long rigged on at each end of the launch. The regular shore station equipment with *A* and *B* batteries used for power was installed in the boat.

Various methods were used for the hydrophone, all on the suspended type principle as the depth of water was usually about twenty fathoms. The first method was the regular suspended type with the lead-in wire running directly from the hydrophone anchor to the launch. The hydrophone was planted about two hundred feet from the launch, which in turn was made fast to one of the signal buoys. This was very satisfactory until the current became so strong as to drag the lead-in wire over the coral bottom and thus cut the insulation.

For distances up to 10 miles and with a wind not over force 3, and sea only moderate, a sixty pound weight (deep sea sounding shot) was fastened to the hydrophone and lowered over the side of the launch to a depth of twelve fathoms. In a comparatively smooth sea this worked fine, but when the launch pitched and rolled to any extent, the noise of the sea against the boat and the constant jerking of the hydrophone caused extraneous noises to interfere seriously. The trouble was lessened somewhat by a man acting as a shock-absorber by leaning over the side of the boat and holding the hydrophone cable in his hand.

In rough weather the suspended hydrophone was anchored near a signal buoy (within measurable distance), the wire run down the hydrophone anchor line, thence about two hundred feet along the ocean bottom to the anchor of a watch buoy, up this anchor to the watch buoy and then into the boat which was made fast to this buoy. A forty gallon oil drum made a good buoy for this purpose. The anchor line of the watch buoy was short, being about one and one-half times the depth of the water. This method gave good results. The gear could be left down for several shiftings of the buoys. It required the use of the ship, however, and took an hour to lay it or pick it up. The launch itself attended to the laying and picking up of the hydrophone in the other methods.

One or two percussion caps made good bombs for distances up to six miles. For distances of six to fifteen miles, gill milk bottles or 2-ounce condiment bottles filled with T. N. T. were used.

When everything was ready the ship was placed practically dead in the water close to the signal buoy — not over two hundred metres — the bomb was thrown over the stern, the distance from the ship to the point of its striking the water estimated, and at the signal of "over", the ship's heading and the bearing and vertical angle to the buoy measured. These measurements gave the relative position of the bomb to the ship's receiver (either the sounding hydrophone or oscillator diaphragm), the receiver to the observer on the bridge, and the observer to the signal buoy. The time recorded on the tape corrected for the distance of the bomb from the receiver gave the distance of the bomb to the launch hydrophone. The relative position of the launch hydrophone and the nearby tie-in buoy was measured by the launch. The bombs were dropped with the vessel under way when bombs larger than the 2-ounce bottles had to be used. With these data the distance between the buoys was determined graphically as it was easier than computing.

Five to fifteen determinations for each buoy distance were made, the ship being at different positions around the buoy at each determination in order to eliminate error in measuring distance and directions of the various component parts of the operation.

For short distances, less than four miles, the oscillator was used instead of bombs. This expedited the work considerably as the vessel could steam slowly around the buoy, obtaining a distance determination as frequently as desired, as the launch receiver would be left on continuously and no reports were made after each determination.

Usually the maximum discrepancy in a series of distance determinations was less than sixty meters, and the average residual about ten meters. The maximum distance determined was thirty miles. Seldom were "jumps" noticed on sounding lines when passing from one side of the line of buoys to the other or when changing fixes.

Azimuths were determined by placing the vessel on range between two buoys when the sun was low or on the horizon and measuring the sun's inclined angle to the horizon over the distant signal and the vertical angle of the sun. Sometimes only one azimuth was measured this way and then the azimuth carried forward by placing the stem of the ship against a buoy and measuring the angle between the buoys, a marker buoy having been placed off to one side to aid in measuring the large angle if necessary.

The set was left in the launch continuously.

DETERMINATION OF SHIP'S POSITION.

The Sumner bisectrix method of determining the best value of the ship's position from a given set of observations was used. When a number of stars were taken for a set at one time, the following methods were used :

Stars considered of value enough to be used in the computations were given equal weight. Others were rejected as having no weight. When observations were taken on stars having about the same azimuths, a resultant of their Sumner lines was secured by bisecting their intersections. This resultant was treated as a Sumner line in combining with other Sumner lines. Each set of sights resolved itself into a figure of four Sumner lines with sides facing approximately North, East, South and West. Sumner bisectrix lines were drawn between the Sumner lines which faced each other. The intersection of the Sumner bisectrix lines was taken as the position of the ship.

DETERMINATION OF POSITION OF ANCHOR OF BUOY.

When sights were taken, the bearing and distance of the buoy were observed. The heading of the ship was noted, for this indicated in what direction the current was running, and hence in what direction the anchor of the buoy lay from the buoy. The scope of the chain was also known. Thus the bearing and distance of the buoy anchor from the buoy could be determined. The bearing and distance from the bridge to the buoy, plus the bearing and distance from the buoy to the buoy anchor gave graphically the bearing and distance of the buoy anchor from the ship's bridge.

Latitude and Departure Tables were used for summing the components of the bearings and distances to obtain the bearing and distance of the buoy anchor from the bridge. This bearing and distance was converted into differences of latitude and longitude by means of Polyconic Projection Tables.

STUDY OF ERRORS.

Intercepts.

The distances of the Sumner lines in a set of star observations from the true position of the ship were called errors in observations. To obtain an idea of the size of this error and the cause of it, these distances, or "intercepts", were scaled on all accepted sets of star sights taken during the season. These intercepts are averaged to obtain the total mean intercept of the season and to compare the mean values obtained by the various observers with each other.

The total mean distance of the Sumner lines from the ship's position was .93 of a mile. The Sumner lines were *from* the observed bodies with respect to the ship's true position.

The greatest difference from the total mean of any observer was .06 of a mile, or 111 metres. This would indicate that the personal errors in observations were small and that the errors were due to external factors.

Intercept Error due to difference between Air and Water Temperatures.

It was noted in the star observations taken on Georges Bank, season of 1930, that the intercept errors were from ½ to 2 miles and that the Sumner lines were invariably *from* the ship's position. This means the observed angles were less than the correct angles, or, in other words, the observed horizon was higher than the correct horizon.

It was also noted that when star sights were taken, surface water temperatures taken were from ½ degree to 6 degrees colder than the air temperatures taken at the same time. This would cause the apparent horizon to be lifted above the correct horizon in accordance with the following quotation from Bowditch, paragraph 301 (*d*) :

"When the sea water is colder than the air the visible horizon is raised and the dip decreased ; therefore the true altitude is greater than that given by the use of the ordinary dip table. When the water is warmer than the air, the horizon is depressed and the dip is increased. At such times the altitude is really less than that found from the use of the table."

A study of observations substantiates this quotation in a general way, but observations were not numerous enough to draw conclusions as to the amount of lifting of the horizon a given difference between air and water temperatures would cause.

Effect of Brightness of Horizon upon Accuracy of Sights.

It was suspected that because the horizon in the west is lightest, and therefore best, during evening sights, and lightest in the east during morning sights, the sights taken in the morning might be consistently east or west of those taken in the evening.

An average of the sights at Buoy *W* taken in the morning was compared with an average of those taken in the evening.

The average of the morning sights gives a value of .04' (74 metres) west of the average of the evening sights, a difference so slight that it is concluded that the difference in brightness of the horizon does not alter the position secured by the observer.