THE SURVEY OF GEORGES BANK

by

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MODERN METHODS OF HYDROGRAPHIC SURVEYING.

During the period since the World War the methods and technique employed in hydrographic surveying, especially on offshore work beyond the sight of land, have made a revolutionary advance, with corresponding increases in the accuracy and the volume of work accomplished. This class of surveying has recently assumed a scientific aspect of no small degree; the general principles involved are based to a large extent on researches of the physical scientist incident to the war for purposes foreign to their present application. These advances include both the determination of depths and their geographic location — echo sounding and radio acoustic ranging.

All the depth determinations on the Georges Bank project, except a small amount of hand-lead sounding over the very shallow water on Georges Shoal, have been made with echo-sounding apparatus.

The depths thus indicated are directly of sufficient accuracy for purposes of navigation, but for surveying purposes corrections to the adopted velocity for the physical properties of the sea water are necessary whenever the actual velocity of the subaqueous sound wave differs from the adopted velocity. And since it has been established that the velocity of sound in an elastic medium, such as sea water, is dependent upon the temperature, salinity, and pressure of the medium, it becomes necessary for the modern hydrographer to give attention to the determination of these physical properties for the area under survey. Observations for temperature and salinity are therefore made at well distributed points over the area surveyed and are made with sufficient frequency to insure correct values for those factors for every sounding obtained.

From these data and the theoretical velocity tables that have been calculated from laboratory considerations of certain properties of water, the actual velocity of sound wave is ascertained at any instant. For sea water the range in velocity for all oceans and all known depths has been found to vary from about 4,740 to 5,220 feet per second.

Water specimen cups and deep sea thermometers attached to piano wire are used to obtain the necessary temperature and salinity data.

Additional corrections to echo-soundings are often made when comparisons with vertical casts with piano wire indicate a more or less constant index error in the instrument. To determine if this index error exists and to permit the preparation of tables to correct it, frequent comparisons are made in different depths well distributed over the working ground.

RADIO ACOUSTIC RANGING.

The position of the survey vessel is determined by its distances from hydrophones located at two or more suitably placed shore stations; the measurement of these distances is obtained by the determination of the time required for a sound wave from the explosion of a depth bomb to travel under water from the ship to each shore station.

The wide continental shelf and off-lying shoal water on the North Atlantic Coast constitute adverse conditions for the transmission of sound waves, generated by distant offshore explosions at the survey vessel, to reach hydrophones located on shore. These unfavorable conditions have been partly overcome by a variation in technique.

In the case of this particular survey of Georges Bank, a system of marine triangulation is extended from a buoy anchored offshore in thirty fathoms of water near the outer edge of the bank and located by a long series of star observations made from the surveying vessel anchored nearby. This method was used for the first time, and successfully, on this survey of Georges Bank.

RADIO ACOUSTIC SURVEYING.

Two station ships, with suspended hydrophones, are anchored at any two of the buoys and a mobile survey vessel steamed along on a system of parallel sounding lines.

Positions of the surveying vessel are obtained at intervals of about ten minutes by radio acoustic ranging. A bomb, similar to those used in locating buoys and timed to sink to about 100 feet before explosion, is dropped overboard while underway. The chronograph of the survey vessel receives electrically from that vessel's hydrophone the impulse from the explosion and records its time on the tape. The sound wave also travels to each station ship's hydrophone where the vibrations set up cause an electrical impulse to travel through amplifiers to a thyratron. The actuation of the thyratron causes the station ship's radio transmitter to send out automatically a dash denoting the exact instant of the arrival of the sound wave at the station ship. The dash from each station ship is received by the survey ship's radio set and transmitted to the chronograph where the exact times of its receipts from both station ships are recorded on the same tape which recorded the explosion. Since radio transmission equals that of light, the elapsed times indicated on the tape are those required for the sound wave to travel via the water to each station ship. These time intervals may be scaled from the chronograph tape to a hundredth of a second, and from these data and a knowledge of the velocity of sound in sea water, the distances are computed; in these calculations, values are used for the velocity of sound in sea water corresponding to the bottom temperatures and the salinities along the lines to the hydrophone.

Some of the sounding lines on this survey extend to the 1,000 fathom curve, out beyond the edge of the continental shelf, yet the sound from these explosions travels through the water 40 or 50 miles back to the station ships anchored on the bank and their arrival is instantly flashed back to the survey vessel.

On the Pacific Coast the sound bombs have carried through a distance of 206 miles. On that coast the narrow continental shelf and the absence in general of off-lying shoals, which tend to absorb or to reflect the sound waves, constitute favorable factors toward the successful use of radio acoustic ranging. In addition, the comparatively low water temperatures furnish a medium conducive to sound transmission. Experiments have demonstrated that the sound waves travel faster in warm water than in cold and not as great distances; the water of high temperatures apparently absorbs the wave energy.

RADIO ACOUSTIC BOMBS.

Ordinary tin cans of half pint, pint, and quart capacity, with friction covers, are used for making up the bombs. These containers are first weighted with molten pig lead, sufficient to cause them to sink at a rate of about 3 ½ feet per second.

Both flake and granulated T.N.T. were used: fewer duds, however, resulted with the granulated since it makes a more compact mass around the detonator. During the season of 1930, the *Oceanographer* used about fifteen hundred bombs with only fifty failures, and the greater number of these failures happened during the early part of the season when flake T.N.T. was being used.

A slow fuse for use in wet work and a N° 8 blasting cap are used to detonate the bomb. A length of 10 to 12 inches of fuse is used; it is lighted from an electric heating unit secured to the taffrail and allowed to burn about 3 inches before it is thrown overboard. This requires about fifteen seconds and as a safety measure, while holding the lighted bomb, the bomber presses the fuse lightly between thumb and fore finger, thus following the flame by its heat along the fuse.

No attempt is now made to have the tin container watertight; bombs made up of T.N.T. thoroughly mixed with water have been successfully detonated as an experiment. The outer end of the fuse, of course, is rendered watertight by allowing about 3 inches to burn before the bomb is thrown overboard; the detonator is securely attached to the fuse and made watertight by being "crimped" several times.

VELOCITY OF SUBAQUEOUS SOUND.

While the use of sound for determining positions in surveying operations has passed beyond the experimental stage and is being used extensively by the Coast and Geodetic Survey in extending surveys beyond the sight of land with far greater accuracy than was possible by the older methods, many points of uncertainty yet remain to be solved. Of particular importance is the determination of the path as well as the form of the sound wave in horizontal transmission in sea water.

Does the energizing power for operating the radio key of the return passage emanate from the sound wave curve at its first part as it arrives at the hydrophone or after it has reached its greatest amplitude ? The Bureau is devising apparatus for analyzing the sound wave and experiments are planned for the near future for determining the form of the wave and its effect on the hydrophone at various stages of amplitude and phase.

In horizontal transmission, is the sound transmitted along the bottom layers of water; is it reflected back and forth from bottom to surface, or in deep water is it transmitted at some depth at which the pressure, density, and temperature is most conducive to its maximum horizontal transmission ? When these questions have been satisfactorily answered the scope of offshore hydrographic surveying by these modern methods will be materially enlarged; since the velocity of sound transmission varies with the density, temperature, and pressure of the medium, the path followed by the compressional wave must be finally determined with some certainty before the velocity of transmission can be deduced with assurance.

The Coast and Geodetic Survey is attacking the problem from an observational standpoint, employing for the study the mass of data from its radio acoustic ranging done on the Pacific Coast for several years past. An attempt is being made to determine the relation existing between experimental values and theoretical values based on assumed paths of horizontal transmission.

Mr. A. L. SHALOWITZ, Cartographic Engineer of the Chart Division of the Coast and Geodetic Survey, has made a study of the problem in the light of data now in the files. These data cover the work of eight survey parties over a period of four years and over areas extending from the Gulf of Alaska to Northern California. Mr. SHALOWITZ's paper, *The Physical Basis of Modern Hydrographic Surveying*, was published in the Proceedings of the National Academy of Sciences, Vol. 17, N° 8, August, 1931.

All reliable observations were used for the comparisons and while the results indicate that the transmission of the sound wave which energizes the hydrophone is by way of the bottom layers of water in depths to about 250 fathoms, no definite theory can be advanced until additional data are available for extending the study. In deep water it appears to take a path at a depth of about 300 fathoms. This layer is possibly most conducive to transmission due to the compensating effect of increased pressure.

In fifty-one observations, the experimental surface velocity averaged 12,3 metres per second higher than the theoretical velocity; the mean depth velocity averaged 3.2 metres per second higher than the theoretical; and between theoretical and bottom the difference was 1.0 metre per second.

The theoretical velocities used in these comparisons are means computed from the temperature, salinity, and pressure data for the three assumed paths of the sound wave from bomb to hydrophone for each particular observation. The experimental velocity was determined from locations of the vessel by the ordinary means of a graphic solution of the three point problem used in connection with shore signals, and simultaneously measuring the time for the sound wave to reach the hydrophone.

On Georges Bank, however, beyond sight of shore signals, experimental data for this area could not be obtained in this manner. Attempts were made, though not with entire success, to measure a base line several miles long on the bank by laying down a known length of piano wire and bombing at various points along this line. It was the intention to obtain in this way a value of the velocity of sound for use in all the work on the bank. Since this plan did not meet with entire success, a study was begun in the office by Mr. SHALOWITZ which led to the Bureau's adopting for the Georges Bank survey a velocity of transmission based on bottom temperatures. It now appears that his studies and conclusions have been corroborated by experimental tests since made in Massachusetts Bay by two different and independent methods. Yet it is not to be inferred that the Coast and Geodetic Survey has adopted this method as a definite policy; it is an expedient only and further studies may result in a different procedure in the light of more definite indications toward other theories.

ASTRONOMICAL WORK ON GEORGES BANK.

Mr. L. S. HUBBARD published a *Review of Astronomical Work and a Study of Errors, Georges Bank*, 1930, in the Bulletin of the Association of Field Engineers, United States Coast and Geodetic Survey, June, 1931.

The astronomical observations on the banks consisted of a series of star sights with navigating sextants made from the bridge of the survey vessel anchored near the origin buoy of the marine triangulation system. The ordinary methods of navigation, with refinements, were employed. The SUMNER bisectrix method of determining the best value of the ship's position from a given set of observations was used.

At the time of the sights, a bearing and distance to the buoy and the set of the current were observed. With a knowledge of the scope of anchor chain of the vessel and of the mooring of the buoy, all sights were thus referred to the buoy anchor, so that a definite point could be established unaffected by the varying position of the buoy.

Eighteen sets of sights were made by three observers on eight days from July 15 to September 5, 1930. A least square adjustment of the eighteen sets gives the probable error of the result in latitude as 0.052 minutes of arc or 96 metres, and of a single set as 0.221 minutes of arc or 409 metres; in longitude, the probable error of the result as 0.061 minutes of arc or 85 metres, and of a single set as 0.258 minutes of arc or 359 metres.

NEW SURVEY SHIP HYDROGRAPHER (*).

The new *Hydrographer* was completed in the spring of 1931 and was detailed to Georges Bank as its first assignment. This vessel was built from plans prepared by the Coast and Geodetic Survey and was designed for hydrographic surveying on the Atlantic and Gulf Coasts. It is a steel, single screw, Diesel electric vessel, 167 feet long, 31 ½-foot beam, 12-foot draft and has a displacement of 900 tons.

The propelling machinery consists of two 4-cycle, 6 cylinder full Diesel engines, each driving a 250 kw., 250 volts, direct current generator; a 500 volts double armature motor is direct-connected to the propeller shaft. Pilot-house control is provided and a regulation of the speed to within one revolution per minute of the propeller can be obtained. The vessel is equipped with an electric windlass, boat hoister, and capstan and an electric hydraulic steering gear. The navigational and survey equipment is of the most modern type, consisting of gyro compass, gyro pilot, course recorder, radio compass, two types of electric logs, range finder, and a high intensity searchlight. The radio equipment is in accord with the most modern developments and, of course, the vessel is equipped with the radio acoustic ranging apparatus developed by the Bureau. An echo sounding machine is provided, in addition to two motor-driven sounding machines, one for deep sea work and one for moderate depths.

The electric refrigeration system consists of a main cold storage room in the fore hold and separate units in the galley, commanding officer's pantry and wardroom officers' pantry.

The vessel is heated by steam furnished by a small water tube, oil burning, boiler installed in the lower generating room.

The boat equipment consists of two 26-foot power launches especially designed for small boat hydrography, two 24-foot whaleboats and two 16-foot dingheys. In addition to the davits and hoisting gear for the boats, the vessel is equipped with a 24-foot boom on the main deck forward for planting and recovering survey buoys and for handling stores.

Eight staterooms on the main deck aft furnish quarters for nine commissioned officers. The captain's quarters are on the boat deck forward directly under the bridge deck; from his dining room and stateroom he is able to keep a general outlook on the vessel's movements without going to the bridge deck. Nine staterooms on the berth deck quarter twenty-one petty officers, and the crew space on the berth deck forward is fitted with pipe berths for thirty seamen, oilers and mess attendants.

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(*) See: *Hydrographic Review*, Vol. V, N° 2, November 1928, p. 25; Vol. VIII, N° 2, November 1931, p. 186.