DEPARTMENT OF COMMERCE
U. S. COAST AND GEODETIC SURVEY
E. LESTER JONES, DIRECTOR

HYDROGRAPHIC MANUAL

BY

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PREFACE

This manual is issued for the purpose of giving the general requirements of the United States Coast and Geodetic Survey for the execution of hydrographic surveys and to describe the equipment and methods used for hydrographic work. It is one of a series of publications covering the various operations of the bureau.

Many of the descriptions contained herein are based on the reports of officers of the bureau, too numerous for individual mention in a publication of this nature, who by their zeal and ingenuity in devising or developing new methods and apparatus have contributed largely to the progress of hydrographic surveying during recent years.

In compiling the manuscript for this publication, much valuable assistance has been received from officers both in the field and office. Special credit is due Capt. W. E. Parker, chief of the division of hydrography and topography, under whose direction the work was done and who prepared the sections of chapter 4 that relate to echo sounding and temperature and salinity observations, for his careful review of the manuscript and for his suggestions for its improvement.

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Department of Commerce,
United States Coast and Geodetic Survey,
Washington, March 1, 1928.

The general requirements for hydrographic work as published in part 1 of this manual supersede all previous instructions and circulars upon the subjects treated and, together with the Regulations for the Government of the United States Coast and Geodetic Survey, shall be complied with in the execution of all field work unless divergence therefrom is authorized in the special instructions issued for each project.

E. Lester Jones, *Director.*

HYDROGRAPHIC MANUAL

GENERAL STATEMENT

The principal object of the hydrographic surveying operations of the United States Coast and Geodetic Survey is to secure information concerning water areas for the compilation of nautical charts and coast pilots or for the correction of existing charts and pilots.

It may be said that hydrographic surveying, exclusive of tidal and current investigations, consists of three essential operations:

(*a*) Depth measurements, usually called "soundings," at certain points throughout the area being surveyed. This work always includes the determination of the nature of the bottom at frequent intervals and may involve the collection of data required for oceanographic research, such as water temperatures and water samples at various depths, and specimens of bottom material.

(*b*) Determination, by reference to control stations, of the position of each sounding and the location and examination of the numerous features, such as rocks, reefs, wreckage, aids to navigation, etc., that must be charted for the guidance of navigators.

(*c*) Recording and plotting all data in order to provide permanent records that will show clearly all the information obtained by the survey and serve as a basis for chart construction and coast-pilot compilation.

With few exceptions, hydrographic work is carried on as a part of combined operations which may include the location of the necessary control stations by triangulation or traverse; topographic surveys for the delineation of land features; tidal and current surveys; and magnetic observations.

In this volume mention of other branches of work is confined in so far as practicable to reference to the publications in which they are described. The Coast and Geodetic Survey has also issued several publications covering special hydrographic operations. Such operations are covered in this manual by a general description and reference to the publication in which complete details will be found.

Part 1.—GENERAL REQUIREMENTS FOR HYDROGRAPHIC WORK.

In this part of the manual are given the general requirements for hydrographic work prescribed by the Director of the Coast and Geodetic Survey to govern the execution of all hydrographic surveys. They are supplemented by special instructions covering the specific requirements for each project contemplated

In a number of cases page or chapter references in parentheses have been inserted at the ends of paragraphs. These references give the page or chapter of part 2 of the manual where the subject treated in the paragraph is discussed or where standard methods, that are used by field parties and that comply with the general requirements, are described. The general requirements are as follows:

1. **Data to start survey.**—Special instructions for all hydrographic surveys will be accompanied by such information, available from previous surveys, as is required by the nature of the work. This information usually will include geographic positions and descriptions of stations previously located; blue prints of previous triangulation schemes; descriptions and elevations of tidal bench marks; copies of previous hydrographic and topographic surveys; and information as to dangers reported or other special features to be examined. All such data should be examined without delay to make sure that they are clear and complete.

2. **Specifications for control.**—Unless otherwise directed in special instructions, the main control for all coastal hydrography shall consist of stations located by third-order triangulation or traverse at intervals of about 5 miles along the coast. To supplement the main control, intermediate stations shall be established at intervals of about 2 miles along the coast, such stations to be located by theodolite cuts, plane-table triangulation, or other methods of equal accuracy. Any additional stations required may be located by plane-table traverse, sextant angles, or other similar method. (See p. 30.)

3. The number and distribution of stations should be such that all sounding lines and features within the field of work can be located with sufficient accuracy for charting purposes.

4. **Recovery of stations.**—In order to furnish information for the correction of office records as well as to provide control for hydrographic work, the sites of all previously established control stations within the field of work should be visited, if practicable, and a thorough search made for the station and other marks. A station shall not be reported as lost unless an exhaustive search or changes in the locality establish this fact beyond reasonable doubt. If such a search is impracticable, a statement relative to the extent of the examination shall be furnished in order that all available information relative to the status of the station may be on hand for proper notation in the office files.

5. Establishment of control.—For all operations involved in establishing new triangulation or traverse stations and in marking and describing such stations, both new and recovered, the instructions in the Manual of Third-Order Triangulation and Traverse shall be followed.

6. For similar operations relating to stations established by topographic methods, the instructions in the Topographic Manual shall be followed.

7. When a station is located by a sextant position obtained at the station, at least three angles should be taken. If this is impracticable, a sum angle between the two outside objects shall be measured. When the station is located by sextant angles from other points, at least three cuts giving good intersections should be obtained. All positions and angles obtained for this purpose shall be carefully recorded either in the sounding record or in a special angle record. (See par. 60a and pp. 30 and 79.)

8. Sextant locations should be confined, in so far as practicable, to relatively unimportant stations. In general, important stations and objects of value for landmarks, such as lighthouses, beacons, prominent buildings, etc., should be located by triangulation or traverse.

9. The officer in charge shall make sure while still in the field that the position of every station used for control is determined with sufficient accuracy for the scale of the projection on which the work is plotted. This must be tested by actual plotting or computing as soon as practicable after the observations are made.

10. Signal building.—When building signals over stations, care shall be taken not to disturb the station or other marks.

11. Names of stations.—Each control station shall be identified by a name or a description. Each recovered station shall retain the name assigned by the original survey, but a new station established with reference to an old station and not in the exact location of the latter shall have a different name.

12. Names of objects.—For convenience in recording and reference, a short name of not more than four letters shall be assigned to each signal erected or object existing over a station. If the station name or description meets this requirement, the same name may be used for the signal or object; otherwise a second name shall be assigned for use in hydrographic work. The use of names similar in sound or spelling in the same locality and the repetition of the same name on any one sheet shall be avoided.

13. Establishment of tidal stations.—Sites for tidal stations or information governing the selection of such sites will be given in special instructions. In establishing tidal stations the directions in the Instructions for Tide Observations shall be followed.

14. Size of hydrographic sheets.—A sheet 31 by 53 inches is considered the standard size for hydrographic work, and Whatman's standard paper of this size, backed with muslin, shall be used for smooth hydrographic sheets whenever practicable. When larger sheets are required, only cloth-backed drawing paper of the type supplied by the bureau shall be used, and the length of such sheets shall not exceed 72 inches. In such cases the maker's name and number of the paper shall be noted on the sheet.

15. Scales.—Inshore hydrography shall be plotted on a scale not smaller than 1:20,000, and important harbors, anchorages, and channels shall be plotted on scales of 1:10,000 or larger.

16. Offshore hydrography may usually be plotted conveniently and economically on smaller scales, in which case scales that are multiples of 20,000 are preferred. The scale for an offshore sheet should not be smaller than is necessary to provide a sheet, of convenient size, that will extend out a short

distance beyond the offshore limit of the proposed work and will include the stations necessary for control.

17. The scale adopted for the survey of a certain area shall not be smaller than the scale of the existing or proposed chart of the area.

18. **Laying out sheets.**—In order to use as few sheets as practicable for the survey of any region, each hydrographic sheet should be laid out in such a manner as to cover as much water area as possible while providing for suitable overlap of adjacent sheets and insuring the inclusion within the limits of the sheet of all stations required for control. The overlap of adjacent sheets should be no larger than is required to provide the necessary control on each and to provide for suitable junction of surveys. (See par. 107.) Sheets containing small detached areas of hydrography should be avoided, if practicable, by placing subplans on sheets adjacent to such areas. (See p. 32.)

19. When practicable without sacrifice of the considerations mentioned above, sheets should be laid out so that the projection lines are approximately parallel with the sides of the sheet.

20. **Projections.**—Polyconic projections shall be used for all hydrographic surveys. In order to eliminate errors due to distortion of projections constructed under different climatic conditions, projections for smooth sheets shall be made, whenever possible, in the field. (See p. 31.)

21. The projection lines, depending on the scale, shall be shown as follows:

Scale	Projection lines
Larger than 1:10,000	Every half minute.
1:10,000 and 1:20,000	Every minute.
1:40,000	Every even minute.
1:60,000 to 1:100,000	Every fifth minute.
1:120,000 and smaller	Every tenth minute.

22. Projection lines shall be fine, full, black lines extending entirely across the sheet. Minutes of latitude or longitude shall be shown in black ink at each end of each parallel and meridian. For scales of 1:20,000 and larger degrees shall be shown for every fifth minute; for a scale of 1:40,000, every tenth minute; and for smaller scales, every thirtieth minute.

23. **Station symbols.**—After the projection is completed, the positions of stations to be used for the control should be plotted on the sheet. Triangulation and traverse stations shall be shown by small red triangles, with name of station and year of location lettered in red. Topographic stations shall be shown by red circles 3 millimeters in diameter, with name in red. Hydrographic stations (stations located by sextant angles) shall be shown by similar blue circles with name in blue. The exact position of each station shall be shown by a fine needle hole, accentuated by a fine black dot, which also shall be the center of the triangle or circle. When the hydrographic name of the object differs from the station name, the former shall also be shown with ink of the same color as the station name. When a syllable of the station name is used as a hydrographic name, it may be indicated by underscoring with ink of the same color. (See par. 142.)

24. **Verification.**—Each projection and all stations plotted thereon shall be checked with the utmost care, as all subsequent plotting of hydrography will depend on their accuracy. In transferring stations from other sheets, proper allowance must be made for distortion.

25. **Projection data.**—At the bottom of each sheet the latitude and longitude, with seconds in meters, of some one triangulation station plotted on the sheet shall be given. At the lower right-hand corner of each sheet the scale of the projection, the date of its construction, the initials of the persons making

and verifying the projection, and the initials of the persons plotting and checking the stations shall be given.

26. Shore line.—The shore line of the area covered by each sheet should be transferred from the topographic sheets or other sources. If surveyed with the plane table or other methods of sufficient accuracy for charting purposes, it shall be shown by a continuous black-inked line; otherwise, by a broken line.

27. The low-water line and other features outside the high-water line that may have been determined by topographic or other surveys should also be shown, being left in pencil for later modification from information obtained by the hydrographer.

28. When the shore line is surveyed or photographed on a different scale than that of the hydrographic sheet, it may be omitted and will be supplied later by the Washington or Manila office.

29. Sheet numbers.—Each hydrographic sheet used during a season shall be designated by a number, assigned in numerical order by the field party. The field number of each sheet shall be clearly shown in ink in one or more corners on the back of the sheet and shall be referred to in all correspondence, reports, etc., relating to the sheet until the latter has been registered and numbered in the office.

30. For surveys of the Philippine Islands, sheet numbers shall be assigned to each field party by the Manila office, and all records, reports, etc., shall be systematically marked in ink with the corresponding sheet numbers.

31. Depth measurement.—No type of sounding apparatus, not approved by the office, shall be used except for experimental purposes. Except as provided below, all soundings in depths of 15 fathoms or less shall be obtained with a lead line or sounding pole. In greater depths vessels equipped with approved types of pressure tubes or echo-sounding apparatus shall use such indirect methods when and as prescribed by instructions covering the work; otherwise depths too great for lead-line sounding shall be measured by vertical casts with sounding machine and wire. *Exceptions:* Where deep water extends close to shore, occasional wire soundings less than 15 fathoms, as at the inshore end of a line, will be acceptable, provided that, when such soundings are danger indications, they shall be developed with the lead line. The use of echo-sounding apparatus to a depth limit less than 15 fathoms may be authorized by special instructions.

32. Depth units.—Lead-line soundings will in general be obtained in fathoms and integral feet, but in smooth, shallow water they should be read to the half foot, if practicable. Cases in which greater accuracy is required will be covered by special instructions specifying the unit. Pressure-tube soundings shall be taken to the nearest half fathom in depths under 40 fathoms and to the nearest fathom in greater depths. Echo soundings shall be taken to the nearest half fathom in depths under 100 fathoms and to the nearest fathom in greater depths. Wire soundings will ordinarily be obtained to the nearest fathom. When taken by a survey launch engaged in surveys of regions where deep water extends close to shore, however, they should be read to the nearest half fathom in depths under 25 fathoms.

33. "No bottom" soundings are not satisfactory. If they can not be avoided in important areas, definite soundings must be obtained later. If such soundings occur near the limits of an area, due to the general depths becoming too great for the method of sounding in use or for other reasons, adjoining areas surveyed by other methods must overlap to a junction with definite soundings.

34. Depth limits for indirect methods.—When indirect methods are authorized for survey work, they may be used within the following depth limits except over important bars or wherever knowledge of exact depths is required: Pressure tubes, 15 to 100 fathoms; fathometer, 15 fathoms (unless a shoaler depth is specially authorized) to limit of capacity; Navy sonic depth finder, over 100 fathoms. Soundings not within these limits shall be treated in the same manner as "no bottom" soundings.

35. Verification of lead line.—Lead lines shall be verified, by comparison with a fixed measure while under tension equal to the weight of the lead in water, at the beginning and end of each day's work. One or more extra lead lines also should be tested in case of loss or damage to the line during the day. This work shall be supervised by an officer of the party.

36. The lead-line correction shall be obtained and recorded to the nearest tenth of a foot. It shall always be computed by first recording the lead-line length and next the true length by standard and not by mental computation, whereby the correction is entered by inspection and the true length by standard is omitted or entered later. (See p. 107.)

37. Use of pressure tubes.—Two tubes shall be used for each cast, being attached to the wire with cap end up and not more than 6 feet from the bottom of the lead. No correction to soundings shall be made for this distance. The mean of both tube readings shall be taken as the uncorrected sounding, but both depths shall be rejected and the sounding considered a "miss" whenever the uncorrected readings of a pair of tubes differ by an amount in excess of the following:

Depths		Allowable difference
15 to 40 fathoms	per cent of depth	3
41 to 70 fathoms	do	4
71 to 100 fathoms	do	5

38. If the average number of "misses" in one hour's run exceeds one in six casts, the use of that particular pair of tubes shall be discontinued until they have been tested, as indicated in paragraph 41, and the trouble remedied.

39. Any tube found defective by such tests shall be eliminated from further use. If the discrepancy is due to faulty handling, either by spilling or pumping water in trailing the tubes on the surface while reeling in, the method of operation must be corrected.

40. Additional soundings shall be taken in important areas where "misses" occur; otherwise they shall be taken when successive "misses" cause a gap greater than the space between sounding lines.

41. Tube corrections.—Corrections for tube readings shall be obtained by simultaneous vertical-wire measurements taken at least once each day and preferably in the middle of the working day. Two pairs of tubes shall be tested and compared at or near the minimum depth measured during the day, and each pair shall be tested at alternate 10-fathom intervals, starting at the even 10-fathom interval next deeper than the minimum depth and continuing throughout the depth range of the day's work. Thus, assuming that two pairs of tubes (call one pair *A* and the other *B*) are to be used for sounding in depths from 15 to 80 fathoms, *A* and *B* will be tested at 15 fathoms, *A* at 20 fathoms, *B* at 40 fathoms, *A* at 60 fathoms, and *B* at 80 fathoms. Great care shall be taken that the registering sheave used for the wire measurements has been tested for accuracy and is read when the tubes are at the surface and at the required depths, so that the depths to which the tubes are lowered will be known as accurately as possible. At the time of making each test the barometric pressure and the air and surface water temperatures shall be noted in the record.

42. Use of fathometer.—Since comparatively few soundings will be recorded, at least where the bottom slope is fairly uniform (see par. 100), the greatest care must be taken to get the true depth every time. The observer must note carefully the fluctuation of the red light, attend scrupulously to all adjustments, and be certain he records the mean position of the red light within the limit prescribed in paragraph 32.

43. Temperature and salinity observations.—When the fathometer is used for sounding, temperature observations of the sea water shall be made at a sufficient number of places and depths (depending on the variation of temperature from place to place and at different depths at the same place) to insure that the estimated mean temperature for each sounding will not be in error by more than 1° C. Salinity observations shall be made with sufficient frequency to establish the salinity at each sounding within 1 part in 1,000. (See pp. 69 and 73.)

44. Velocity of sound.—All soundings with the fathometer shall be taken with the instrument adjusted to standard speed (that is, with the middle reed of the tachometer vibrating at maximum amplitude), whereby all depths indicated are based on the assumed velocity of sound for which the instrument is calibrated. When the actual velocity of sound, as determined from temperature and salinity observations, differs from the assumed velocity, soundings shall be corrected by means of a correction factor and not by adjusting the speed of the fathometer.

45. Verification of fathometer soundings.—Fathometer soundings shall be checked by vertical-wire or lead-line soundings whenever observations for bottom temperature are made in accordance with paragraph 43 or bottom characteristics determined in accordance with paragraph 50. In such cases the fathometer shall be read to tenths of a fathom in depths less than 100 fathoms (to the nearest fathom in greater depths), and the vertical soundings shall be taken with the greatest possible accuracy.

46. Use of Navy sonic depth finder.—Soundings with this apparatus shall be checked whenever there is opportunity in connection with the determination of the character of bottom or the collection of oceanographic data.

47. Use of sounding machines.—Registering sheaves shall be used for all soundings obtained with sounding machine except when pressure tubes are used. For deep-sea soundings, the time of reeling out and in for each 100 fathoms shall be observed as a check. The tension for reeling in should not exceed 100 pounds.

48. Verification of registering sheaves.—Sheaves should be tested before use for the first time during a season and several times during the season. When found to have an appreciable error for the wire in use, suitable corrections shall be applied to the soundings obtained.

49. Record of tests.—All tests of sounding equipment shall be recorded in the sounding records. (See ch. 6.)

50. Character of bottom.—In all hydrographic work the character of the bottom shall be determined as frequently as necessary to meet the needs of navigation. Inside the 100-fathom curve such information should be sufficient to define the approximate limit of each type of bottom and should be especially complete in harbors and anchorages. Outside the 100-fathom curve the character of bottom shall be determined at intervals of about 5 miles over the surveyed area.

51. Oceanographic data.—Water samples and temperatures and bottom specimens shall be preserved only when directed by special instructions. When samples or specimens are collected, a label shall be pasted or tied to the bottle, giving an index number, the date, time, depth, latitude, longitude, number of position, and day letter.

52. **Position determination.**—Positions for hydrographic work in areas where a sufficient number of control objects are visible shall be obtained by sextant angles in accordance with standard methods, unless more precise methods are necessary as in the unusually close survey of an important locality or in detailed surveys to verify dredging operations in the vicinity of docks or slips. (See ch. 5.)

53. Beyond the limit of visibility of fixed objects, ships equipped with radio-acoustic sound-ranging apparatus shall use this method of control to the limit of sound reception and astronomical observations and dead reckoning beyond this limit. Ships not equipped with radio-acoustic apparatus may use the latter methods but should supplement them to as full an extent as is practicable or economical by the more accurate methods involving the use of floating signals. (See ch. 5.)

54. Indefinite objects, such as the tops of round hills and centers of islands, shall not be used for critical or inshore hydrography. In case it is necessary to use the tops of hills or mountains located by triangulation for offshore hydrography, definite and conspicuous points shall be selected as far as practicable.

55. **Adjustment of instruments.**—Sextants used for position determination shall be tested and adjusted at the beginning and end of each day's work and preferably several times during the day. Protractors shall be tested and adjusted before they are used for plotting and at frequent intervals during the season.

56. **Records.**—The "soundings" record book (Form 275) shall be used for recording all hydrographic work except wire-drag surveys, for which Form 411 shall be used, and deep-sea soundings with wire, for which Form 376 shall be used.

57. A separate set of consecutively numbered sounding volumes shall be kept for each hydrographic sheet. If work is done by more than one unit in the area covered by a sheet, a temporary number shall be assigned to each volume. After completion of all work on the sheet, the records of each vessel shall be grouped in proper order, the various groups shall be combined, and the complete set of records shall be numbered consecutively and permanently.

58. The field number of the hydrographic sheet shall be plainly marked in ink on the cover label and title-page of each volume of soundings.

59. In records of ship work the deviation card for the compass used for hydrographic work shall be entered on page 1 of the first volume of each set of records and in the proper record (with reference to date) if changed during the course of the work.

60. On the second page of each record volume for all hydrographic work the following shall be entered:

(*a*) An index of signals, aids to navigation, etc., the positions of which have been obtained by sextant angles recorded in that volume, with references to page numbers on which the position angles will be found.

(*b*) An index of special hydrographic information, such as currents, tide rips, etc., that may have been noted in that volume, giving in each case the page reference.

61. **Day letter.**—For proper identification, each day's work shall be assigned a letter in alphabetical order, such letter to be shown at the top of each page in the record. The survey ship and each smaller unit shall have a separate series, distinguishing them by using capitals of one color for the ship and lower-

case letters and a different color for each other vessel; these distinctions to be preserved in the records and sheets.

62. When the alphabet is exhausted for day letters, double letters or primes, as AA or A′, should be used. For colors, red, blue, and green should be given preference in the order named. Black or yellow shall not be used.

63. **Information notes.**—The information required at the top of the record page shall be given in full on each page used for recording.

64. On the first page of each day's work in the record the following shall be given (see ch. 6):

(*a*) Names of persons in charge, taking right angle and left angle, plotting, and recording.

(*b*) Name of leadsman (for lead-line sounding); otherwise a description of the sounding apparatus used—if machine, give type, weight, and form of lead, kind and size of wire, and instrument number of registering sheave.

(*c*) Instrument numbers of sextants, protractor, and clock.

(*d*) Type and location of tide gauge to be used for that day's soundings. If more than one gauge is to be used, specify where change is to be made.

(*e*) Statement that sextants and clocks are correct.

(*f*) Corrections to sounding apparatus or statement that it is correct. For lead lines, give results of test; for sounding machine, give correction to registering sheave and manner and date of testing, or reference to record in which these data are recorded; for tubes and echo-sounding apparatus, give page on which comparisons are recorded, also distance from caps of tubes to bottom of lead.

(*g*) State of weather, sea, and wind.

(*h*) Time party left headquarters and distance to point of starting work.

65. On the final page of each day's work in the record the following shall be given:

(*a*) Results of examination of sextants and clocks.

(*b*) Results of lead-line tests at end of day.

(*c*) Distance to headquarters and time of arrival.

(*d*) Statistics for day, including number of statute miles of sounding lines run, number of soundings obtained, and number of positions taken. (See p. 111.)

66. **Position numbers.**—Positions shall be numbered consecutively, starting with No. 1 at the beginning of each day. The position number should be entered in the proper column on the left-hand side of the record page on the same line as the first angle of the position and repeated on the right-hand side in the angle column.

67. **Time.**—Standard time shall be used in all hydrographic work, and the standard meridian shall be noted at the head of the column "Time" at the beginning of each day.

68. The time of obtaining a sounding or position shall be carefully recorded on the same line as the sounding or position number.

69. When stops are made for vertical casts, the time when the engines are reversed shall be considered the time of the sounding or position, and the time of going ahead again shall be noted below with the abbreviation "*ah*" in the position number column.

70. **Recording soundings.**—The subhead of the "Soundings" column at the top of each page shall give the units in which soundings are recorded. (See ch. 6.)

71. **Recording character of bottom.**—The character of the bottom shall be shown at the top of each record page and wherever changes occur by the usual abbreviations printed on charts. (See p. 158.)

72. **Compass heading.**—The vessel's heading by compass shall be entered at the beginning of each sounding line in the first column on the right-hand side of the page, and for ship work the compass used (standard or steering) shall be noted at the head of the column. Changes in course shall be noted in the same column by the abbreviation "C. C.," followed by the new course, care being taken that the record shows the exact time of such change.

73. **Recording positions.**—Positions shall be recorded in the "Angles and ranges" column. For sextant positions both objects and angles shall be recorded in this column, the objects always being named from right to left and the same order applying to objects used for supplementary cuts or angles.

74. When the same objects are used for successive positions, it is desirable to repeat the names, but if this will delay the recording of more essential data, the word "same" or letter "S" may be used at each position instead of the names, providing that the names shall be entered at the top of each page and that particular care is taken to record all changes in objects.

75. **Remarks.**—In the "Remarks" column shall be entered all additional information required for the proper understanding and correct plotting of the work, including the following:

(*a*) At the beginning and ending of each line the words "Line begins" or "Line ends," as the case may be, shall be entered. At the beginning and ending of each day, and when the general locality of the work changes during the day, these words shall be followed by the latitude and longitude of the position (giving the nearest lower parallel and meridian shown on the sheet) in order that the plotter may locate the position quickly by noting the section of the sheet, as divided by the projection lines, in which the position is located. When a line begins or ends less than 100 meters from the shore, a reef, breakers, or similar feature, the estimated distance in meters of the position from the feature shall also be given.

(*b*) When a sounding line passes within a short distance of any important feature, such as rocks awash, breakers, buoys, wharves, etc., a bearing and estimated distance to the feature should be noted.

(*c*) Changes in leadsmen or other personnel and changes in speed of vessel should be noted.

(*d*) Note should be made of special information such as changes in wind and current, existence of grass, growing or floating kelp or hyacinth, tide rips, whirlpools, etc. Localities where kelp is towed under and the stage of tide at which it is submerged should be given.

(*e*) Full explanation must be given of all corrections, rejections, and omissions in the record.

(*f*) Salinities determined in echo-sounding work shall be noted.

76. A distinctive reference mark shall be made against every sounding or time to which a note refers, and, if practicable, the note should be started on the same line.

77. Should there be any correction or fact recorded during the day that should be known before the smooth plotting is begun, a note calling attention to it should be inserted at the beginning of the day's record.

78. **Erasures** shall not be made at any time in the record, all corrections being made by crossing out the incorrect entry.

79. **Courses and bearings** shall be given in degrees, clockwise from 0° at north to 359°. If not true bearings, it must be noted whether they are magnetic or compass bearings. General directions may be given in points and will be considered magnetic unless otherwise noted.

80. Character of records.—A clear, complete, and accurate record is essential for satisfactory hydrographic work. The requirements given above shall be carefully observed in so far as they apply to the work in hand.

81. Boat sheets.—A boat sheet or set of sheets should conform to the limits of a smooth sheet. The field number of a smooth sheet shall be plainly marked on its boat sheet or sheets. If the smooth sheet is prepared first, a careful tracing of the projection intersections and stations may be used in preparing the boat sheet. In this case the tracing cloth shall be laid out flat for an hour or two to become acclimated and the transfer shall be made soon after the tracing is completed. (See p. 34.)

82. A boat sheet is used for plotting and directing field work and shows graphically the data obtained during the progress of the work. From this sheet the hydrographer determines the facts necessary to enable him to make a thorough survey of the area covered by the sheet. For the purpose of this study and for use as a reference record in plotting the smooth sheet, accuracy, neatness, and attention to details in the use of a boat sheet are essential. Only approved boat-sheet paper should be used, and the construction of the projection and plotting of signals should be accurate. Soundings, position numbers, and other data should be carefully entered. Suitable notes should be made on the margin of the sheet to call attention to the need for additional development before leaving the field and for assistance in preparing the descriptive report. No information should be put on the sheet carelessly at any time. Except in very unusual cases, the boat sheet should be kept up with the progress of the work by plotting the positions as the work is carried on and the soundings as soon thereafter as time permits. The sheet should be reviewed daily, and all omissions and doubtful plotting should be corrected before the details are forgotten.

83. All soundings, reduced by the use of predicted tides, should be plotted on the boat sheet in ink. If this is impracticable, a sufficient number shall be plotted to enable the hydrographer to keep a close watch on the work, to detect all danger indications or critical areas, to determine whether or not soundings on crosslines agree, and to make sure that the area is properly covered.

84. If a rock, breaker, signal, or other feature is located by sextant cuts, the latter should be carefully plotted, and the lines should indicate the positions from which the cuts are taken.

85. Limits of reefs, breakers, kelp, etc., should be sketched as accurately as possible, and isolated rocks or groups of rocks not actually located but sketched in their approximate positions or transferred from other sources should be so marked lest they conflict with other, and possibly more accurate, information. Any additional notes that will assist in plotting details on the smooth sheet also should be placed on the boat sheet.

86. Hydrography in advance of control.—When in exceptional cases it is desired to carry on hydrographic work simultaneously with the triangulation or topography, in order to save time or utilize the services of all of the party at the beginning of the season, preliminary locations of the control stations should be plotted on the boat sheet from the best information available. Such work must be planned with the view of ultimate compliance with the control specifications and should be replotted, with relation to the final locations of the stations, in ample time to permit any necessary additional work before the party leaves the field.

87. Systems of sounding lines.—Systems of parallel lines cover an area most evenly and economically and should be used, except in special cases where diagonal or zigzag lines may be preferable for the development of certain features.

88. In surveys along open coasts the main lines of soundings should be either normal or parallel to the general trend of the coast, or a combination of the two directions may be used. The bearings of the lines should be adopted with the idea of securing a complete survey in as economical a manner as practicable. (A discussion of this subject will be found in ch. 7.)

89. In fairly regular bottom crosslines should be run out to the 10-fathom curve, and beyond this limit when such lines can be used to check sounding lines that are not controlled by strong positions. In very uneven bottom crosslines are of little value for checking purposes and need not be run.

90. In bays, harbors, and similar indentations the bearings of the lines will depend on the configuration of the feature. The lines should be laid out so as to give a complete and economical development.

91. Adjoining systems of lines run by different vessels, or on different scales by the same vessel, shall overlap slightly. (See also par. 107.)

92. Spacing of lines.—The spacing of lines for each project will be given in special instructions. (The considerations governing the spacing of lines are given on p. 126.)

93. For the sake of economy care must be taken not to extend close inshore systems of development into open and deep areas where they are unnecessary.

94. Inshore limit of work.—In general, hydrographic work should be carried inshore approximately to the low-water line, using pulling boats if necessary in the shoaler water. When this can not be done, on account of surf or other dangers, explanation should be given in the record. In some localities soundings in to a limiting depth safe for hydrographic launches may be sufficient for charting purposes, in which case costs may be reduced by eliminating additional work by pulling boats. Such cases will be covered by special instructions.

95. Sounding speed.—When soundings are obtained between positions, the speed of the sounding vessel should be uniform between successive positions and in no case should be so great as to prevent accurate sounding; otherwise it should be varied to attain the approximate maximum speed at which soundings can be obtained at the intervals desired. (See p. 129.)

96. Sounding interval.—The interval between soundings will depend on the nature of the bottom and the depth of the water. Short intervals are desirable whenever a close determination of the bottom profile is important, as in channels or when crossing bars, ridges, submarine valleys, or shoals. In general, intervals should be uniform between successive positions.

97. Uniform intervals for lead-line soundings, by hand or machine, and for tube soundings should be secured by adopting a definite time interval between soundings. This interval should be an integral factor of 1, 2, or 3 minutes, but otherwise should be the shortest time, to the nearest 5 or 10 seconds, in which soundings can be obtained regularly. (See p. 130.)

98. In depths of critical importance to navigation or where the bottom is very irregular, the uniform interval should be abandoned and soundings taken as rapidly as is consistent with accurate work. In such cases the recorder must be careful to note the exact time of each sounding.

99. Intervals between vertical-wire soundings should not exceed one-half the distance between sounding lines. Fathometer (red-light method) sounding intervals are prescribed in the next paragraph. Fathometer (white-light method) and Navy sonic depth-finder sounding intervals should be from 2½ to 10 minutes, depending on the depth.

100. Fathometer (red-light method) sounding interval.—Because of the great rapidity with which soundings can be taken by this method, a distinction is made in that the sounding interval is between recorded soundings and not between successive soundings and is varied in such a way as to give a true profile of the bottom without superfluous soundings. To accomplish this purpose, soundings shall be recorded as follows:

(*a*) At intervals of about 10 minutes where depths do not vary more than 5 per cent.

(*b*) All marked changes in depth at instant of change.

(*c*) Whenever a sounding is taken by any other means.

(*d*) Soundings need not be recorded on even-time intervals nor at times of taking angles or other position fixes, but the exact time of every sounding and position fix must be noted to the nearest five seconds.

101. Position interval.—The interval between positions will depend on the character of the hydrography and the scale on which it is plotted. Positions should be taken with sufficient frequency to insure proper direction of the work and to locate the sounding lines with the accuracy required for charting purposes. For work on large scales, the interval should seldom exceed three or four minutes but may be increased considerably for offshore work on small scales. Positions should be taken at the beginning and end of each line. In crossing narrow channels a position near the middle as well as one on each side should be taken.

102. For work in moderate depths, where a number of soundings are taken between positions, the latter ordinarily should be taken on the full minute and when possible at uniform intervals, as this will assist in plotting and spacing soundings. In this class of work additional positions should be taken as follows:

(*a*) When the vessel gains full headway at the beginning of a line or is slowed down near the end of a line, and at all other times when the speed is changed.

(*b*) Just before an appreciable change of course. When the change is considerable, positions should be taken both at the time the change is made and as soon as the vessel is on the new course, the track of the vessel, if the scale warrants, being plotted as a curve and not as a sharp angle.

(*c*) When the depth changes abruptly and considerably.

103. When soundings are taken with wire, a position may be taken at each sounding, but when the soundings are fairly close together and there is little probability of deflection from course due to currents or other causes, a position every second or third sounding usually will be sufficient.

104. Radio-acoustic position interval.—Except for any limitations that may be imposed by the time required to obtain positions by this method, the interval between positions should be governed by the considerations applying to all position-finding operations.

105. Extent of survey.—In general, surveying operations in any region should be sufficient to determine the depths and character of the bottom and to locate all dangers and other features that should be charted for the guidance of the mariner. The chief of party should not hesitate to decrease the sounding-line spacing prescribed in special instructions if this appears desirable in areas where the nature of the shore line indicates the possibility of hidden dangers or where ships are likely to approach the land, as in anchorages, and off projecting points and promontories. Special attention should be paid to this phase of operations in regions previously unsurveyed.

106. Depth curves.—As far as the development of bottom relief is concerned, a valuable test of the completeness of the survey is obtained by drawing the depth curves specified in paragraph 156. In some cases auxiliary curves will be needed to develop significant depths. In general, the information from sounding lines should be sufficient to permit the delineation of continous curves. Special care must be exercised in this respect when the sounding lines are parallel to the coast.

107. Junction of surveys on different sheets.—Except as provided in paragraph 91, junction of work on adjacent contemporary sheets shall be effected by running the limiting line of soundings on one sheet at the proper distance (as prescribed by the instructions for the work) from the corresponding limiting line on the other sheet. Any discrepancies in the depth curves at the junction shall be investigated and corrected before leaving the field. When a junction is made with previous surveys, an overlap shall be secured by rerunning at least one line of soundings forming the limit of previous work. In this case any discrepancies shall be investigated to determine their probable cause, and details relative to the investigation made and conclusions reached shall be included in the descriptive report.

108. Danger indications.—It must not be assumed that the regular system of sounding lines will show the least depth in any region. A sounding showing even slight change from the average depth should be regarded as an indication of a possible shoal, and such evidence is greatly increased when shoaler soundings occur on adjacent lines in the same locality.

109. Such indications should be emphasized on the boat sheet as soon as noted, by ringing with red pencil or other means, and a very careful and complete examination to develop the bottom thoroughly and to determine the least depth shall be made, regardless of any prearranged system of lines. (See p. 131.)

110. When control is weak, as in dead reckoning, so that it may be difficult to find the shoal again, or when it may be uneconomical to revisit the locality, the examination shall be made at once, dropping a marker buoy and temporarily discontinuing the regular line if necessary; otherwise the examination should be made as soon as practicable. Care must be taken not to postpone such work until near the end of the season, when stormy weather may prevent the completion of all work planned.

111. When the bottom is rocky, or when detached rocks are known or suspected to exist, additional precautions shall be taken. The sounding interval should be made as small as possible and a close watch kept on both sides of the sounding line for shoal indications, such as current swirls, kelp, piling up of swell, etc.

112. Local information.—In all regions pilots, fishermen, shipmasters, and others with local knowledge should be consulted freely for the purpose of collecting hydrographic information, and all reports or rumors of rocks and shoals must be investigated.

113. Visible features.—These may be located by angles from shore stations, by positions taken close by, or by sextant cuts from three or more sounding line, or special, positions.

114. In the case of rocks or similar features that are bare at some stage of the tide, their height at low tide or the stage of tide at which they are awash shall be noted. (See par. 160c.)

115. Development.—The primary duty of the hydrographer is not the mechanical operation of running sounding lines but is properly to develop the area being surveyed. For the development of shoal indications and such features as channels, bars, and flats, or when working under unusual conditions, as in very strong currents, the methods generally used for surveys should be modified as may be necessary to secure a complete and economical development of the feature under examination. (See pp. 131 to 133.)

116. **Wreckage.**—All wreckage not afloat should be located, and as complete information as practicable should be furnished. Large pieces of floating wreckage or logs that might cause damage to ships, sighted in areas where such obstructions are not commonly encountered, should be reported to the office by radio or telegraph.

117. **Use of wire drag.**—Dragging for dangers, using the standard or light wire drag or improvised apparatus, should be resorted to in cases of important channels and anchorages, where obstructions have been reported but not found, or where the nature of the bottom and adjacent shore indicates the probable existence of dangers that may be missed by ordinary sounding lines. In many cases time can be saved by developing danger indications with the drag. Unless otherwise directed, all drag work shall be executed in accordance with the requirements of Coast and Geodetic Survey Special Publication No. 118.

118. **Clearing marks for dangers.**—Care shall be taken to note in the field all useful ranges, bearings, and other marks for clearing dangers or passing close by or over them. These shall be noted in the descriptive reports and shown on the sheets. (See par. 160 *k*.)

119. **Depths off wharves.**—Lines shall be run to and along the outer faces of wharves and in docks and slips. The lines shall be run at such distances off the faces of the piers as will give the depths at the bilge and keel lines of vessels using them.

120. **Development of remote areas.**—For development of areas beyond the limit of visibility of shore stations, floating signals located with reference to the shore stations shall be established, if practicable, in order that details of the areas may be plotted in their proper positions. When dead reckoning only can be used, the work may be tied into a single well-located floating signal.

121. **Comparison with previous surveys.**—In executing hydrographic surveys, comparison shall be made with the results of previous surveys and with charts covering the region, and such comparison shall be made the subject of special comment in the descriptive reports. When dangers or less depths previously indicated on a chart, sheet, or publication are not found by the survey in progress, the locality must be so carefully examined and the records must be so complete as to show beyond doubt that the danger does not exist; otherwise no previously reported danger or less depth can be removed from any publication.

122. When a shoal is found close to one previously located, sufficient examination must be made to determine whether the newly found obstruction is a separate shoal, an unknown extension of the one first located, or the same feature with a different location due to different or faulty methods of control.

123. **Verification of sailing lines.**—A line or lines of closely spaced soundings should be run along the center lines of channels and along ranges and sailing lines. Such ranges and sailing lines shall not be recommended for use unless this is done.

124. **Determination of aids to navigation.**—The positions of and depths at all aids to navigation in the area of the field of work should be determined. If found to be out of position or unfavorably located, this should be promptly reported, as well as any recommendations as to desirable positions for additional aids to navigation. Even outside of the limits of proposed work, when practicable, lights and buoys established by proper authority should be determined in position and described when they are not shown on the charts or have not previously been determined by this bureau.

125. Vessels en route from one port to another, when weather and other circumstances will permit, should verify the positions of lightships and seacoast buoys.

126. Revision of shore line.—When a change is found in shore line previously surveyed or when the hydrography precedes the topography, the important features should, if practicable, be located in connection with the hydrography by carefully estimated or measured distances from inshore positions of the sounding lines and by determining prominent objects by sextant cuts (preferably three at each point) and sketching in the intermediate shore line. Shore line so located shall be drawn with a broken line, and a proper note shall be made on the boat sheet to indicate the revised shore line, stating the method used in determining it.

127. Blank areas on charts.—Surveying vessels when proceeding to or from the field of work should take opportunity, when it will not materially delay more important duties or interfere with their instructions, to obtain occasional soundings in areas on the charts where no information is at present given, particularly in the ordinary tracks of vessels. Such soundings may be plotted on charts. Complete data regarding the control should be furnished.

128. Information affecting navigation, reports of dangers, and changes in aids to navigation.—All persons in the service of the Coast and Geodetic Survey should communicate to the director any valuable information obtained affecting the interests of navigation along the coasts. Special reports should promptly be made of any information of the following classes (giving in each case the authority and such recommendations as may seem desirable): Rocks, reefs, shoals, or sunken wrecks (with depth of water over same), either not shown or incorrectly shown; aids to navigation differing in any respect from the data given on the charts or in the light or buoy lists; important errors or omissions on charts or in Coast Pilots; changes in depths or directions of channels; changes in coast line, currents, etc.

129. Supervision by chief of party.—During the progress of work, close supervision of field work and frequent inspection of boat sheets and records by the chief of party are required. He shall assure himself, by personal inspection of field operations when necessary, that all units under his command are carrying on such operations in accordance with the requirements. When examining boat sheets, close attention shall be given to the adequacy of the survey, with special reference to the determination of the least depth on shoals, the location and data regarding rocks of all classes, the least depth and extent of bars obstructing a fairway, and the development of channels having moderate depths. Each channel should be studied carefully, from soundings plotted on the boat or smooth sheets, to make sure that the soundings are sufficient to show the limits and navigable depth of the channel throughout its entire length, or to determine where additional soundings are required. Sounding records shall be examined, daily if practicable, to make sure that they are kept in accordance with the general requirements and are complete and satisfactory in all respects. The fact that boat sheets and records have been examined shall be noted in the records, together with the date of inspection. This note should contain any instructions to the hydrographer, such as soundings to be verified, references concerning lack of completeness or clearness in the record, and any instances where the records do not conform with the general requirements. When it is impracticable to examine the records daily by reason of the detached work of a party, the note may be made at the close of the day upon which the examination is made and should state the period in the records covered by the examination.

130. Office work on records in field.—The office work on records in the field ordinarily will consist of entry of tide reducers, reduction of soundings to the required plane of reference, entry of data called for on the cover label and title-page, preparation of a list of signals, and a final examination to make sure that the records are complete in every respect.

131. Planes of reference.—The planes of reference adopted for the reduction of soundings and the publication of charts of the Coast and Geodetic Survey are as follows:

(*a*) For the Atlantic and Gulf coasts of the United States and Porto Rico, the mean of the low waters.

(*b*) For the Pacific Ocean, the mean of the lower low waters, except for Wrangell Narrows, Alaska, where the plane is 3 feet lower than the mean of the lower low waters.

132. Reduction of soundings.—Soundings are reduced by applying to them corrections determined by tests of the sounding apparatus, and also by applying the tide reducers; that is, corrections for stage of tide above or below the reference plane. (See p. 117.)

133. Correction to sounding apparatus.—This correction may be omitted if less than 1 per cent of the depth below the reference plane. When over this amount, corrections to lead line shall be entered in integral feet for open-ocean areas. In all other areas, including entrance bars and channels, they shall be entered to the nearest half foot for depths of 10 fathoms or less and in integral feet for greater depths. Corrections for other sounding apparatus shall be entered to conform with the depth unit. (See par. 32.) In all cases the depth at which the correction unit is changed shall be the depth below the plane of reference and not the actual sounding. In cases where the depths fluctuate above and below the depth at which the unit is changed, the smaller unit shall be used until the depths are uniformly greater than the limiting depth. The plus sign will be used for corrections to be added to the soundings and the minus sign for those to be subtracted.

134. Tide reducers.—The entry of tide reducers shall be governed by the same considerations as apply to the entry of corrections to sounding apparatus, except that they shall not be entered when the general depths exceed 100 fathoms and that, as most reducers are to be subtracted from the soundings, the minus sign may be omitted. The plus sign for reducers to be added, however, shall always be included.

135. In entering corrections and reducers the following equivalents shall be used:

(*a*) When the correction or reducer is entered in integral feet and is to be *added* to the sounding:

0 to 0.7 foot=0 foot.
0.8 to 1.7 feet=1 foot, etc.

(*b*) When entered in integral feet and to be *subtracted* from the sounding:

0 to 0.2 foot=0 foot.
0.3 to 1.2 feet=1 foot, etc.

(*c*) When entered in half feet, *whether added or subtracted:*

0 to 0.2 foot=0 foot.
0.3 to 0.7 foot=½ foot.
0.8 to 1.2 feet=1 foot, etc.

(*d*) When entered in fathoms and to be *added* to the sounding:

0 to 4.7 feet=0 fathom.
4.8 to 10.7 feet=1 fathom, etc.

(*e*) When entered in fathoms and to be *subtracted:*

0 to 1.7 feet=0 fathom.
1.8 to 7.7 feet=1 fathom, etc.

(*f*) When entered to the half fathom, *whether added or subtracted:*

0 to 1.7 feet=0 fathom.

1.8 to 4.7 feet=½ fathom.

4.8 to 7.7 feet=1 fathom, etc.

136. Units for reduced soundings.—For lead-line soundings obtained in the waters of the Pacific Ocean, reduced soundings shall be entered in fathoms and feet; elsewhere they shall be entered in feet. In both cases fractions of a foot shall be shown when they result from the reduction. For soundings by other methods in the waters of the Pacific Ocean, reduced soundings shall be entered to conform with the depth units (fathoms or half fathoms) prescribed in paragraph 32; elsewhere they shall be entered in integral feet.

137. Entry of reducers, correction to sounding apparatus, and other similar operations shall be checked, and the records shall show, by initials at the end of each day, the persons who made and those who checked the various entries and reductions.

138. Cover label.—The data called for on the cover label and title-page shall be entered in black ink except the position numbers and day letters, which shall be entered with ink of the color or colors used in the record.

139. List of signals.—A list of the signals used on each sheet shall be prepared and pasted inside the title-page of the first volume of records. The list should give the hydrographic name, full station name or description, year of location for triangulation or traverse stations, and information as to the record or sheet where the location of other stations will be found. (See p. 120.)

140. Plotting smooth hydrographic sheets.—Unless otherwise directed, all smooth plotting on hydrographic sheets shall be done by the field party. This work will include plotting the sounding lines, plotting soundings in pencil, and the showing of all other features by the proper symbols. In order that errors and omissions not apparent on the boat sheet may be detected in time for any necessary correction in the field, smooth plotting should be started as soon as possible after beginning field work and be kept up, as closely as practicable, with the field work. The initials of the persons who plot the sounding lines and soundings must be entered at the end of each day in the sounding record.

141. Character of drafting.—The drafting work on the finished hydrographic sheet requires accuracy, neatness, and legibility, and, of course, good judgment and knowledge of the work, but it does not require expert penmanship.

142. North the top of sheet.—In plotting and inking smooth hydrographic sheets, north shall be considered to be the top of the sheet (regardless of the direction of the sheet borders or the sounding lines) and, except as provided below, names, soundings, and position numbers and letters shall be entered so that the bases of the letters and numerals are normal to the meridian and with their tops toward the north. Triangulation-station symbols shall be plotted with the base normal to the meridian and the apex toward the north. *Exception:* Where it is desirable that names be lettered to conform to geographic features the above requirement may be disregarded, but in this case the names shall be lettered so as to be read when looking north.

143. Names shall, by their directions and proximity, clearly indicate the feature designated.

144. Plotting positions.—For this work the sheet should be protected by heavy tracing paper or tracing cloth, so that the protractor, especially if of metal, will seldom touch the sheet. Each position should be marked by a needle hole accentuated by a small ink dot. Successive positions should be connected by pencil lines. Small circles must not be used for marking positions. (See p. 137.)

145. The position number shall be shown at each position, and the day letter shall be shown at the beginning and end of each line, at every fifth position, and at the point of any decided change in direction of the line. Numerals and letters should be small and placed just below and on the right or left of the position, so that they will not be obscured by the soundings. Position dots and numbers and day letters shall be inked with the color assigned to the sounding vessel.

146. Plotting soundings.—Soundings from the column "Reduced soundings, field" in the sounding record shall be plotted in pencil by the field party, using a pencil hard enough to avoid smudging but not so hard as to indent or cut the paper. (See p. 137.)

147. Spacing soundings.—Soundings shall be plotted in accordance with the recorded time except when a note in the record showing a change in sounding speed necessitates an adjustment of spacing to conform to the change in speed. Spacing dividers shall be used and the soundings not spaced by eye. Where considerable change in the direction of the line is made and the soundings are continued, allowance must be made for plotting the soundings on the path made in turning. The center of the depth figures shall indicate the position of the sounding.

148. Style and arrangement of numerals.—Vertical block numerals (no hair lines) shall be used. They should not be so large as to mar the appearance of the sheet nor so small as to be illegible. For general smooth-sheet plotting, the numerals should average about 2 millimeters in height, with some reduction, if necessary, in congested areas.

149. Selection of soundings.—In so far as practicable, the smooth sheet should show all soundings obtained. Where the number of soundings taken is greater than can be plotted on the sheet, however, as many soundings should be plotted as is consistent with clearness. Those showing the least depths on shoals, greatest and least depths in channels, and changes of slope must be shown, the selection being such that a cross section drawn from the soundings will show all important features. In no case should a mere mechanical selection be made, as, for instance, every third or every fourth sounding. (See also next paragraph.)

150. Distinctness of important features.—It is important in plotting hydrographic sheets that the more important features, such as rocks and least depths on shoals, shall be perfectly clear and distinct, and great care must be taken not to obscure them by attempting to plot all of the numerous soundings that may have been taken for the development of such a feature. If for any reason an important feature is not clear on the finished sheet, or is so shown that there is a likelihood of its being overlooked, a note should be added calling attention to it. Along rocky coasts care must be taken that zero soundings are not shown in such a manner as to be mistaken for off-lying rocks or islets.

151. Depth unit for plotting.—The unit to be used in plotting soundings will depend upon the locality, character of the body of water, and closeness of detail to be shown, but only one depth unit (fathoms or feet) shall be used for the whole area of any sheet.

152. Except as provided below, soundings in the waters of the Pacific Ocean shall be plotted in fathoms and sixths of a fathom to a depth of 6⅚ fathoms; in fathoms and quarter fathoms from 7 to 10 fathoms (disregarding fractions of feet in the reduced sounding column and plotting three-sixths and two-fourths fathom as one-half fathom); and in whole fathoms in greater depths. *Exception:* When a hydrographic sheet includes all or a part of an area that is covered by a chart on which soundings are shown in feet, soundings shall be plotted in feet.

153. In other regions soundings shall be plotted in feet except in oceanographic work or offshore soundings where the survey is beyond the limits of charts on which soundings are shown in feet. In the latter case soundings shall be plotted in fathoms. At important points on navigable bars and at critical places in channels having a general depth of 42 feet or less, and in shallow inclosed waters and inside routes, soundings shall be plotted to the nearest half foot. Otherwise no fractions shall be shown unless required by special instructions. On off-lying dangers all fractions shall be dropped, the depth in integral feet being given; elsewhere fractions shall be dropped unless the soundings are reduced to tenths of a foot, when fractions of 0.7 or less shall be omitted and those of 0.8 or more entered as the next whole foot.

154. Conversion of sounding units.—When soundings are reduced to tenths of a foot and plotted to the half or quarter foot, in accordance with special instructions, the equivalents given in Table 2, page 158, shall be used in plotting. When soundings are plotted in fathoms and quarter fathoms, the following equivalents shall be used:

1 foot and 2 feet=¼ fathom.
3 feet=½ fathom.
4 and 5 feet=¾ fathom.

When plotted in whole fathoms, 1 to 4 feet shall be dropped and 5 feet shall be plotted as the next whole fathom.

155. Minus soundings.—When soundings represent the height above the plane of reference of an area bare at low water, they should be given with a minus sign and inclosed within the low-water line. In plotting minus soundings the following equivalents shall be used:

0 to —0.5 foot=0 foot.
—0.6 foot to —1.5 feet=—1 foot, etc.

156. Plotting depth curves.—The depth curves must be drawn on the sheet. All soundings of the depth represented by each curve must be on or within it. When curves run so close together as to be confusing, the less important, or those representing greater depths, may be dropped. Curves must not be completely drawn where the information is insufficient, but parts of curves or curves with broken lines may be put in.

The field party should leave the curves in pencil. When the sheet is verified at the office the curves will be inked with full colored lines, according to the following scheme:

Zero or plane of reference curve	Yellow.
6-foot or 1-fathom curve	Green.
12-foot or 2-fathom curve	Red.
18-foot or 3-fathom curve	Blue.
24-foot or 4-fathom curve	Yellow.
30-foot or 5-fathom curve	Red.
36-foot or 6-fathom curve	Green.
60-foot or 10-fathom curve	Yellow.
120-foot or 20-fathom curve	Blue.
300-foot or 50-fathom curve	Red.
600-foot or 100-fathom curve	Green.
1,200-foot or 200-fathom curve	Yellow.
6,000-foot or 1,000-fathom curve	Blue.

157. Enlarged scales of complicated areas.—When it is difficult to plot the soundings to show the development of a complicated area on the scale of the general hydrographic sheet, an enlargement of the plotted positions should be made and the soundings plotted on the enlargement, which may appear on the sheet as a subplan. The enlargement should be to some natural scale which shall be stated on the plan. The curves at the margin of the subplan should be reduced and transferred to the main sheet to make sure that the work is consistent.

158. Errors in record.—These may sometimes be detected during the smooth plotting, but no deviation from the record shall be made unless it is reasonable and supported by other evidence. Such cases, or the rejections of any part of the record, shall be fully explained by an initialed note in colored pencil in the record.

159. Use of boat sheets and notes in records.—All remarks, comments, etc., in sounding records should be carefully noted in plotting; abrupt changes in depth should be verified by rechecking tide reductions, etc.; boat sheets should be examined and compared to see that all essential information is on the smooth sheet.

160. Additional details on sheets.—In addition to the details mentioned heretofore, as much of the following information as has been secured by the survey shall be shown on the smooth sheets, using black ink unless otherwise noted:

(*a*) All rocks must be shown by the following symbols: Rock extending above high tide, heavy dot or shape; rock awash at any stage of the tide, three lines crossing; and sunken rock, simple cross. When the least depth over a sunken rock is obtained, however, the depth shall be shown with the legend "rock" or "rk" instead of the symbol. The same legend should also be used *with* the symbol when it is likely that the latter may be overlooked or mistaken for a defect in the paper. Great care must be taken not to confuse these symbols. See also section (*c*) below.

(*b*) Such features as reefs, ledges, and bars that are either bare or awash at low tide and wreckage, sunken, awash, or showing at high tide must be clearly marked *in pencil* to show their nature and extent by the proper symbols, legends, or combination of the two. The danger limit of rocky bottom having some depth of water, but which can not be investigated in detail, should be indicated by sunken-rock symbols.

(*c*) Definite information should be given on the sheet as to dangers which show at various stages of the tide, as "bares so many feet at low water," "awash at low water," "awash at high water," "breaks at half tide," "breaks in heavy weather only," and the like. "Awash" should always be qualified by the stage of tide at which it occurs, and the mere use of the symbol for rock awash will not be sufficient for any important danger. The height (above high tide) of rocks extending above high tide should be shown.

(*d*) Bottom characteristics should be noted *in pencil* on the sheet at moderate intervals and wherever changes occur, using standard abbreviations. (See p. 158.)

(*e*) When cuts are taken to breakers, their intersection should be indicated by the sunken-rock or rock-awash symbol, as the case may be. If there are no rocks, the spot should be marked by a broken line inclosing the word "breakers."

(*f*) Tide rips should be indicated by these words, qualified as heavy, moderate, or light, and surrounded by a broken line showing their approximate limits.

(*g*) The positions of and depths at all aids to navigation should be shown *in pencil*, using the proper symbols.

(*h*) Large buildings and prominent landmarks determined in connection with the hydrography should be indicated on the hydrographic sheet and designated by appropriate legend; if necessary, a reference letter or arrow may be used and the legend placed where there is more room.

(*i*) The limits of grass, kelp, etc., and the conditions of tide or current when these show must be indicated. If the bottom is grassy, it must be so noted. Kelp may be marked with the proper symbol or by the word "kelp," surrounded by a broken line showing the limits of this growth.

(*j*) The names of islands, points, rocks, reefs, shoals, banks, channels, creeks, etc., must be given *in pencil* on the sheet. Care must be taken to obtain these names correctly. Names should, as far as practicable, be placed on the land area, leaving the water area clear. Lettering should not be allowed to obscure soundings.

(*k*) All ranges, bearings for dangers, etc., and sailing lines on courses or ranges should be given and drawn as follows: The range in black lines broken with long dashes; the bearings in black dotted lines; and the sailing lines in black lines broken with short dashes, with the positions of the objects for ranges and bearings determined, marked, and named, and the names of the objects and the purpose of the range or bearings written along its line.

(*l*) Current stations and tidal stations must be plotted in position.

(*m*) The low-water line should be shown *in pencil* by the proper symbols or by a broken line with the nature of the area between the low-water and the high-water lines indicated by legends. This area should never be sanded. When the determination of the low-water line by the hydrography and topography differ, preference shall be given to the former.

161. **Limits of adjacent sheets.**—On each sheet the limits of work on all adjoining sheets shall be shown by a dashed pencil line, with notes of the sheet numbers from which the limits are taken.

162. **Inspection of plotting.**—The chief of party shall keep in close touch with the smooth plotting both to make sure that it is being properly done and to determine whether or not there are errors, omissions, or discrepancies that should be corrected in the field. (See p. 141.)

163. **Titles.**—Titles shall not be inked on original sheets by the field party but shall be furnished on Form 537. The information for the title shall include the general locality, special locality, names of persons actually in charge of sounding, and of chief of party, vessel, dates of beginning and ending work, and scale, together with a list of all data forwarded with the sheet. The title of a hydrographic sheet must clearly indicate the limits of the hydrography in conformity with the locality given in the record books pertaining to it.

164. **Statistics.**—Statistics for each hydrographic sheet, giving, under the heading "Statistics for sheet, field No. —," the total number of positions, soundings, and statute miles of sounding lines plotted on the sheet, shall be included in the descriptive report.

165. **Tidal data.**—A tidal note should be furnished for each sheet, giving the location of each tide gauge used for reducing soundings plotted on the sheet; and if there was more than one gauge, the parts of the sheet for which each was used. This note should also give the reading on each gauge for the plane of reference and the highest and lowest tides observed. It should be prepared on a separate sheet of paper to be forwarded with the hydrographic sheet.

166. **Descriptive reports.**—Descriptive reports shall be submitted to cover all hydrographic work. It is preferable to have a separate report for each sheet, but where much of the information in the report is common to several sheets, a single report may be submitted to cover two or more adjoining sheets of a season's work. Each report shall be headed "Descriptive report to accompany sheet (insert field number and title of sheet or sheets)." Writing should not

be nearer than 1 inch to the left edge of the paper. The report need not be in duplicate. The purpose of a descriptive report is to furnish information, not readily shown on the sheet, that will assist the cartographer in verifying and reviewing the sheet and in applying to the chart the data shown on the sheet. This information shall be given under the following headings, and in the order named:

(*a*) *Date of instructions.*—Give dates of original and supplemental instructions.

(*b*) *Survey methods.*—Describe the survey methods used and give complete details relative to any deviation from standard methods of obtaining depths or positions or of determining locations of signals. Mention any part of the work that is incomplete or less reliable and state the reason for the latter.

(*c*) *Discrepancies.*—Give complete details regarding discrepancies found and adjustments made, during the course of the work, either in depths, positions of soundings, or locations of signals. If unadjusted discrepancies remain, submit definite recommendations as to adjustments to be made for charting purposes.

(*d*) *Dangers.*—Describe the important dangers found in the area covered by the sheet, giving either the latitude and longitude of each obstruction or its distance and bearing from some feature that is named on the sheet; least water found, with position number of least sounding; ranges or bearings for clearing the danger; and any information, in addition to that appearing in the sounding record, regarding the extent of development, such as the time spent in drift sounding over the danger or in watching for breakers.

(*e*) *Channels.*—Describe important channels, giving least depth on entrance bar, if any; controlling depth in channel, with location of least depth; and usual draft of vessels that use the channel. If more than one entrance channel to a port, mention the one used to the greatest extent or submit recommendations as to the channel most suitable for use, with reasons therefor.

(*f*) *Anchorages.*—This information need be submitted only for regions where anchoring is difficult owing to depth of water or other reasons. Give depth, character of bottom, ranges for anchoring, and extent of use by survey ship or other vessels.

(*g*) *Comparison with previous surveys.*—Give results of comparison with previous surveys. Describe investigation made of any discrepancies found; give conclusions reached as to reasons for discrepancies and recommendations for adjustment.

(*h*) *Wire-drag groundings.*—When the report covers a wire-drag sheet or a sheet on which the wire drag was used in conjunction with other survey methods, give a list of all groundings where an investigation failed to find less depth than the drag depth, with probable reasons therefor, if determined; also all groundings not investigated, with reasons therefor.

(*i*) *Geographic names.*—Give a list of all new place names used on the sheet under two headings: (1) Well-established local names, and (2) names assigned by field officers. After each name give reasons for recommending its adoption. When this information is given in descriptive reports of topographic sheets, it may be omitted except for a reference to the report containing it. (See p. 145.)

(*j*) *Statistics.*—See paragraph 164.

Each descriptive report shall be prepared and signed by the hydrographer and approved by the chief of party.

167. Descriptions of hydrographic stations.—A description of each object, located by sextant cuts or positions, that may be recoverable and useful for future work shall be furnished on Form 524. This applies also to objects located by topographic methods. (See par. 6.)

168. **Landmarks for charts.**—A list of prominent objects on each sheet that are recommended for charting as landmarks for navigational purposes shall be furnished in duplicate on Form 567, one copy being attached to the descriptive report and the other mailed to the office under separate cover. In localities where prominent objects are numerous, a careful selection should be made of those best recognized and most useful for navigation. The scale of the chart should be considered in order to limit the selection of objects to a number that can be charted in a satisfactory manner. The same form shall be used to report charted landmarks no longer in existence. This information, under appropriate heading, should follow the data mentioned above, being separated therefrom by a ruled line.

169. **Ranges for compass deviations.**—A special report should be made, for each region surveyed, of prominent and easily distinguished objects and ranges that will be suitable and useful for the purpose of determining compass deviations of vessels.

170. **Abstract of temperatures and salinities.**—Parties using echo-sounding apparatus shall furnish at the end of each season an abstract of all water temperatures and salinities observed in connection with the use of such apparatus. This should be in the form of a special report giving the latitude, longitude, time, and depth of each observation.

171. **Progress sketches.**—Monthly, semiannual, and season's progress sketches, showing the work accomplished by field parties, are required by the regulations of the bureau. Standard specifications for the preparation of progress sketches shall be followed in all cases. (See p. 144.)

172. **Coast Pilot information.**—All hydrographic parties shall collect Coast Pilot information and furnish notes covering the data obtained. These notes should include information obtained while en route to and from the field of work as well as that gathered on the working grounds. Important information should be forwarded at once, and general notes should be submitted at the end of each season. In all cases where information in the pilots is found to be accurate and adequate a statement to this effect should be included in the notes. (See ch. 9.)

173. **Completion of field records.**—It should be the aim of the chief of party to turn in all field records and sheets in a completed condition as far as circumstances may permit. All field results shall be transmitted to the office as early as practicable and, unless otherwise authorized, before beginning another season's work.

174. **Approval of records.**—Before transmitting records to the office the chief of party shall inspect each sheet and record and furnish on a separate sheet of paper attached to the descriptive report for each hydrographic sheet or group of sheets a statement that the sheet and accompanying records have been inspected and are approved. This sheet should also serve for the conveyance of any information not included in the descriptive report that may be of assistance to the office in reviewing the work and for any recommendations for future field work that the chief of party may wish to make. If desired, a statement relative to the amount of supervision that the chief of party has been able to give to the field and office work or any other pertinent comment may be included. When a hydrographic sheet is transferred to another officer for completion, in accordance with instructions from the office, approval as above by the chief of party who transfers the sheet shall cover only the period for which the smooth plotting has been completed, which shall be specified on the approval sheet.

175. Boat sheets shall be forwarded to the office for use in final verification.

176. Sounding records and other data should not be duplicated except when specially directed, or when there is considered to be an unusual risk in the method of forwarding.

177. Records of hydrography controlled by precise dead reckoning, floating signals, radio-acoustic sound ranging, or astronomical observations shall be accompanied by all supplemental data obtained, such as current diagrams, precise dead-reckoning log sheets, tabulations of log tests and full-speed runs to locate signals, observations and computations of compass deviations, tests to determine the velocity of sound in sea water, bomb records, and computations of astronomical positions. The standard printed forms, where provided, shall be used for these data.

178. Sheets and records, when sent by mail, should be well wrapped and registered. A sheet and its records should be mailed at different times as a security against loss. When sheets and records are forwarded to the office, each package shall be numbered, beginning with No. 1 and continuing in consecutive order until all data for the season have been forwarded. The number of each package and the number or letter of each field sheet shall be noted in the transmitting letter.

179. Care of property.—Reasonable and proper care shall be taken at all times of vessels, instruments, and other property. (See p. 135.)

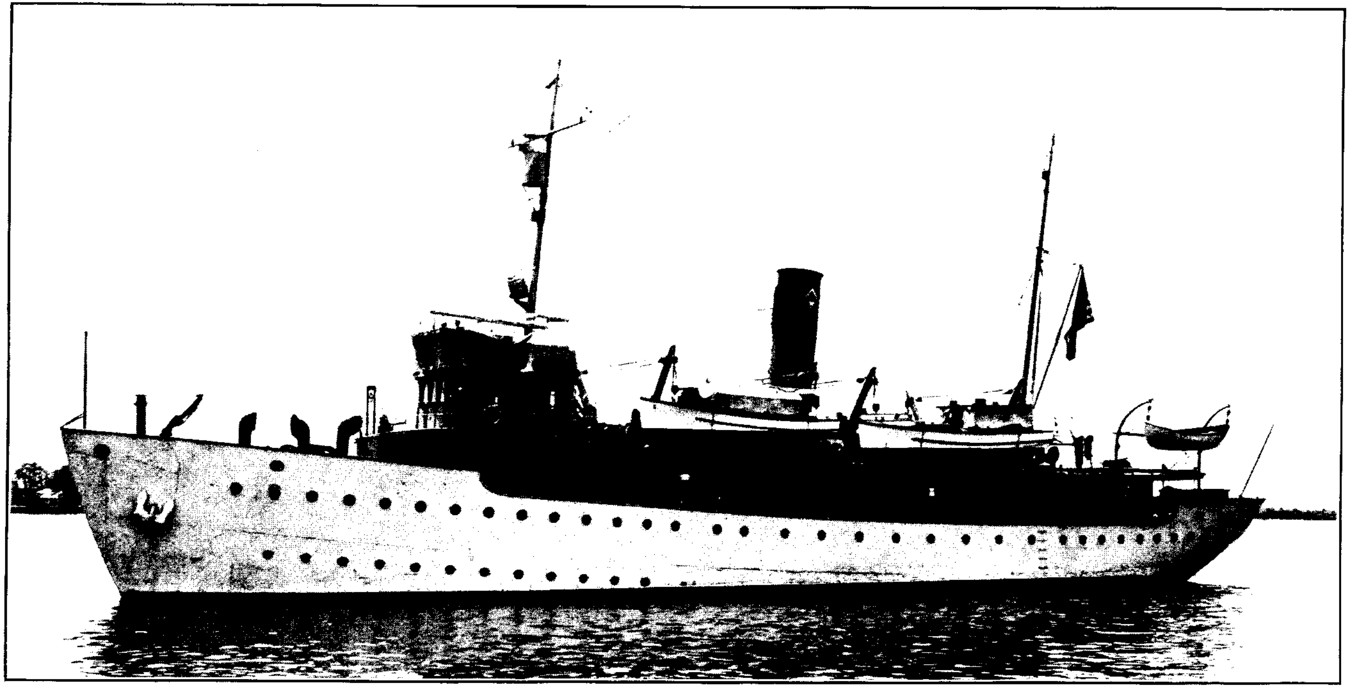

FIG. 1.—COAST AND GEODETIC SURVEY SHIP SURVEYOR

This ship is 172.8 feet long, 34.1 feet beam, and 12 feet draft. Her complement is 11 officers and 60 men; she has davits for hoisting four survey launches and several pulling boats. She is equipped with a fathometer and two electric sounding machines. One or two tenders usually operate in conjunction with this ship

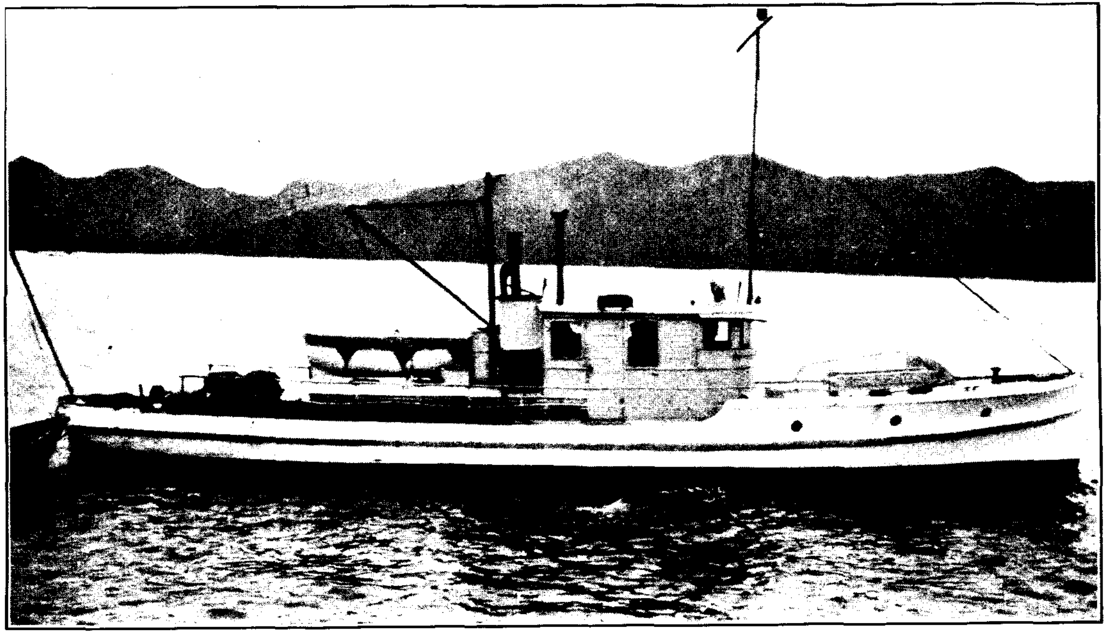

FIG. 2.—COAST AND GEODETIC SURVEY TENDER HELIANTHUS

This tender is 64 feet long, 13½ feet beam, and 4 feet draft. She has a 58-horsepower gasoline engine. Her usual complement is 2 officers and 8 men.

Part 2.—EQUIPMENT AND METHODS USED FOR HYDROGRAPHIC WORK

Chapter 1.—SURVEY VESSELS

TYPES OF VESSELS

The various types of vessels suitable for hydrographic operations may be divided into the four classes described below:

Survey ships.—These are seaworthy steam or motor vessels, usually from 100 to 200 feet in length, carrying a personnel large enough to operate from two to five survey units. Each ship generally operates as a complete party engaged in combined operations along a certain, and often extensive, section of the coast. In addition to furnishing living accommodations and transportation for the personnel, such a ship executes the greater part of the offshore hydrographic work.

As headquarters for combined operations, a survey ship should have suitable quarters for officers and crew, a well-lighted drafting room, ample storage space for supplies so that she can remain on the working grounds for a considerable period, and efficient apparatus for hoisting and carrying her survey launches and boats. For survey work a large bridge, affording as clear a view all around the horizon as practicable, and suitable space for installation of sounding and position-finding apparatus are essential. The propelling and deck machinery of a survey ship is subject to hard usage and should be of substantial construction.

Tenders.—This term is used to designate small steam or motor vessels, usually from 40 to 75 feet in length, with permanent living accommodations for sufficient personnel to operate them for hydrographic work. If quarters are available for a second unit, for topographic or other work, such an arrangement is economical. A tender may operate in conjunction with a survey ship, as a subparty, or as a separate party engaged in the survey of a harbor or small section of the coast. It should carry sufficient supplies to remain away from headquarters for at least one week and, in so far as practicable, should have the other special qualifications mentioned in the preceding paragraph.

Several tenders, operating with a Coast and Geodetic Survey ship, have been equipped for radio communication with the ship, which has added materially to the efficiency of the party.

Survey launches.—These are open or partly decked boats of various types, usually from 24 to 40 feet in length and with a draft from 2 to 3 feet, propelled by steam or internal-combustion engines. They are used for hydrographic work that can not be done safely or economically with a ship or tender, for transportation of units engaged in other classes of work, etc. Survey launches work from a ship or from shore headquarters, so that living accommodations or storage space for supplies are not required.

A survey launch should be as seaworthy as possible, strongly constructed, and should have as much clear space in the cockpit as practicable. Arrangements for hoisting and carrying such launches on the survey ship should be provided whenever possible. Launches that can not be hoisted are sometimes used through necessity, being towed from place to place, but, for their proper care and transportation when not in use, provision for hoisting all survey launches is by far more satisfactory and economical. Gasoline engines should be of the four-cycle type in order to insure proper speed control and quietness in running. When the clutch is used constantly, as in machine sounding, it is a good plan to provide, in addition to the spare parts usually carried, a complete spare clutch in order to reduce loss of time due to clutch repairs to a minimum.

Small boats.—In this division are the various types of ship's boats, propelled by oars, that are used for sounding close to shore, surf, breakers, or other dangers; for the survey of the shoalest parts of offshore dangers under development by a ship, etc. For running to and from the working grounds, transportation of units engaged in other work, and for certain classes of hydrographic work, such boats are often equipped with portable gasoline engines.

This class also includes flat-bottom, shallow-draft boats, propelled by small gasoline engines, that are used for surveys of areas of little depth, such as tide flats, shallow streams, etc.

SURVEYING EQUIPMENT

The fixed equipment of a vessel engaged in hydrographic work includes a drafting table on which the work is plotted; a platform for the leadsman, usually called a "sounding chair"; and one or more sounding machines. It may also include apparatus for measuring depths by the echo-sounding method and for radio-acoustic position finding. The instruments and apparatus used for depth measurements and position finding are described in chapters 4 and 5.

The arrangement of fixed equipment will vary considerably, depending on the design of the vessel on which it is installed. In general, it should be such that the officers, from their positions near the drafting table, will have as clear a view as possible around the horizon and will be able to keep a close watch on the helmsmen and on the operations involved in measuring depths. On ships and tenders there is usually enough room so that such an installation presents no special difficulty. On a ship, for example, the drafting table will naturally be located on the bridge, and the sounding chair can be installed on a wing of the bridge. Sounding machines and apparatus for obtaintaining positions by other than visual means can not be so conveniently located, but this is not important, as, when such apparatus is in use, the officers on watch are generally not confined so closely to the bridge as they are when sounding in moderate depths.

On survey launches, where space is limited, a satisfactory arrangement of fixed equipment will usually require a little study and experimentation. A suggested installation for a launch with open cockpit is given in Figure 3. On this type of launch a sounding machine is required only for work

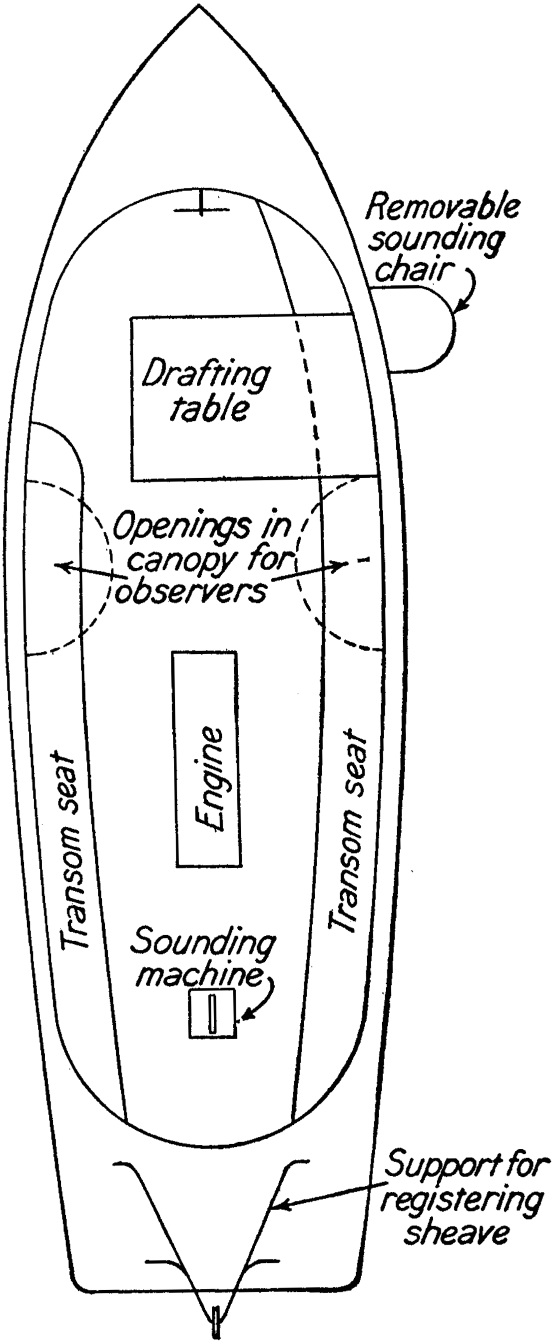

FIG. 3.—Installation of equipment on survey launch

in regions where deep water extends close to shore. It may be installed so that the wire leads over the stern or over either side.

A passageway around the drafting table (on either side desired) is convenient but is not essential if space is limited. On small launches consideration must be given to stationing the various members of the party so that the launch is trimmed properly.

Chapter 2.—PRELIMINARY WORK

The preliminary operations usually required in hydrographic surveying are outlined below. They are termed preliminary in the sense that they are in the nature of preparations for actual hydrographic work. The order in which they will be taken up and whether or not they will all be completed before sounding work starts will depend on circumstances.

The natural aim of a chief of party is to start actual surveying operations as soon as practicable after arrival in the field and to prosecute them vigorously and with as few interruptions as possible throughout the season. Having clearly in mind the results that it is desired to accomplish and the various working units into which the party can be divided, his success in maintaining the most economical relation between the various operations, in contending with weather and other conditions encountered, and in securing the maximum output consistent with good workmanship will depend in large measure on his experience and judgment in handling the different units of his party, both in preliminary and actual survey work.

Preparation of equipment.—Various types of vessels, instruments, and other items of equipment are used for hydrographic surveying as described in this manual. It is only necessary to emphasize here that such equipment should be put in the best possible condition before beginning a season's work in order that maintenance work during the season may be reduced to a minimum.

Reconnaissance.—Upon arrival in the field a reconnaissance should be made for the purpose of planning the work, recovering stations and tidal bench marks previously established, selecting sites for new control stations, and investigating local conditions to determine suitable locations for the necessary tidal stations.

In planning and carrying on extensive operations, it will often be of assistance to lay out, on a suitable chart, the limits of work to be joined and other boundaries of the project; limits and indentification numbers of sheets used for previous work, copies of which have been furnished; principal control stations, etc.

Establishment of control points.—This operation involves the recovery of stations previously located and the location of a sufficient number of new stations to meet the requirements for control. The amount of work necessary to achieve this result will vary considerably. In some localities previously established control may be so complete that few or no new stations need be located. In other regions it may be necessary to carry triangulation or traverse from a base more or less remote.

The requirements for control do not specify an exact distance between main and intermediate control stations. It is desirable that such stations be located at commanding sites, as on points, prominent elevations near the shore, etc., and approximate distances are given in order to allow the hydrographer reasonable latitude in adapting his control scheme to existing conditions.

The number of stations, in addition to the main and intermediate control stations, that are required will depend on the configuration of the shore line, and their establishment calls for considerable judgment. It is necessary to have a sufficient number of stations to control the survey, but too many are frequently as objectionable as too few, as a multiplicity of stations may lead to confusion in the field and increase the possibility of errors in plotting.

For ordinary coast hydrography the minimum distance between stations usually will be required on straight stretches of coast with no off-lying features. In such localities stations from 300 to 400 meters apart will suffice in most cases. With this spacing the inshore end of at least every other line can be determined by a sextant position, and the ends of other lines can be determined with sufficient accuracy by a distance and bearing from a station. Small bights into which one or two lines of soundings will be taken should have a station at or near their heads.

For the close development of important areas a strong control system must be provided, regardless of the number of stations required.

In general, the minimum number of signals that will provide the necessary control will be found most satisfactory and, to insure this arrangement, the officer in charge of the establishment of stations should understand the principles involved in selecting stations for sextant positions. In this connection a study of chapter 5 will be of value.

Hydrographic stations.—It is sometimes desirable to locate certain control stations by sextant angles or cuts. When such a station is located by a hydrographic party, it is called a hydrographic station. It may be located by a sextant position obtained at the station (see p. 79) or by cuts from other points. To obtain a sextant cut, the observer determines his position by sextant position and then measures the angle between a previously located station (preferably one of the stations used for the fix) and the new station.

When such stations are mountain peaks or similar features, it is a good idea to observe a vertical angle from one or more positions, so that the approximate height of the feature may be computed for possible use by the topographer or in chart construction.

Signal building.—The term "station" is used to denote a definite point on the earth's surface that has been located for control purposes. Its location may be indicated by marks established by the surveyor or by a natural or artificial object existing over it. Each station must be made sufficiently conspicuous to be visible from any point on the field of work where it is required for control.

Such objects as lighthouses, spires, etc., are ready for use. Others, such as bowlders, trees, etc., may be improved by whitewash or other means. Stations identified by marks must be made conspicuous by erecting structures called "signals" over them. Various types of signals are described in chapter 3. Care, of course, must be taken not to deface public or private property without the owner's consent.

Establishment of tidal stations.—All soundings on nautical charts show the depths of water at a certain stage of the tide called the "plane of reference." In order to secure tidal data for the reduction of soundings, it is usually necessary to establish one or more tidal stations in the vicinity of hydrographic work.

This involves the installation of a tide staff or automatic gauge, the recovery of bench marks previously established, the establishment of such new marks as are necessary, and the connection of the staff and marks by levels. Full directions for tidal work are given in the Instructions for Tide Observations, Coast and Geodetic Survey Special Publication No. 139. Brief instructions and spaces for entry of essential data are also provided in the volume (Form 277) used for recording tide observations.

Hydrographic sheets.—In order to plot his work in the form of a permanent record, the hydrographer must have a sheet on which the control stations, shore line, and certain other features are shown. The general requirements for such sheets are given in part 1.

Instructions for constructing projections will be found in Tables for a Polyconic Projection of Maps, Coast and Geodetic Survey Special Publication No. 5. The usual procedure is to construct the projection in pencil, after which it is verified and inked, the verifier examining it again to make sure that the inking has been properly done. The stations may be plotted in pencil, before or after the projection is inked, and checked before the symbols are inked.

The position of a station is usually given in degrees, minutes, seconds (to three decimal places), and seconds in meters, of latitude and longitude. The seconds in meters are the distances in meters along the parallel or meridian corresponding to the seconds of latitude and longitude. To plot the position of a station on a projection with one-minute intervals, it is only necessary to lay off the seconds in meters from the minute of latitude and longitude. For larger intervals the proper number of minutes in meters can be taken from the projection tables and added to the seconds in meters.

Stations and shore line determined by the survey in progress can, of course, be added at any time before the sheet is used for plotting.

A sheet carefully prepared and verified in accordance with the general requirements is called a "smooth sheet."

Sheet plan.—As different scales are generally used for inshore and offshore hydrographic work and as the size of a sheet is limited, more than one sheet usually will be required for the survey of an extensive region. Before starting the preparation of sheets, a plan of all or a part of the sheets required is usually laid out on a suitable chart or, in an unsurveyed region, on a reconnaissance sketch.

The distances that will be included on a sheet of given size and scale may be obtained readily from the following table of scale equivalents, by dividing the length or width of the sheet by the length of 1 mile on the given scale. For instance, a sheet 42 inches by 60 inches on scale 1:20,000 will include an area 11.5 by 16.5 nautical miles.

Scale	Nautical mile		Statute mile	
	Inches	Centimeters	Inches	Centimeters
1/5000	14.593	37.06	12.672	32.19
1/10000	7.296	18.53	6.336	16.09
1/15000	4.864	12.36	4.224	10.73
1/20000	3.648	9.27	3.168	8.05
1/30000	2.432	6.18	2.112	5.36
1/40000	1.824	4.63	1.584	4.02
1/50000	1.459	3.71	1.267	3.22
1/60000	1.216	3.09	1.056	2.68
1/80000	0.912	2.32	0.792	2.01
1/100000	0.730	1.85	0.634	1.61
1/200000	0.365	0.93	0.317	0.80
1/400000	0.182	0.46	0.158	0.40
1/1000000	0.073	0.18	0.063	0.16

A convenient method of laying out definite-sized sheets is to construct a plan of the sheet on tracing cloth, its length and width in nautical miles from the above table being laid off from the mile scale on the chart. This plan is then laid on the chart and shifted about until the best position for the projection is determined. When sheets of different sizes are required, their limits may be drawn on the chart and their sizes determined by a reverse computation. All sheets should be laid out in accordance with paragraphs 18 and 19 of part 1. When a station desired for control falls a short distance outside the limits of a sheet and the latter can not be shifted without sacrifice of other desirable considerations, a small section of paper can be attached in the proper position to include the station. Such an addition is called a "dog-ear." A typical sheet plan is given in Figure 4.

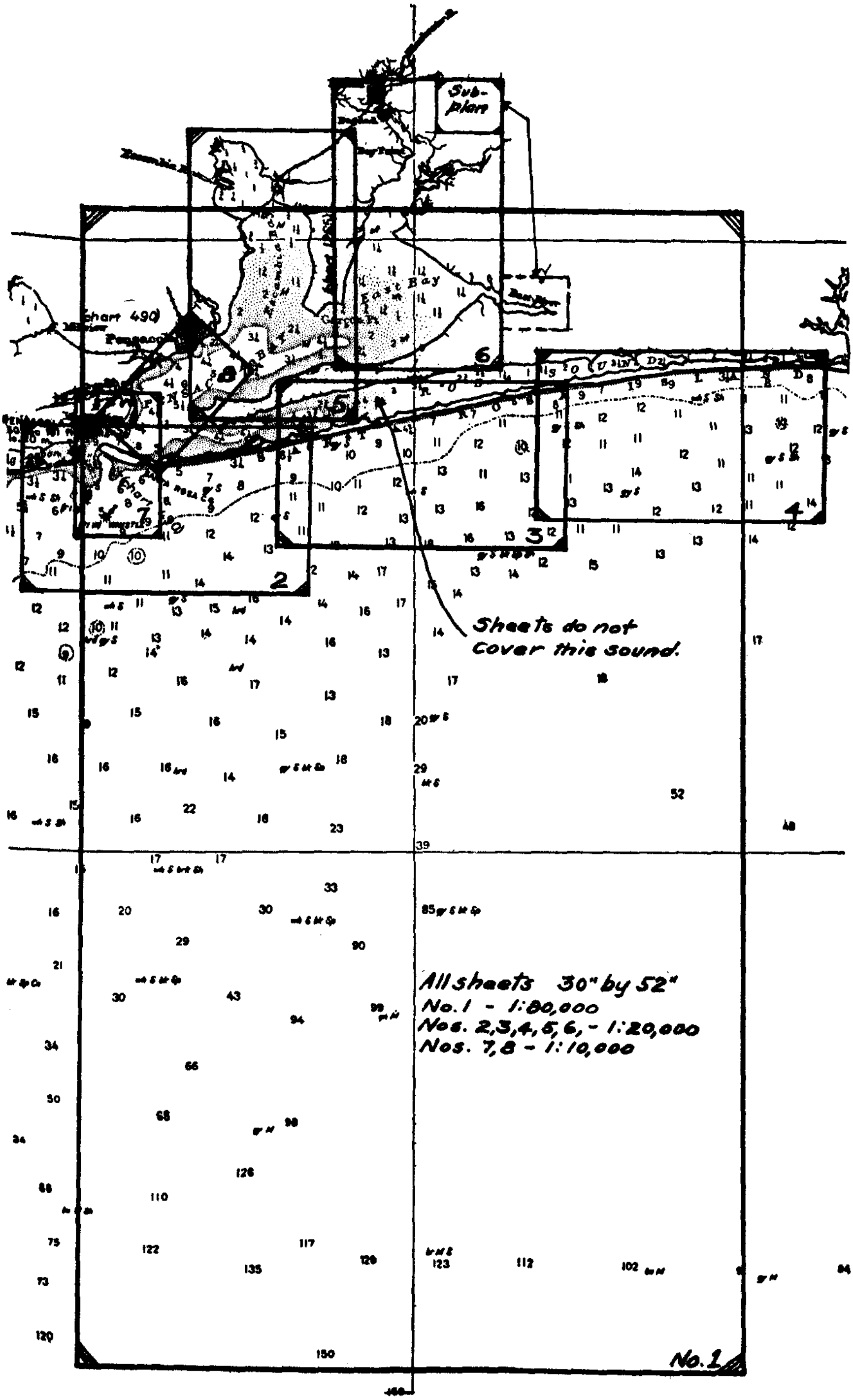

FIG. 4.—Layout of hydrographic sheets

Boat sheets.—In order to direct his field work, the hydrographer uses a second sheet called a " boat sheet." Such a sheet covers all or a part of the same area as its smooth sheet but may have a margin of spare paper, as the edges are likely to become frayed in use. If more than one unit is to work in the area covered by a smooth sheet, two or more boat sheets covering all or parts of the area may be required.

A good quality of cloth-backed paper should be used for boat sheets, and paper with a buff tint has been found very satisfactory. A boat sheet is prepared in the same manner and with the same accuracy as a smooth sheet but with considerably less attention to quality of drafting and lettering, size of station symbols, etc. As it is not so important to guard against distortion, such sheets may be prepared before reaching the field, if desired.

Names or descriptions of stations are shown on the sheet, the hydrographic names usually being assigned by the officer in charge of the hydrographic party. Short descriptions of the closely spaced topographic signals that are varied in form or color to avoid confusion are especially important.

In addition to the data shown on smooth sheets, a compass rose and scale of statute miles should be provided. Data such as reported dangers, critical depths from old surveys or charts, and the soundings along the limits of previous surveys to be joined should be shown preferably in red ink, so that the hydrographer may have this information constantly before him. If more than one tide gauge is to be used, the area to which each gauge applies should be indicated if practicable.

Under exceptional conditions thin transparent celluloid has been used advantageously for boat sheets; one side of this material should have a dull finish, so that it will hold a pencil mark. The celluloid is laid over the smooth sheet and the signals marked. In the boat the celluloid is used over a sheet of paper.

Chapter 3.—SIGNALS

LAND SIGNALS

Hydrographic work in which the position of the sounding vessel is determined by angles between control stations, measured with sextants on board the vessel, will be greatly facilitated when the station objects are conspicuous enough to be seen readily by the observers. For this reason, as well as for economy and durability, natural objects such as bowlders, lone trees, distinctive markings on cliffs, etc., and artificial objects such as towers, lighthouses, gables of buildings, etc., should be used for control objects whenever available. Signal structures erected over stations on the ground vary in type and size, depending on their location, purpose, and on the materials available. The types of signals commonly in use are described below.

Topographic signals.—This term is used to denote the small signals erected over temporary stations at short intervals along the beach in order that positions may be obtained when sounding close inshore. They are usually built and located during the course of a plane-table traverse and may be of various types, such as a whitewashed tree trunk, post, or rock; crosspieces on trees; signal cloth on bushes, etc. To avoid confusion, signals of this class should be varied in form and color as much as possible.

Hydrographic signals.—This term is applied to the signals of various sizes used in conjunction with natural and artificial objects for the main control of ordinary hydrographic surveys. For this purpose a tripod signal with two or three sides covered with board slats or cloth is often used. The height of such a signal is easily increased by a center pole made conspicuous by crossed boards, cloth banners, or other means, and a center pole should always be provided when the signal is to be observed on with a theodolite.

Signals of this type may be built of poles cut on the ground, driftwood, cut lumber, or a combination of these materials. When cut lumber can be obtained at a reasonable cost and transported readily, the economy of picking up materials on the ground is doubtful. Boards are usually more satisfactory and cheaper than cloth for dressing signals and should be used whenever practicable. In some cases painted canvas, being more easily transported than boards and more durable than cloth, may be used to advantage.

In building signals, the directions from which they will be viewed should of course be considered. Tripod signals along the coast will usually be erected with one leg toward the water and with the two adjacent sides covered. The apex of the tripod or the center pole should be carefully centered over the station mark, and each leg should be secured to the ground by a stake or other means. Wire guys to the center pole are often desirable. Signals, dressed with boards, as well as certain kinds of natural and artificial objects, may readily be made more conspicuous with whitewash. A whitewashed object is very conspicuous when the sun is on it or when it is seen against a dark background. Signals dressed with boards show up fairly well against the sky. When cloth is used and in some cases when boards are used for dressing signals, it will be best to have the part of the signal showing against the sky black in color.

The largest tripod signals usually have a height of about 20 feet to the apex of the tripod and from 30 to 35 feet to the top of the center pole. When cut lumber is available, timbers 4 inches square are generally used for the legs and center pole of large signals while 2 by 4 inch lumber may be used for smaller tripods. One-inch boards are usually provided for dressing signals and should be rough or with only one side dressed, as a rough surface is superior for holding whitewash.

A convenient method of constructing a large tripod signal is indicated in Figure 5. The drawing shows the legs and center pole assembled on the ground, the identifying letter being placed at the lower end of each part. This assembly is placed so that the lower ends of the legs "A" and " C " are in the approximate positions they will occupy when the signal is completed. The tripod is then erected by using leg " B " as a lifting pole and prop. When the tripod is erected and secured in the proper location, the lower end " D " of the center pole, which pivots on the bolt, is brought within reach by means of a line attached at " D " and is then adjusted to a vertical position and secured by cross braces to each leg of the tripod. The targets on the center pole may be attached before or after this operation. The sides of the tripod are then boarded up as desired. The space between boards need not be less than the width of the boards, and wider spacing may be necessary in order to cover as much surface as possible with a limited amount of material.

Other forms of structures suitable for use as hydrographic signals will be suggested by the materials available and the possibility of using natural or artificial objects as parts of signals.

Cloth used for dressing signals should be slashed with a knife, so that it will be useless for other purposes and less likely to be stolen.

Tall hydrographic signals.—In some regions the coast is so low and flat that ordinary types of signals can not be elevated sufficiently for hydrographic work out to the limit desired, and in such cases it is necessary to use a special type of signal structure called a tall hydrographic signal.

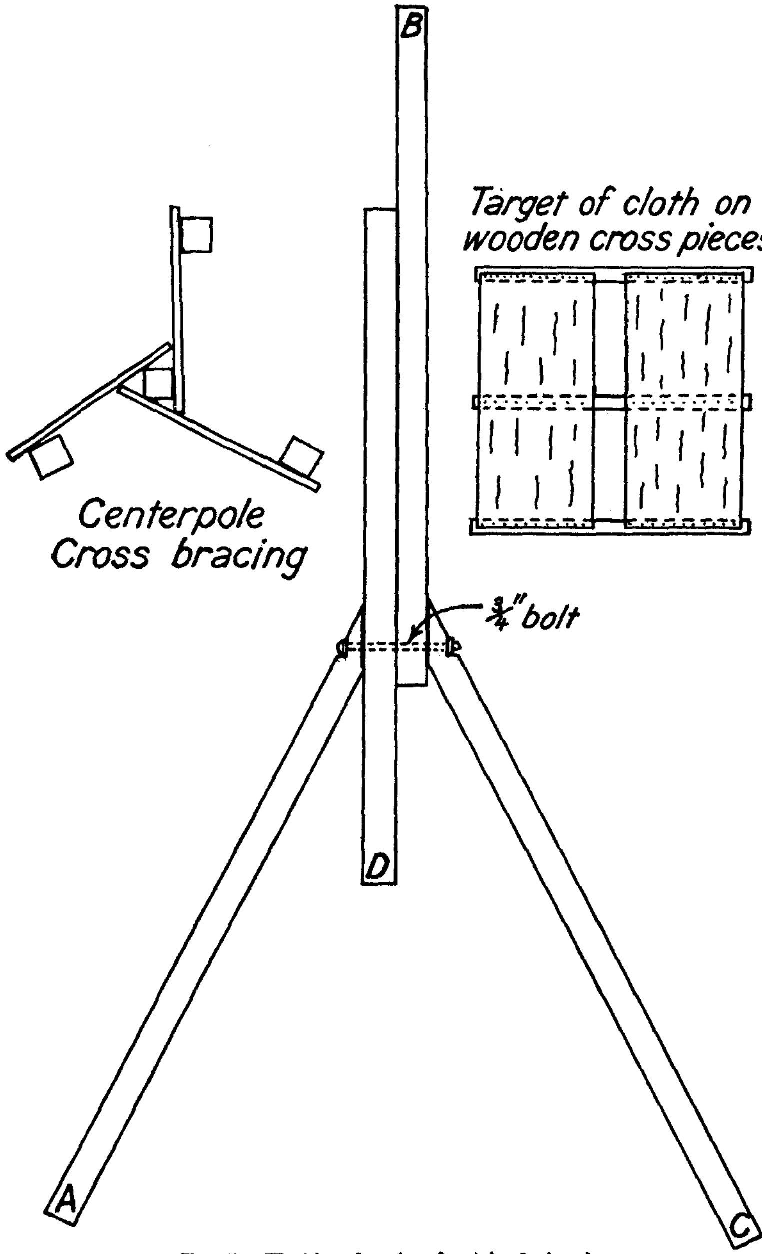

FIG. 5.—Working drawing for tripod signal

A signal of this type, consisting of a four-sided scaffold and superstructure supporting a large target, is described, together with a bill of materials and complete directions for its construction, in

Reconnaissance and Signal Building, Coast and Geodetic Survey Special Publication No. 93. This type has been used extensively by the bureau and in general has given satisfactory service. It is difficult, however, to effect a strong junction of the base scaffold and the superstructure, and there have been a number of failures due to breakage at this point.

In order to avoid this difficulty and to simplify construction, the signal illustrated in Figure 7 has been designed recently. In this type the base scaffold is not used, the signal being built with the same cross section throughout its height and held erect by guy wires.

The specifications for this signal are as follows:

Cross section.—Four feet square.

Legs.—Four by four inches, built up of 2 by 4 inch lumber with joints broken at least 4 feet and strengthened by pieces 1 by 4 inches by 3 feet nailed over them.

Horizontal braces.—Spaced 4 feet; of 2 by 4 inch lumber up to a height of 16 feet, then of 1 by 4 inch boards.

Diagonal braces.—All 1 by 4 inches; cross braces on three lower panels; single, zigzag braces on remaining panels.

Target.—Made up in sections of three ½ by 6 inches by 12 foot boards, spaced 4 inches, from 40 to 60 boards used on each signal. Boards are sprung around a line of 2 by 4 inch pieces, nailed vertically along middle of seaward side of signal, so that target presents a convex surface to seaward.

Guy wires.—Of No. 8 galvanized-iron wire. Four guys at height of 40 feet, one leading out from each corner of structure. A set of 8 guys at intervals of about 20 feet above the 40-foot level, 4 guys in each set to lead out from corners of structure, 2 to lead directly seaward from the target, and 2 to lead landward from the target.

In constructing this signal, a section 16 feet high is built on the ground and raised into place. The bottom horizontal braces are doubled (one inside and one outside the legs) and extended about 2 feet beyond the sides of the structure. A hole about 8 feet square and 6 feet deep is dug so that the entire base of the signal can be buried in the sand. Scrap lumber or driftwood is laid across the bottom horizontal braces, and the hole is filled with sand. Construction is then continued by adding leg pieces, braces, and guy wires until the desired height is reached. Braces should be cut as the construction progresses so that allowance can be made for slight variation in cross section and height of panels. The various sets of guy wires can be fastened to the same anchors but for the taller signals it is best to provide a longer lead and separate anchors for the upper sets of guys.

The following directions for constructing guy-wire anchors are repeated from Special Publication No. 93:

For each anchor dig a trench 8 feet long, 2 feet wide, and about 3 feet deep. Lay an anchor timber 8 feet long and not less than 4 by 4 inches in section in the trench and fill the trench with earth to a level with the top of the timber.

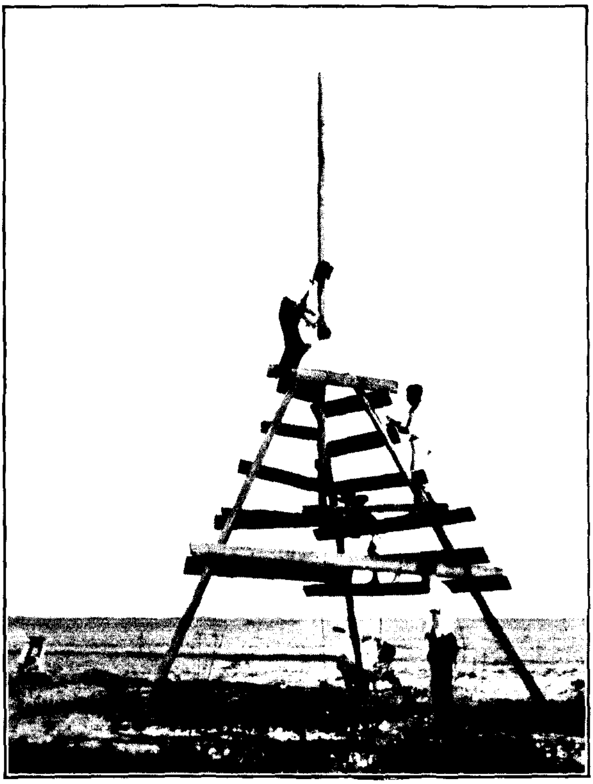

FIG. 6.—BUILDING LARGE TRIPOD SIGNAL

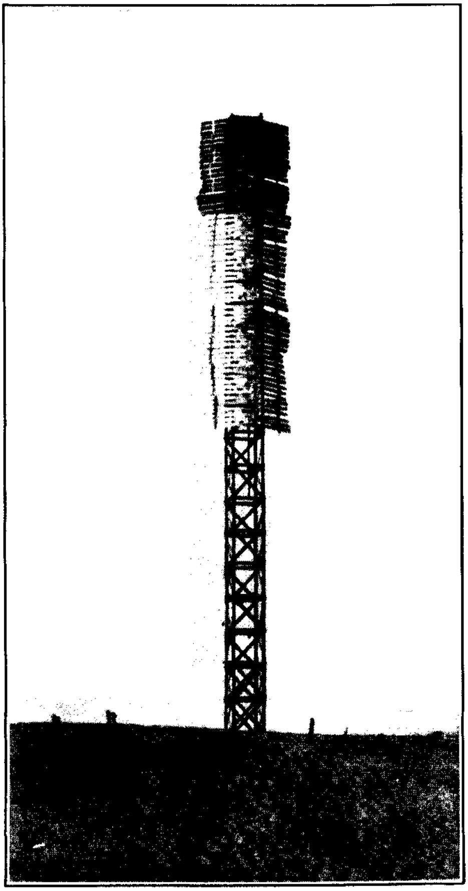

FIG. 7.—TALL HYDROGRAPHIC SIGNAL

Then nail scraps of lumber across each end of the timber and fill in the ends of the trench with earth, leaving the middle of the trench open until the guys have been made fast. More scrap lumber is then nailed across the middle part of the timber and the trench filled.

Target boards are raised and attached in sections of three. The boards should be given two coats of paint, on shipboard if practicable, in order to avoid getting sand in the paint.

A signal of this type can be built in from one and one-half to two and one-half days, including the time required to land lumber and other materials. Construction is much easier in fairly calm weather, and it is very difficult to raise the target except in calm or light winds. Signals of this type built to date have been very satisfactory and durable.

Steel towers such as those used for windmills have been used to some extent for tall hydrographic signals. There is not much difference in cost of materials between steel and wooden towers, and the former have the advantage that they can be dismantled and used over again. In most of the localities where tall signals have been used by the Coast and Geodetic Survey, however, transportation has been an important factor, it being necessary in most cases to land the material through the surf, so that the convenience and economy of rafting lumber ashore and then abandoning the signal when of no further use have led to the use of lumber in the majority of cases.

The character of tall hydrographic signals has an important bearing on the success of work for which they are used. Three qualities—sufficient height, proper design, and sturdy construction—are essential and should receive careful attention, for the time used for signal building is practically wasted unless these qualities are secured.

Signals varying in height from 70 to 120 feet have been used. The height necessary for any required distance is easily computed, but this is only one of the factors to be considered. The visibility of a signal is greatly increased when its target (painted white) reflects the sun, and signals so located that the sun shines on their targets for the greater part of the day, as when working to southward of a coast extending approximately east and west, can usually be observed on until they disappear below the horizon. It is sometimes desirable to face a signal at an angle with the shore line in order to obtain a better reflection from the sun, but this angle, of course, should not be so great (usually not over 15°) as to prevent the face of the target from being seen from any point where the signal is required for control.

When cloudy weather predominates or when the sun is behind a signal for all or part of the day, the height must be sufficient to insure a considerable part of the target (painted black) showing above the tops of any trees in the background, even though the limit of visibility due to atmospheric conditions is less than that imposed by the curvature of the earth. Painting a section of the target black is useless unless this section shows against the sky and is large enough to show distinctly and avoid resemblance to a tree extending above the general tree line.

For work close inshore signals of the smaller types are provided at proper intervals between the tall signals. The type of construction described above has been used with good results for hydrographic signals of greater height than can be secured with tripod construction, say up to about 40 feet. In this case the scaffold is built with one corner facing the water and the two adjacent sides covered with canvas down to within 10 feet of the ground. It is guyed with wire and may have cross banners, about 8 by 8 feet, at the top.

WATER SIGNALS

It is sometimes desirable to erect signals in shallow water some distance from land. A tripod made of lengths of iron pipe, wired together through crosses at the top, makes a simple signal that will stand in a moderate depth of water and, if wrapped with cloth and with flags set in top, may be seen at a long distance. In exposed situations in the water such signals may be made more secure by pumping the legs into the bottom by means of a water jet; long poles and saplings have also in this manner been pumped in on ocean bars and have withstood storms.

A type of water signal that is constructed on land and then towed out and sunk in position is described in Special Publication No. 93.

Signals of this nature should be located preferably by triangulation or, if this is impracticable, by sextant fixes or cuts.

Floating signals.—Along some sections of the coast it is desirable to carry accurately controlled hydrography beyond the limits of visibility of shore signals or to develop banks out of sight of land. For these purposes various types of floating signals are anchored at suitable offshore points and located with reference to the shore objects. Several types of floating signals are described in Special Publication No. 93, and various other designs have been used by different hydrographers. Their essential features are a center pole or light structure supported near the middle by one or more barrels or a pontoon raft; crossed targets at the upper end to increase their visibility; a counterweight at the bottom to hold them upright; and suitable anchoring gear. For cheapness and convenience in handling and stowing the one-barrel signal illustrated in Figures 8 and 9 is usually preferred. This signal is similar to the one described on pages 74 and 75 of the above publication, with a few modifications now considered desirable.

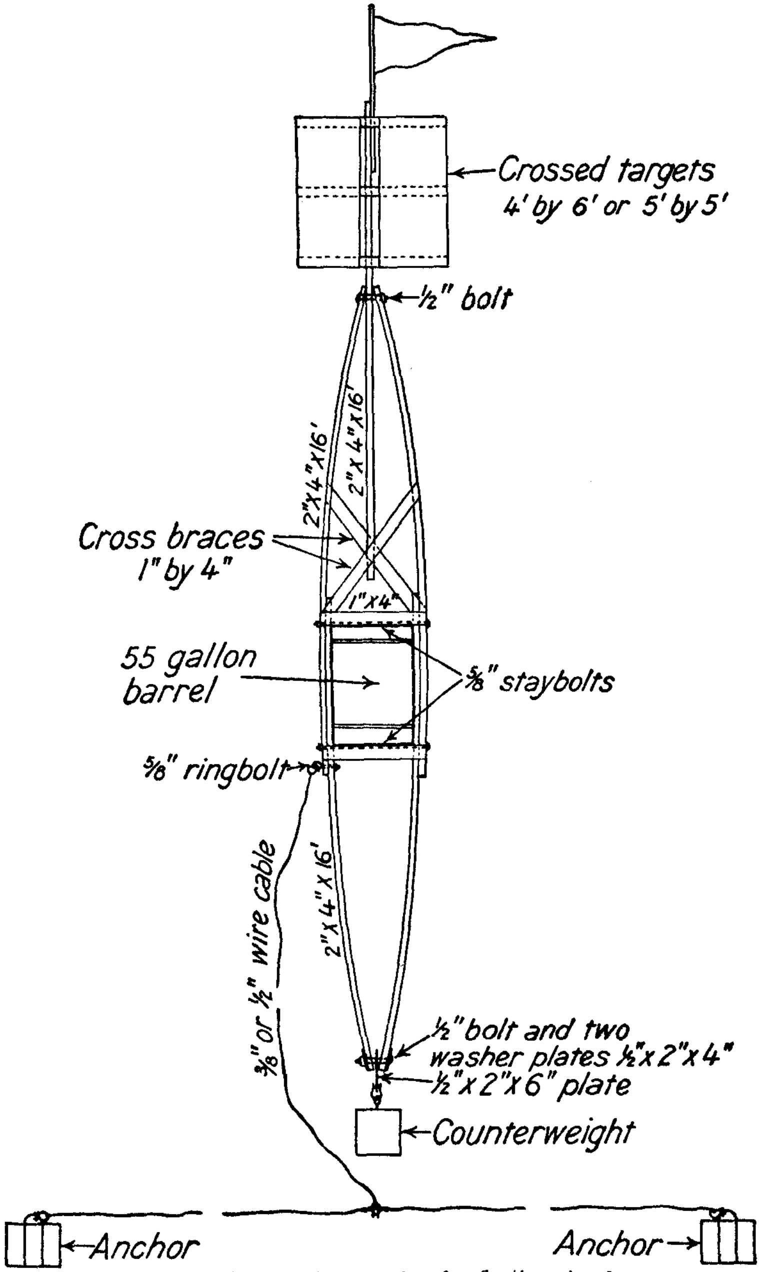

FIG. 8.—Working drawing for floating signal

Black-iron screening or canvas strips painted black, attached to 1 by 2 inch crosspieces, are used for targets, and a flag may be added if desired. Each signal is provided with a distinguishing mark, such as crosspieces at various angles or variation in the color of the flag, so that, when a number of signals are used, each may be identified under all conditions.

A heavy wooden oil barrel or galvanized-iron gasoline drum may be used. The latter will usually give the best results and should be well painted with red lead. The framework is clamped against the barrel with two bolts and the 1 by 4 inch crosspieces on both sides of the framework above and below the barrel are notched to fit over the chimes of the barrel.

Some hydrographers paint the entire signal with black asphaltum, while others prefer white paint for the framework above the barrel and antifouling paint below.

Old railroad-car couplers, purchased as scrap iron, have been used with considerable success for anchors and counterweights. They are considered superior to concrete blocks, as they hold better and are easier to handle. One coupler is sufficient for a counterweight, while three, linked together with an iron bar, are required for an anchor.

In order to shorten the swinging radius of these signals and to prevent fouling of anchors, two anchors and a bridle of three-eighths or one-half inch wire rope may be used for anchoring, as indicated in Figure 8. The horizontal part of the bridle should be about three times the depth of water and the upright part about equal to the depth. If a single anchor line is used, its length should be about two and one-half times the depth, with its upper part of wire rope about equal in length to the depth of water, and the remainder of $\frac{5}{16}$-inch boat chain.

Floating signals are planted and taken up by the survey ship. When anchoring with a bridle an effort should be made to lay out the anchors in the direction of the prevailing wind, or current if the latter is strong. Signals may be planted in fairly rough weather, but comparatively smooth weather is required for picking them up. The latter operation will be facilitated by attaching a length of nine-thread rope to the anchor ringbolt of the signal. A large eye-splice in the free end of this line is hung over a screw hook near the top of the signal. The line should have plenty of slack, so that it can be lifted off the hook and brought aboard by means of a long boat hook.

When not in use these signals may be stowed in a small space by removing the targets, cross braces, barrel, and counterweight. Their location and use are described in chapter 5.

Materials for one-barrel signal

Barrel, 55-gallon, wood or galvanized iron		1
Bolts, ½ by 7 inches		2
Bolts, ⅝ by 32 inches		2
Car coupler (scrap iron)[1]		1
Cloth	yard	1
Lumber, 2 by 4 inches by 16 feet	pieces	5
Lumber, 1 by 4 inches	linear feet	28
Lumber, 1 by 2 inches	do	42
Nails, eightpenny	pound	1
Paint	gallon	½
Plate, iron, ½ by 2 by 6 inches		1
Plates, iron, ½ by 2 by 4 inches		2
Ringbolt, ⅝ by 5 inches		1
Screen, wire, black[2]	square feet	32
Tacks, 6-ounce	package	1

Anchoring with one anchor

Cable, wire, ⅜ or ½ inch	feet	60
Car couplers (scrap iron)[3]		3
Chain, boat, 5/16 inch	feet	90
Bar, iron, ½ by 1 inch[3]	do	5
Shackle, screw anchor, ⅜ inch		1
Thimbles, wire rope		2

Anchoring with two anchors and bridle

Cable, wire, ⅜ or ½ inch	feet	240
Car couplers (scrap iron)[3]		6
Bar, iron, ½ by 1 inch[3]	feet	10
Shackles, screw anchor, ⅜ inch		4
Thimbles, wire rope		6

[1] For concrete counterweight, substitute 1½ bags Portland cement and equal amount of sand and broken stone.

[2] For canvas targets, substitute 20 square feet of canvas.

[3] For concrete anchor, substitute about 200 pounds of Portland cement and 300 pounds of sand and broken stone for each anchor block.

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Chapter 4.—EQUIPMENT AND METHODS FOR MEASURING DEPTHS

To contend with the great variation in ocean depths and to meet other conditions, the hydrographer has available a number of methods and depth-measuring devices which will be described in this chapter. The conditions governing their use are prescribed in part 1.

LEAD AND LINE

This apparatus consists of a suitably graduated line, to one end of which is attached a lead weight called a sounding lead. It is used for depth measurements by lowering the lead until it touches bottom and reading the depth by means of the graduations on the vertical line.

Sounding pole.—For continuous sounding in depths of a few feet, as in the survey of a tide flat, a graduated pole may be substituted for the lead and line. For occasional use, foot marks may be provided on the boat hook that should be a part of the equipment of every party.

Preparation of lead line.—To avoid large corrections to soundings, due to errors in lead-line graduation caused by stretching or shrinking of the line, the Coast and Geodetic Survey has adopted a line with a wire center as standard material for lead lines. Best results have been obtained with a line known as Sampson mahogany tiller rope, size No. 8, which is a waterproof solid-braided rope with a phosphor bronze stranded-wire center.

This line is prepared for use by soaking for two 24-hour periods, between which it is placed under considerable tension throughout its length for several hours. After attaching the lead, the line while still wet is placed under tension equal to the weight of the lead, and the fathom marks, in accordance with the system given below, are attached. The intermediate marks may be supplied afterwards by extending the line on a flat surface and averaging the spaces.

The fathom marks may be laid off with a tape, but the most convenient arrangement, which will be available also for the required lead-line verification, is to establish permanent marks with copper tacks on the deck of the ship, or on a wharf if the party is working from a shore station.

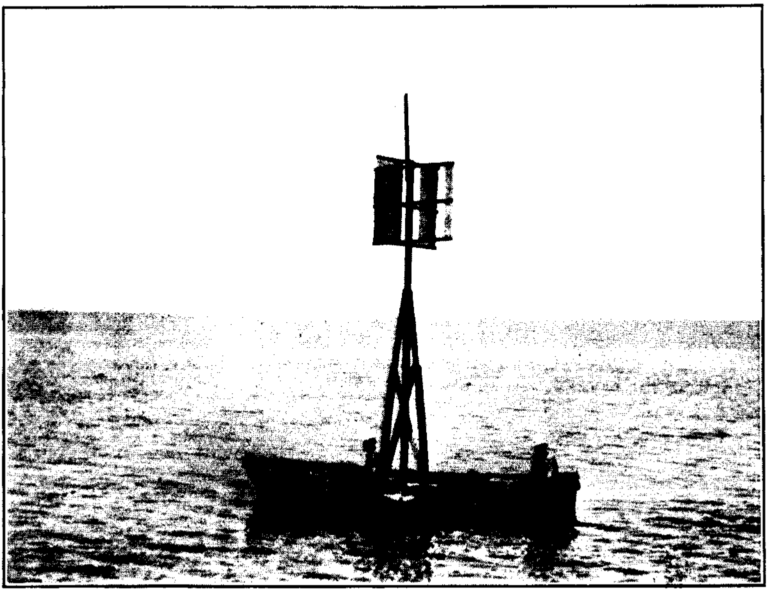

FIG. 9.—FLOATING SIGNAL

FIG. 10.- HEAVING THE LEAD

Graduation of lines.—Lead lines are marked as follows:

1 fathom.—A piece of leather with one strip.
2 fathoms.—A piece of leather with two strips.
3 fathoms.—Blue rag.
4 fathoms.—A piece of leather with four strips.
5 fathoms.—White cotton rag.
6 fathoms.—A piece of leather with one strip.
7 fathoms.—Red woolen rag.
8 fathoms.—A piece of leather with three strips.
9 fathoms.—A piece of leather with four strips.
10 fathoms.—A piece of leather with a hole in it.
11 fathoms.—A piece of leather with one strip.
12 fathoms.—A piece of leather with two strips.
13 fathoms.—Blue rag.
14 fathoms.—A piece of leather with four strips.
15 fathoms.—White cotton rag.
16 fathoms.—A piece of leather with one strip.
17 fathoms.—Red woolen rag.
18 fathoms.—A piece of leather with three strips.
19 fathoms.—A piece of leather with four strips.
20 fathoms.—Two knots.

For intermediate marks between the fathom marks on dark-colored cord, a seizing of white linen thread is used for each foot except the half fathom, which is marked with black thread.

Weight of sounding lead.—A lead weighing not less than 8 pounds should be used for sounding in depths up to 8 fathoms and a 10 to 12 pound lead for greater depths. Where there are subsurface currents it may be necessary to increase the weight of the lead in order to obtain vertical casts.

To avoid subjecting a lead line to different tensions, each line should always be used with the same-sized lead.

Sounding with lead and line.—Soundings with lead and line are usually taken from a slowly moving vessel. To obtain a sounding the leadsman, stationed in the sounding chair, heaves the lead far enough ahead so that it will reach a point on the bottom just before the chair comes over the point. He then hauls the line taut and, when directly over the lead, lifts it slightly and, as it touches bottom again, reads and calls the depth. Lifting the lead is an important precaution for the purpose of straightening the line and keeping the lead vertical. As soon as the sounding is obtained the line is hauled in and coiled in readiness for the next sounding.

The leadsman should be trained to estimate the probable depth of a sounding, from those immediately preceding, in order to pay out an adequate amount of spare line; too much may be more objectionable than too little. If a sea or swell is running, he must also be careful to allow for the height of the waves or swell, so that the reading of the lead line will give the depth from the mean surface.

For work at night a flood light should be trained on the water below the sounding chair. The depth should not be obtained by subtracting an estimated height from the water to the mark in the leadsman's hand.

Hand-lead sounding.—The use of the lead and line as described above is called hand-lead sounding. It is practicable until a depth is reached where, with an economical speed of vessel, the leadsman can not heave the lead far enough ahead to obtain a vertical cast. This limit will vary considerably, depending on the skill of the leadsman and the height of the sounding chair above the water. Under average conditions it will lie between 10 and 15 fathoms, although with an exceptional leadsman, hand-lead soundings can be obtained in a depth of 20 fathoms.

Lead-line sounding with machine.—To extend lead-line soundings beyond the depth limits of hand-lead work, a method has been devised for using a sounding machine and stranded sounding wire to heave the lead forward. For this purpose the sounding chair is installed near the stern of the survey ship. A lead line of No. 10 cord, prepared as previously described, and a lead not less than 30 pounds in weight are used. Between the lead and the end of the lead line a 10-fathom section of unmarked stranded sounding wire is inserted to decrease resistance, and a second 10-fathom section may be added when working in depths not less than 20 fathoms.

For heaving the lead, the sounding wire is attached to the eye of the lead and extended forward through a sheave on a boom rigged out near the bow and thence through suitable fair-leads to a sounding machine installed near the bow. It is important that the boom sheave be of a design that will prevent the wire from flying off when slack. A counterbalanced sounding sheave (see p. 52), with a special guide consisting of a metal strip, with a narrow slot, passing entirely around the sheave, has given excellent results.

Operation.—To obtain a sounding the lead is hove forward as far as necessary and the brake of the machine released. As the wire runs out freely the lead sinks to the bottom, the depth is obtained in the same manner as described for hand-lead sounding, and the lead is again hauled forward with the machine. This operation is very simple but requires close coordination between the leadsman and the machine operator, which can easily be obtained with a little practice, preferably in moderate depths and with speed of vessel slower than usual. The lead should not be hauled farther forward than is necessary to obtain a vertical reading, as an error may result from having more of the measuring line out than is required for the sounding.

In paying out the operator should apply the brake lightly, if necessary, in order to prevent the wire from slacking enough to kink, but otherwise must not check the wire until the depth is obtained. The leadsman must be trained to keep a light tension on the line and to call a "miss" if the lead is checked enough to tow along the bottom before the sounding is obtained. These operations must be supervised closely by an officer of the watch, especially until the men become thoroughly proficient. A system of signaling between leadsman and the operator should be used, and operations will be facilitated if they are in sight of each other.

With a 30-pound lead, 5-knot speed, and distance between leadsman and sounding boom of about 100 feet, this apparatus can be used to obtain 30-second soundings in depths up to about 30 fathoms. Soundings up to 35 or 40 fathoms can be obtained by increasing the weight of the lead, decreasing speed, or both.

Trolley soundings.—This is an older method of lead-line sounding beyond hand-lead depths. From a point above the head of the leadsman, who is stationed aft, a wire cable is led down to a boom rigged out near the bow. A wheeled carriage traveling on this cable holds the lead on a trigger that is tripped when the carriage strikes a buffer on the boom or hauls taut a trip line leading aft. There should be considerable spare lead line, so that it can be led to a sounding machine for heaving in.

An improvement to this method has been made whereby the carriage is attached to an endless cable passing over sheaves forward and aft and around a small hand winch mounted on the rail aft. A fair-lead is attached to the inboard side of the carriage. The carriage is reeled forward as far as necessary, tripped, and then hauled aft at a speed corresponding to that of the ship. The lead line passes over the fair-lead and enters the water vertically with corresponding decrease in resistance. The leadsman throws the line off the fair-lead just before taking the sounding.

Sounding with trolley requires more men and a longer sounding interval than lead-line sounding with machine and consequently has been superseded by the latter method for general use by the Coast and Geodetic Survey.

SOUNDING MACHINES

A sounding machine may be briefly described as a reel or drum suitably mounted on standards so that it will turn freely, provided with a brake, and operated by hand or power. The depth-measuring equipment consists of stranded or piano wire wound on the reel, a lead attached to the end of the wire, and a registering sheave over which the wire passes and which measures the amount of wire run out. To obtain a sounding the vessel stops, the wire is allowed to run out until the lead reaches bottom, the depth is read from the counter on the sheave, and the wire is reeled in by hand or by means of a power unit connected with the machine.

Sounding machines are used by survey launches when working in depths too great for hand-lead sounding and by survey ships when not equipped with echo-sounding apparatus and working in depths beyond the capacity of pressure tubes; also for testing echo-sounding apparatus or pressure tubes and for securing oceanographic data, such as bottom specimens and water samples and temperatures at various depths.

Ship sounding machines.—The Coast and Geodetic Survey has designed a series of ship sounding machines that are superior in ease, smoothness, and speed of operation to those in previous use. These machines are now furnished as standard equipment. The general method of mounting is illustrated in Figure 11. A strong cast-metal reel is mounted so as to turn freely on the shaft. The inner side of the rim is beveled. On one side of the reel a driving wheel, with a beveled rim faced with brake lining, is securely keyed to the shaft. On the other side two segments of a similar beveled wheel are bolted to one of the standards. The entire arrangement is such that the reel, by means of a lever, can be held in a neutral position so that it turns freely, can be forced against the driving wheel so that it is connected with the power unit, or can be held against the segments bolted to the standard so that it is securely braked.

Three types of machine are in use. The L-type machine, illustrated in Figure 12, has a reel one-half fathom in circumference with a capacity of about 1,000 fathoms of stranded wire. It is driven by an electric motor, mounted below the reel, through a silent chain drive.

A similar machine, driven by a Dake steam engine, and known as the SL-type, is provided for ships that can not furnish sufficient electric power to operate the L-type machine.

The deep-sea machine, shown in Figure 13, has a reel 1 fathom in circumference with a capacity of about 6,000 fathoms of piano wire. The motor is mounted at the rear of the reel.

The L-type machine can be used to the limit of its wire capacity, but ships equipped both with this type and the deep-sea machine generally use the former with stranded wire in depths up to from 200 to 500 fathoms and the latter with piano wire for greater depths. The deep-sea machine is equipped with a revolution counter.

Launch sounding machines.—Various types of sounding machines have been used on survey launches. A hand sounding machine supplied by the Coast and Geodetic Survey to field parties is illustrated in Figure 14. This machine has a bronze reel and brass standards. The brake is a clamp, lined with wood, forced against the reel or released by the small brake handle seen at the top of the apparatus.

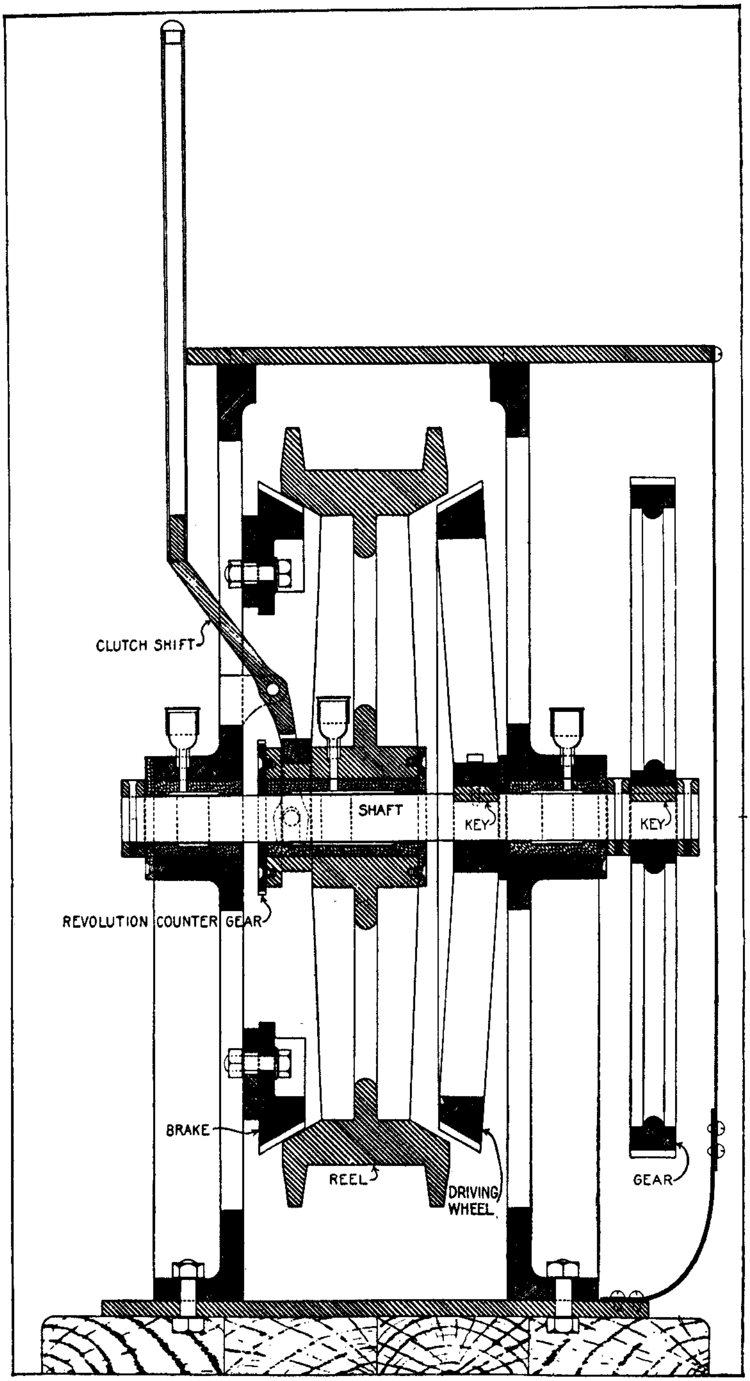

FIG. 11.—Deep-sea electric sounding machine (vertical section)

The handles are hinged in such a way that they can be disconnected from the shaft when reeling out. The machine is secured to a wooden base provided with clamps, so that the box may be used as a cover for the machine or as a part of its base when in use.

When a sounding machine is used extensively, it is very desirable to supply power for reeling in. On account of the wide variation in the design and power plants of survey launches, no standard power machine for launch work has been provided. Hydrographers of the bureau, however, rig up power machines, usually by connecting a hand machine to a small steam engine, on steam launches, or to the engine of gasoline launches by a belt to the flywheel or by gears and shafting. In constructing small sounding machines the arrangement for mounting ship machines, described above, will be found satisfactory on account of the great flexibility of control.

Sounding wire.—Stranded wire is generally used for sounding in depths up to from 200 to 500 fathoms. This wire consists of seven tightly twisted strands of double-galvanized wire, each No. 24, B. and S. gauge, and has a breaking strength not less than 500 pounds. It is furnished in sealed tins containing 300 fathom lengths.

For greater depths, steel piano wire, No. 21, B. and S. gauge, is used. This wire will stand a strain of about 140 pounds but should not be subjected to a pull of over 100 pounds when reeling in. It is furnished in sealed tins containing 2,000-fathom lengths. To avoid kinks due to coiling on the bottom, from 20 to 30 fathoms of stranded wire or a few fathoms of cotton line should be inserted between the end of the piano wire and the lead.

Splicing wire.—In splicing stranded wire a lay of 16 inches with neat tucks at each end will suffice. A very satisfactory and durable splice for piano wire is made as follows: Overlap the two ends of wire for a distance of about 10 feet with both wires fairly taut. Seize the wires at one end of the splice with sail twine and then wind the free end of wire around the other wire in a long spiral, having about one turn in 2 inches and keeping the wire taut. Then seize the other end of the splice and see that the two wires are contiguous throughout the entire length of the splice. Then with fine copper wire seize each end of the splice for a distance of 2 inches, continuing for a distance of about 1 inch along the single wire. Next place two 2-inch seizings so as to divide the splice into three equal parts. Clean all seizings with muriatic acid, wipe with soldering paste, and cover each with a thin coat of solder.

For emergency repairs to piano wire the following alternate method may be preferable, as it requires less time than the one described above: Anneal the end of each wire for a distance of about 2 inches. Then overlap the two wires and wind one around the other

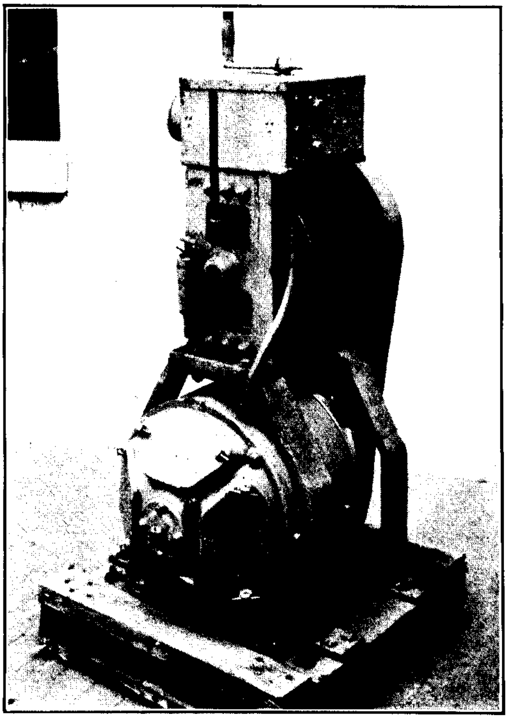

FIG. 12.—L-TYPE ELECTRIC SOUNDING MACHINE

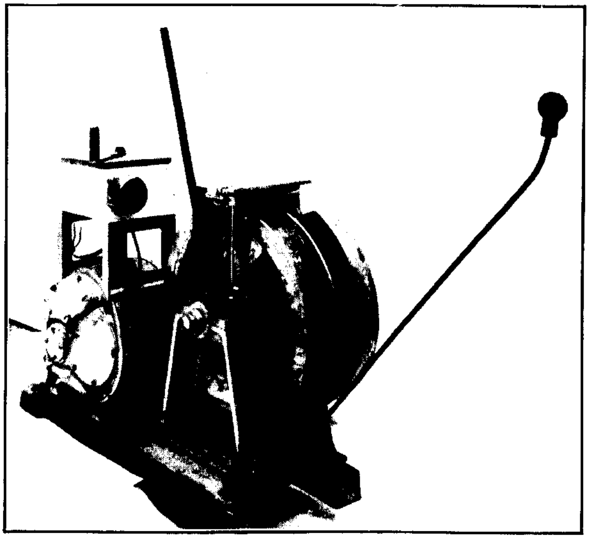

FIG. 13.—DEEP-SEA ELECTRIC SOUNDING MACHINE

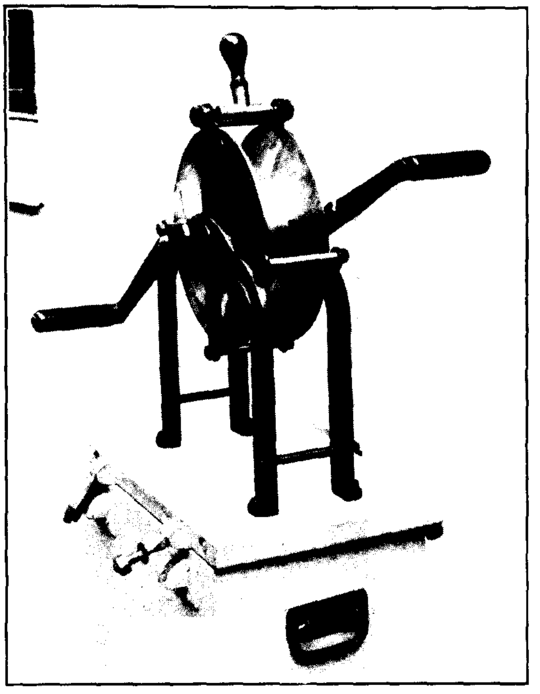

FIG. 14.—HAND SOUNDING MACHINE

FIG. 15.—REGISTERING SHEAVE

in long spiral turns for a distance of about 2 feet. At each end of the splice wind the annealed end of wire in close turns around the other wire; clean splice with muriatic acid and wipe with soldering paste. Prepare a shallow trough by grooving a piece of timber somewhat longer than the splice and fill with melted solder. Then dip the entire splice in the solder and wipe with several layers of felt or other heavy material, greased with tallow, sperm candle, or sweet oil, and held in the palm of the hand.

When stranded wire is used as stray line at the end of piano wire, it may be spliced to the latter by unlaying one strand of the stranded wire, laying the piano wire in its place, and seizing and soldering both ends of the splice.

Placing wire on sounding machine.—For winding piano wire on a sounding machine the coil of wire is generally placed on a wooden cone from 2 to 3 feet high and so proportioned that the coil rests about halfway between the apex and base of the cone. The latter is pivoted at top and bottom with the apex up. A supply of wire is generally carried on a storage reel from which it can be transferred to the sounding machine by power in a short time.

Sounding leads.—Leads of from 30 to 40 pounds in weight are used with stranded wire and also with piano wire in depths where the lead is recoverable; that is, depths from which the lead can be reeled in without great danger of parting the wire. One thousand fathoms is generally considered the approximate maximum depth for recovery of the lead. For greater depths a detachable, pear-shaped, cast-iron sinker, from 35 to 75 pounds in weight, is used with a Belknap-Sigsbee specimen cylinder. (See p. 77.) The cylinder passes through a hole in the sinker, which is slung by a wire bale. Upon reaching the bottom the sinker is detached, thus decreasing the strain on the wire when the cylinder is reeled in.

Registering sheaves.—A registering sheave, sometimes called a sounding sheave (see fig. 15), consists of a grooved wheel of certain diameter, mounted in a yoke so that it will turn freely, and connected with a revolution counter which indicates the number of fathoms of wire that runs out over the wheel. A sheave differing in design from that illustrated, in that a numerical counter is used instead of a dial and pointer and that the bottom of the score of the wheel is formed by a removable steel ring, is being constructed for trial in the field.

The practice of furnishing two sizes of sheaves, one for stranded and the other for piano wire, which has been followed to some extent in the past, has been discontinued, and all sheaves secured hereafter will be designed for piano wire. The readings of such sheaves, when used with stranded wire, will be too short by 16 inches in 100 fathoms, an error that in most cases will be negligible.

A complete turn of wire is taken around the wheel of a registering sheave to prevent slipping.

Testing sheaves.—A registering sheave may be tested by running the wire over it for a measured distance along a wharf or other level space. Another method is to caliper the wheel carefully and calculate the length of one complete turn of wire, using the diameter of the wheel plus the diameter of the wire. The wheel can then be marked and turned a certain number of revolutions, the indicator being checked for different numbers of revolutions multiplied by the length of a complete turn of wire.

If, after testing a sheave, it is found necessary to apply a correction to its readings, a correction factor should be computed both for piano and stranded wire.

Use of sheaves.—The accuracy of a registering sheave is impaired as it becomes loose in its bearings through extensive use or is scored by the wire. After a sheave has been in use for some time the frequency of tests should be increased, and the sheave should be discarded and returned to the office when it becomes unreliable. Sheaves should be oiled properly and handled carefully. Every precaution should be taken to prevent the wheel from jamming in its yoke, as this will nearly always result in scoring by the wire.

Sheaves in use for some time will usually develop side play in the yoke, which may cause an error of as much as 1 fathom in the dial reading. Therefore, when special accuracy is required, as in comparative readings with tube or echo soundings, a fairly new and carefully tested sheave should be used if practicable. In such cases, if it is necessary to use a sheave with side play, the wheel should be held against one arm of the yoke to set the pointer and against the same arm to read the depth. In the new type of sheave a worm gear is not used, so that the error due to side play should be eliminated.

The design of registering sheaves suggests their use as fair-leads, for which they are well adapted. A sheave used for measuring depths, however, should never be used solely as a fair-lead. If it is desired to use a sheave as a fair-lead, one that has been discarded as a measuring device on account of wear may be retained for such use.

Arrangement of apparatus.—A ship-sounding machine may be installed on the stern or on one side forward. In the latter case it is generally preferable to install it on the port side for vessels with a single, right-hand screw. A fair-lead should be carried on a davit or boom, so that the wire will lead clear of the side while the registering sheave is mounted near the machine.

A satisfactory installation is indicated in Figure 16. The fair-lead is carried at the outboard end of a boom of $2\frac{1}{2}$-inch galvanized pipe. It is attached to a pipe cross, which turns freely on the boom and is

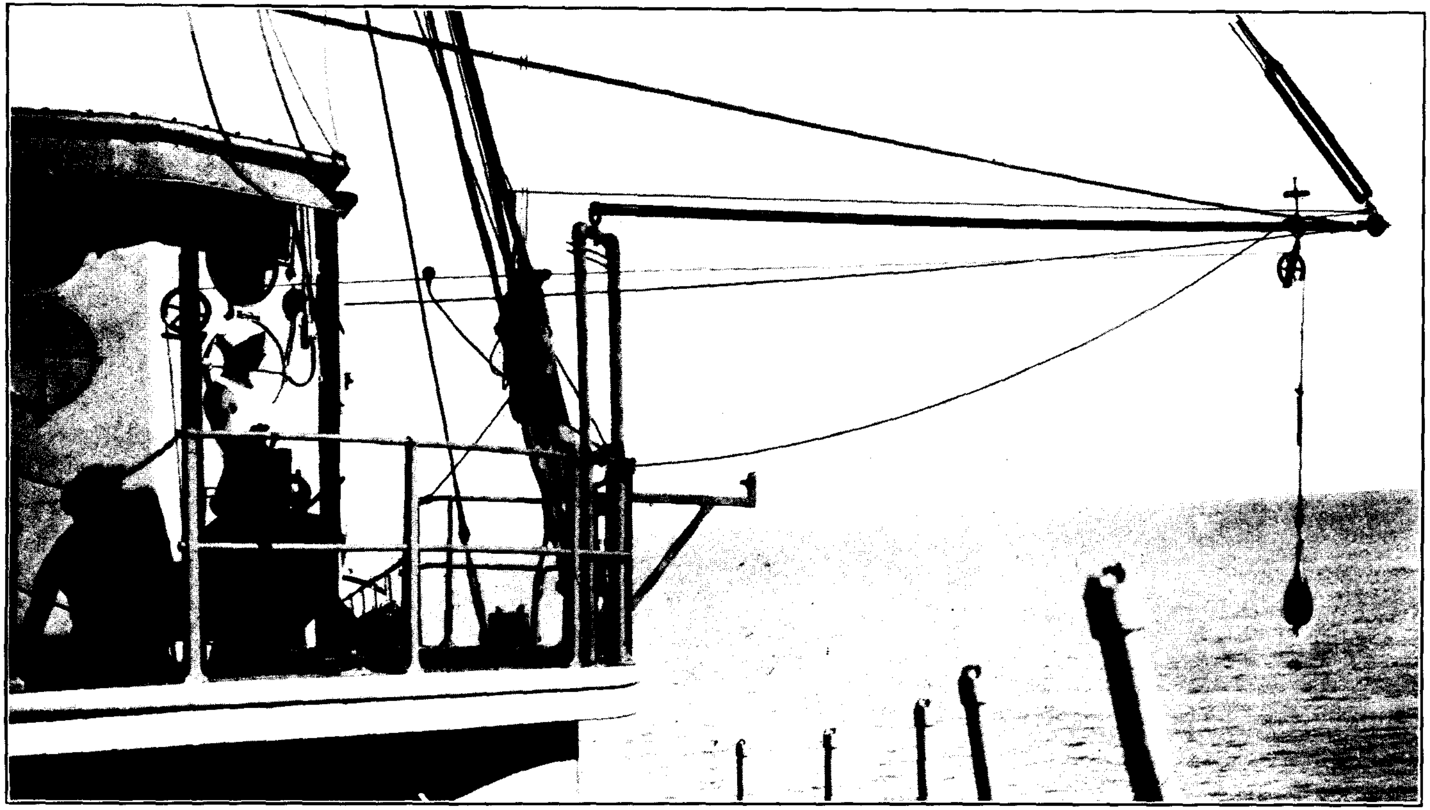

FIG. 16.—INSTALLATION OF DEEP-SEA SOUNDING EQUIPMENT

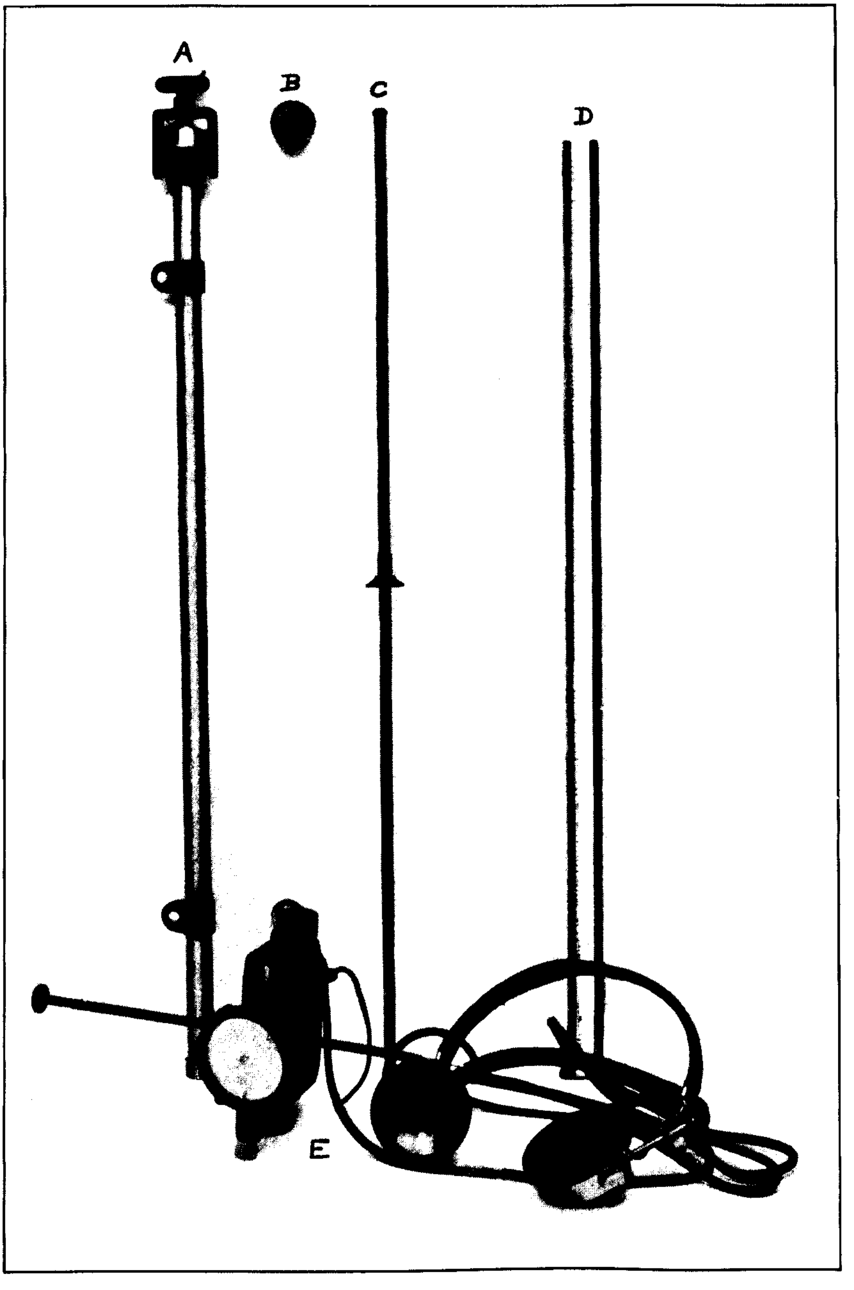

FIG. 17.—COAST AND GEODETIC SURVEY SOUNDING-TUBE EQUIPMENT

A, Sounding tube; *B*, tube cap, cut away to show capillary tube; *C*, measuring rod; *D*, scale; *E*, electric measuring device counterbalanced by an adjustable weight at the top. The registering sheave may be seen just above and to the left of the operator's head. A tension arm is hinged to the machine or rail and carries a small sheave at the other end, which rides on the wire. The weight of this arm takes up any slack and indicates clearly when the lead strikes bottom.

An accumulator spring between the end of the boom and the stay supporting it serves the double purpose of taking up sudden strains due to surging of the vessel and of indicating the tension when reeling in. The tie-rods of this spring are marked to show each 25 pounds of tension up to 150 pounds. A spring should be used for piano wire in depths over 200 or 300 fathoms, and the speed of reeling in should be so regulated that the tension does not exceed 100 pounds.

PRESSURE TUBES

For this method of sounding, a tube, closed at one end, is lowered to the bottom, and the depth is determined by measuring, by various means, the amount of water that has been forced into the tube by the water pressure acting against the pressure of the air in the tube.[1]

Various types of tubes on the market have been used for navigational purposes for many years, but their use as surveying instruments has not been satisfactory on account of the uncertainty of the results attained. As soundings with tubes can be obtained up to a depth of 100 fathoms without stopping the vessel, their use for survey purposes is desirable in many regions. To meet this need the Coast and Geodetic Survey has designed a tube that gives results superior in accuracy to any type heretofore used and that is satisfactory, when certain precautions are observed, for use in hydrographic surveying.

Coast and Geodetic Survey sounding tube.—This tube and the equipment used with it are illustrated in Figure 17. The tube consists of a 2-foot section of standard brass tubing, one-half inch inside diameter, with one end permanently closed. It is fitted with two straps with eyes for attachment to the sounding wire. When used for sounding, the open end of the tube is covered by a brass cap in which a small winding hole forms a capillary tube about 3 inches long. This opening will admit water to the tube under pressure without allowing the air to escape.

When the tube is lowered to the bottom, a certain amount of water, depending on the pressure due to the depth, is forced into it. When

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[1] For a general discussion of pressure tubes and the physical laws on which their use is based, see Physical Laws Underlying the Scale of a Sounding Tube, Coast and Geodetic Survey Special Publication No. 61.

it is brought to the surface the water is trapped in the bottom of the tube and the air escapes through the cap. The amount of water in the tube is measured by removing the cap and inserting a brass rod of certain cross section until the water is about to overflow. The distance that the rod is inserted is indicated by a sliding marker that rests against the end of the tube. The depth is read by holding the rod against a scale so graduated that, when the end of the rod rests against a stop, the depth in fathoms is indicated by the position of the sliding marker.

Electric measuring device.—The insertion of the measuring rod exactly to the overflow point is a delicate operation, especially if the sea is at all rough. To obviate this difficulty, an electric measuring instrument has been devised. This also is illustrated in Figure 17. It incloses two flash-light batteries and has a head-phone connection. It is clamped to the open end of the tube, and the movable rod is lowered until its point strikes the water in the tube, when an electrical circuit is established which causes a click in the phones. The moving rod actuates a pointer which indicates the proper depth on a dial.

Sounding with tubes.—For tube sounding, stranded wire and a 30 or 40 pound lead are used with a hand or power sounding machine, the latter of course being preferable and always used if available. As the vessel moves slowly on her course, the machine is released, the wire runs out at an angle over a fair-lead until the lead reaches bottom, and the wire is then reeled in. The general practice is to use two pairs of tubes, lowering one pair while the others are being read and prepared for the next sounding. No record is required of the amount of wire run out.

The following method of securing the tubes has been found satisfactory. A wooden strip is secured just above the end of the wire. This strip is split so that the wire will lay along a groove in each half section, and the two sections are seized to bind the wire between them sufficiently to prevent the strip from slipping along the wire. Four snap hooks are made fast to the strip, and the tubes are secured by means of these snap hooks. The lead is attached to the wire by a stray line. Swivels are placed above the tube strip and at each end of the stray line.

The tube described above is the only one approved at the present time for use in hydrographic surveying. The general requirements for its use are given in part 1. The prescribed tests will take care of any variation in temperature or barometric pressure, but these data are required for use in the study of the graduation of pressure-tube scales.

Precautions to be observed.—Care must be taken that all water has been removed before a tube is used for sounding, and tubes must not be allowed to submerge or skip along the water after they reach the surface, as this will cause them to spill or pump water. On one ship of the bureau a tendency to skip along the surface was corrected by attaching an 8-pound lead by a short line to the heavier lead. The tubes should be kept as nearly as practicable at the temperature of the sea water. This may be accomplished by keeping the tubes (between soundings) covered with burlap which is moistened at frequent intervals with sea water.

ECHO SOUNDING

By this method, depths are determined by measuring the time interval required for a sound wave, or rather a train of sound waves, to travel from or near the surface to the ocean bottom and to return to the ship. The ocean bottom reflects these sound waves just as a wall reflects a sound in air, producing an echo. One-half of this time interval multiplied by the velocity of the sound waves gives the depth. Echo-sounding machines consist of apparatus for producing sound under water, apparatus for detecting the echo, and a device for measuring the time interval that elapses between the production of the sound and the reception of the echo. In some types of echo-sounding machines depths can be determined by a single operation (by reading a scale which has been calibrated in depth units corresponding to time intervals multiplied by some adopted velocity); in other types the time interval only is indicated and must be multiplied by a velocity value to get the depth.

Velocity of sound in sea water, as explained in Special Publication No. 108 (see p. 69), varies over an extreme range of from about 790 to 870 fathoms per second, depending upon temperature, pressure, and salinity. As pressure depends upon depth, it is necessary to get an approximate determination of depth before a correct velocity can be selected. Accordingly, it is the usual practice to determine depth first in terms of an arbitrary standard velocity (usually 800 fathoms per second, which is a fair average value) and then either to recompute the depth for a new value based upon the actual conditions of the water or to apply a correction to the first determined or observed depth for differences of temperature, pressure, and salinity from those that would give the standard sound velocity.

As this method can be used to get soundings with great rapidity from a ship running at full speed, it will undoubtedly revolutionize ship hydrography in depths over 10 or 15 fathoms.

Fathometer.—This echo-sounding apparatus, developed and manufactured by the Submarine Signal Corporation, of Boston, Mass., was first installed on a vessel of the Coast and Geodetic Survey in the spring of 1925. Subsequently similar apparatus has been installed on other surveying vessels, and it is now used extensively when surveying in depths in excess of 15 fathoms. The fathometer differs from most of the other types of echo-sounding apparatus in that it indicates directly the depth, automatically converting time intervals into equivalent depth units corresponding to the adopted velocity of sound wave. Corrections to the indicated depths must be applied only when the actual velocity of the subaqueous sound wave differs from the standard adopted velocity to which the apparatus has been adjusted.

The essential parts of the fathometer system are:

(1) The time-measuring device, known as the *fathometer unit.*

(2) The sound-producing device, known as the *oscillator.*

(3) The device by means of which the echo is detected and reported to the fathometer unit, known as a *hydrophone.*

(4) The device used to reduce disturbing noises and to amplify the intensity of the echo, known as a *filter.*

(5) The *motor generator*, which receives electrical power from the ship supply and transforms it to power of the particular voltage and number of cycles required for the oscillator.

(6) The wiring, switches, and circuits required to connect the above apparatus in a manner to insure successful operation.

Fathometer unit.—All of the time-measuring apparatus is contained in a metal box the outside dimensions of which are about 13 by 15 by 11½ inches. The front of the box has a circular hole fitted with a glass dial on which are two concentric scales, the inner reading by fathoms from 5 to 100 fathoms and the outer by 5-fathom intervals from 0 to 600 fathoms. A speed indicator, a starting and stopping switch, and two adjustment regulator knobs are also installed in front. On the left side of the box (when facing the dial) is a knob for shifting the gears, and on the right side is a push button for interrupting the oscillator signals. The whole right side is a hinged door giving access to the internal mechanism. (See fig. 18.)

The purpose of the fathometer unit is to measure the time elapsing between the creation of a signal and the return echo. This is accomplished by revolving an opaque disk at a uniform known speed just back of the glass dial. This disk has two narrow slots, 180° apart, one exactly behind each of the scales of the glass dial. A Geissler tube (neon gas tube) is installed back of one slot in such a manner that when illuminated a red light shines through the slot and is visible against the inner scale of the dial. This is used in what is known as the "red-light method." Back of the other slot is a small incandescent electric lamp which, in the same way, shows a band of white light against the outer scale. It is used in the so-called "white-light method."

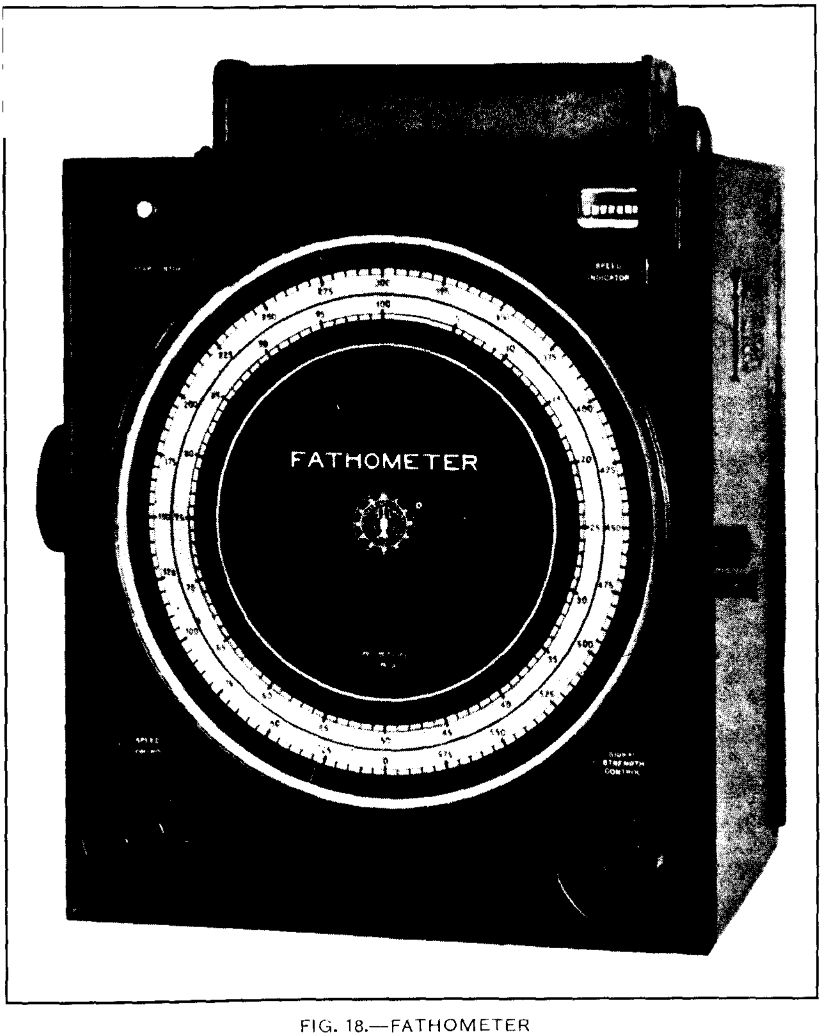

FIG. 18.—FATHOMETER

The disk is rotated by a small motor which maintains a constant speed as long as the ship's voltage remains between 90 and 115 volts. Changes in speed of the motor for voltage changes outside these limits can be made by means of the rheostat, the control knob for which is in the lower left-hand corner of the front face. A special vibratory tachometer to indicate the speed of the motor is installed in the upper right-hand corner of the front face. As a further guarantee against variations in speed due to fluctuations in the voltage of the ship lines, a centrifugal governor is attached to the motor of sets furnished to surveying ships.

The disk is mechanically connected with the small motor through a train of gears which can be shifted by means of the knob in the left side of the case so as to cause the disk to rotate at a speed of exactly four revolutions per second or at a speed of exactly one revolution per 1½ seconds. The faster speed (one-fourth second) is employed with the red-light method for all depths not in excess of 100 fathoms, but may be used to depths of 200 fathoms or more if the Geissler tube can be made to flash. With this speed the inner scale (5 to 100 fathoms) must be used, and if in depths over 100 fathoms, which can be determined as described hereafter, 100 must be added to the scale reading. The slower speed (one and one-half seconds) is used with the white-light method for depths over 100 fathoms, but it is possible to measure less depth by this method and also to hook up the Geissler tube so that it will operate in conjunction with the white light at this speed. The outer scale must be used in measuring the depth at this speed of revolution of the disk.

At the instant one of the slots in the disk passes the zero of its scale a circuit is closed by a cam, which energizes the oscillator for an instant and causes it to emit a very short train of submarine sound waves of a frequency of 1,050 cycles per second. These sound waves are reflected from the bottom of the ocean and, when they reach the vessel, actuate the hydrophone and indicate to the observer their arrival in one of two ways. In the red-light method the hydrophone circuit is connected through filters, amplifiers, and relay in such manner that the Geissler tube is illuminated at the instant of arrival of the echo. This red flash opposite the position on the scale to which the tube has traveled in the interval since the sound was produced indicates the depth. (See fig. 20.) In the white-light method the small incandescent lamp back of the second slot is lighted permanently and, shining through the slot, is seen to travel around the glass dial in contact with the outer scale. The hydrophone is connected with a pair of head phones in such manner that the echo can be heard in the phones. The observer, therefore, notes the exact position, on the scale, of the white light at the instant he hears the echo.

The sound waves travel outward from the oscillator in all directions and reach the hydrophone in an extremely short interval of time, producing a reaction similar to that produced by the echo. There are, therefore, two records for each series of vibration of the oscillator, one at about zero of the scale, due to the waves that travel by the shortest path to the hydrophone, and a second, due to the arrival of the echo. To avoid ambiguity at depths of about 100 fathoms, that would result from the arrival at about the same instant of an echo and the following direct sound waves, a cut-out switch has been placed in the oscillator circuit to prevent it closing on every alternate revolution of the disk. Hence, oscillator signals are produced by the red-light method at intervals of one-half second, or at every alternate revolution of the disk, rather than at every revolution. At depths around 200 fathoms there is this ambiguity, but at that depth the white-light method is readily available to take care of that condition.

On the right face of the fathometer case is a push button which, when depressed, holds the oscillator-circuit open. This is for use with the white-light method and serves to prevent succeeding signals overlapping and obscuring an echo. This button may be used also with the red-light method to obviate ambiguity at 200 fathoms.

An adjustment is provided on the inside surface of the rotating disk in order that the depth reading may be made to indicate either depth from the surface or depth below the ship. By means of the same adjustment, lag in the plate-circuit relay and elsewhere in the hydrophone circuit and recording mechanism may be taken care of.

Electrical connections—Fathometer unit.—The complete electrical connections of the entire system are schematically illustrated in Figure 19. A diagram illustrating the operation of the red-light method is given in Figure 20.

Taps from the positive and negative wires of a 110-volt circuit are connected to a start-stop switch used to control the entire operation. It is similar to an electric-light push-button switch and can be seen at the upper left-hand corner of the face of the fathometer unit.

The shunt-wound motor which operates the rotating dial is shown in connection with the associated wiring of its governor which keeps the motor-speed constant throughout line voltage changes from 90 to 110 volts.

On the armature shaft are mounted slip rings connected electrically with diametrically opposed segments of the commutator. The brushes which bear upon these rings are connected with the vibratory tachometer, seen at the upper right-hand corner of the face of the unit. When the motor is running at its correct speed there will be generated in this tachometer circuit an alternating current having a frequency corresponding to 1,800 revolutions per minute. With a current of this frequency the reed above the arrow will vibrate at a maximum amplitude. The supplementary reeds are provided so that the observer can readily see whether the motor, and hence the disk bearing the illuminated pointers, is running too fast or too slowly and thus be enabled to easily adjust the potentiometer and bring the motor to the correct speed.

Rocker switch 1 is provided so that there may be no injury to the motor at the time of shifting the gears when the load on the motor is rapidly removed and restored. The switch contacts are shunted by a resistance, which arrangement allows the motor to continue in motion while the gears are being shifted or while the gears are not interlocked.

Rocker switch 2 controls the circuits of the lamps on the rotating disk. When the switch blade is connected with the contact marked "shallow," the connections are established with the Geissler tube of the red-light method. When the gear-shift lever is turned to change from the rapid revolution of the disk, switch 2 is simultaneously turned and a circuit is established through contact marked "deep" with the incandescent lamp on the disk used in the white-light method.

A wire goes to starter in the engine room so that the motor generator will be controlled by the start-stop switch on the fathometer unit.

The completion of the circuit, through the wire, will be explained in detail under the description of the filter circuit.

Filter.—The fathometer filter consists of a four-stage triode valve circuit for amplifying the received echo to a point where it is sufficiently strong to operate the plate-circuit relay, and a system of inductances and capacities which passes frequencies in the neighborhood of the signal frequency but which eliminates or considerably reduces all other frequencies.

As this circuit is placed between the hydrophone and the amplifier, water noises, etc., which are chiefly of low frequency, are cut out, and the only currents which reach the amplifier with any magnitude are those caused by the signal. This tends to keep strays, water noises, etc., from operating the relay.

The batteries to operate the filter circuit are contained in the battery box, there being a 4-volt battery for supplying filament voltage and a 72-volt battery for the plate or anode current.

On the schematic diagram the circuit through the filter and its batteries along with the fathometer circuit may be traced as follows:

On closing the 110-volt start-stop switch, current in the positive wire passes through the motor field and armature and a parallel

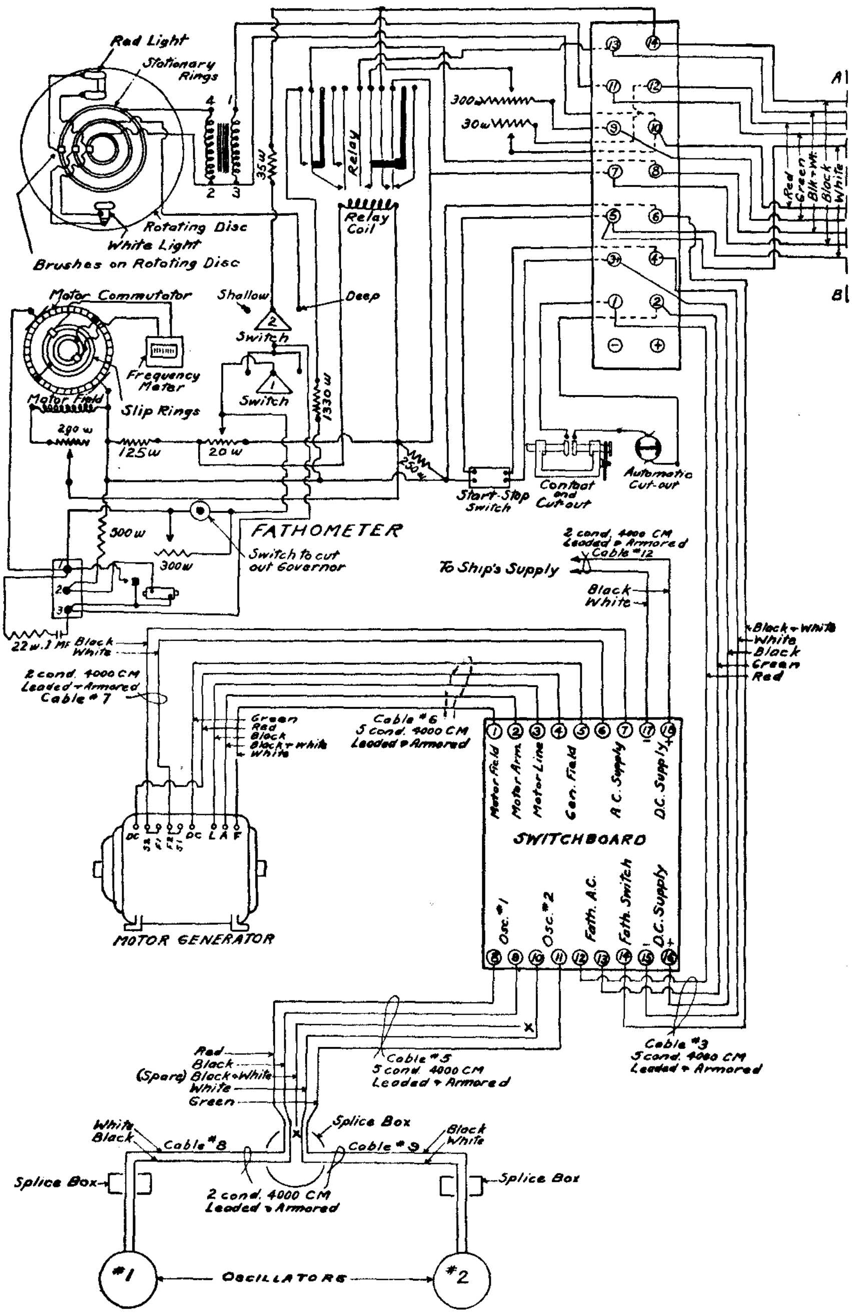

Fig. 19.—Fathometer wiring diagram

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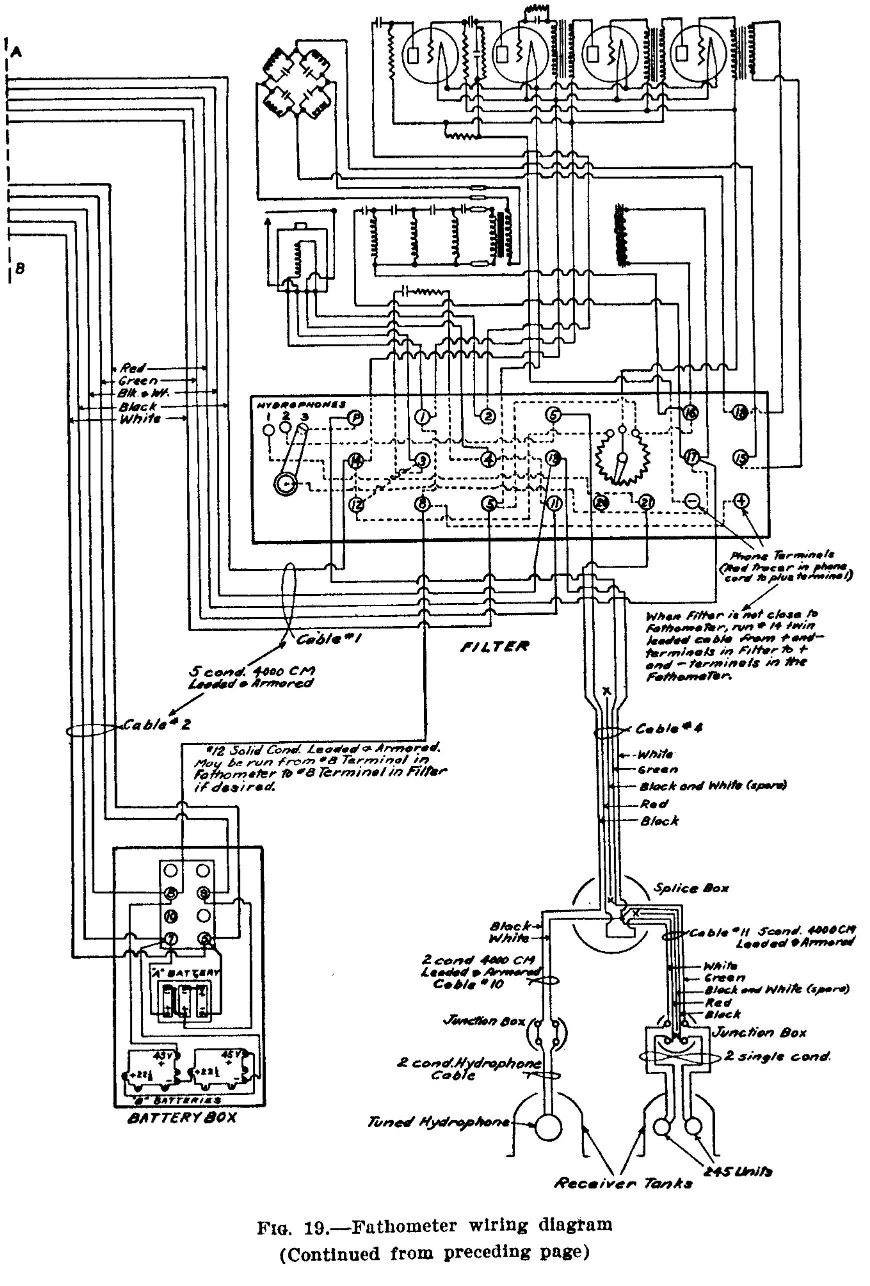

FIG. 19.—Fathometer wiring diagram
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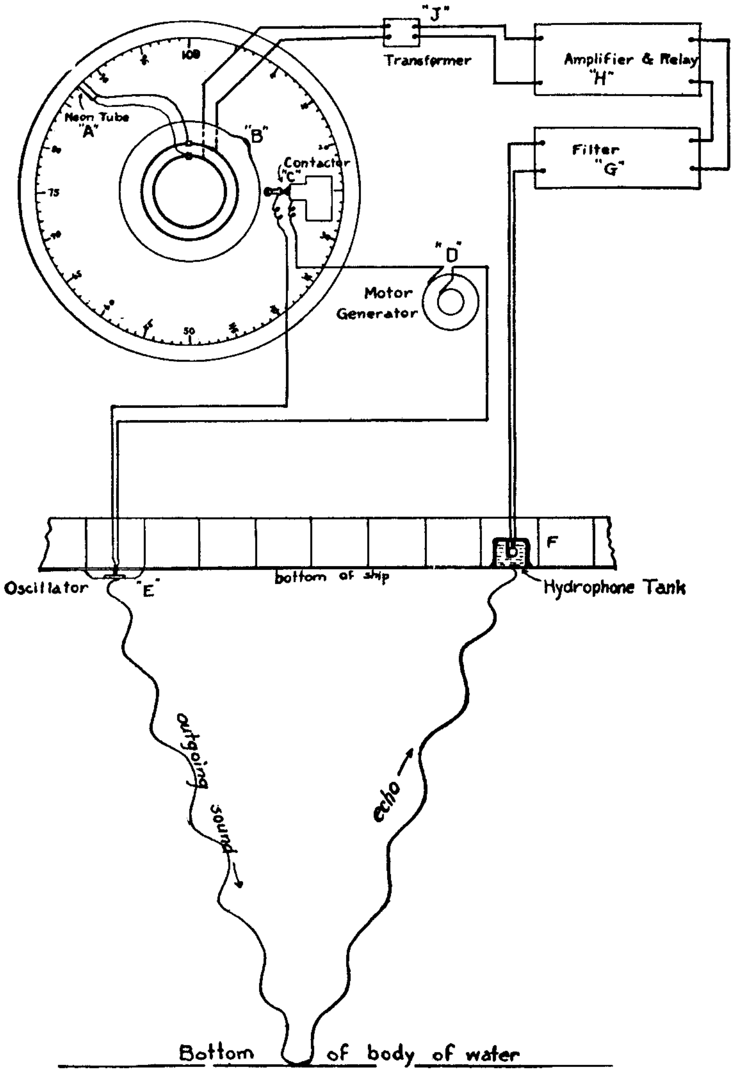

FIG. 20.—Operation of fathometer red-light method

As the neon tube *A* passes its zero position on the depth scale, cam *B* closes contactor *C*, which sends an alternating current from motor generator *D* through oscillator *E*. This produces a sharp sound which is transmitted through the water to the bottom and is reflected, so that a hydrophone *F* placed in a tank of water adjacent to the skin of the ship receives these sound waves, transforming them into electrical waves of the same frequency. There are other sounds or noises about a ship which set up currents of various frequencies, but these are filtered out by the filter *G*, and only the current caused by the echo is allowed to pass on to the amplifier *H*. Here it is amplified to such an amount that it will operate a relay, breaking a circuit in the primary of a transformer, which induces a current in the secondary of the transformer of sufficient voltage to cause a momentary glow of the neon tube, indicating the proper depth on the dial. This operation is repeated each time the neon tube passes its zero position.

circuit in the fathometer and then through to the A battery and back through to the negative side of the switch. This insures that the A battery, or filament-heating battery, is always being charged whenever the fathometer is being operated; and, since the charging current is somewhat greater than the discharging current, the battery is kept fully charged.

From the positive side of the 110-volt line, before it reaches the switch, a wire connects to a 1,330-ohm resistance in series with the positive side of the B battery, thence back to the positive side of the A battery, and thence to the negative side of the switch, so that, whenever the switch is closed, a charging current will be sent through the B battery.

By this arrangement both batteries are being charged while in service, with the result that the batteries are kept charged by the current supplied during the normal operation of the fathometer.

The difference of potential across the 20-ohm resistance shown in the motor circuit is used to actuate a relay which closes the microphone-battery circuit, the amplifier-filament circuit, the spark-coil circuit, and the circuit which provides for the charging of the B battery.

Operation of filter circuit.—When not in use there is no current flowing through any of the tubes or hydrophones or any part of the filter circuit. As soon as the start-stop switch is closed on the fathometer the amplifier cut-out relay is operated and the battery circuits are closed, so that current will be flowing through the hydrophones and through the tube circuits, provided the fathometer is in operation for shallow depths. If in shallow depths, each time the echo is received on one of the hydrophones, depending on which one the switch is turned to, the current in the hydrophone is changed at the same frequency as the oscillator note—namely, 1,050 cycles per second—and a voltage of corresponding frequency, after passing through the filter, is impressed on the grid of the first tube, where it is amplified and passed on to the second and third tubes.

Before reaching the grid of the third tube the signal passes through a condenser and grid leak. In so doing it causes the grid of this tube to become more negative and hence decreases the plate current. This change in plate current gives rise to an alternating voltage across the plate-circuit resistance which is passed on to the grid of the last tube through a condenser. A similar action takes place here in that the change in plate current causes a current to pass through the condenser and relay coil. This pulse of current causes the relay to open its contacts and, therefore, the spark-coil circuit.

The sudden change in the primary or low winding of the spark coil causes a rapid decrease in the magnetic flux through the secondary, so that the voltage induced in the secondary of the spark coil is more than 1,000 volts, which, passing into the red light (a Geissler tube with neon in it), produces a momentary glow of red color. Immediately after the cessation of the signal the circuit is again closed through the spark coil, allowing time for the current to build up to its normal value, which is of the order of 0.05 ampere.

In general, the rheostat in series with the hydrophones, the one at the lower right of the fathometer, should be turned as far to the left, counterclockwise, as will bring in the greatest number of echoes or red flashes with the least number of stray signals. This adjustment to the left gives the maximum amount of resistance in the rheostat.

When operated for deep depths, changing the gears from shoal to deep closes a rocker switch which lights the white light. The flash of the red light will then take place at one-sixth of the true depth, due to the change in gear ratio. Multiplying the red-light reading by six will then give a check on the depth as determined by the white-light method. The adjustment of the rheostat now may be whatever best suits the condition of relative signal strength heard in the telephones, since the whole object now is to be able to distinguish when the echo returns and be able to read the position of the white light simultaneously. Practice is about the only guide in this case, for some people distinguish the echo more easily when it is faint and there is a small amount of water noise, while others hear more readily when it is loud, even with a greater amount of water noise.

On the inside of the filter box, to the right of the hydrophone switch, a rheostat is provided in shunt with the hydrophone input to give a rough adjustment of the signal strength. Turning this rheostat all the way to the right open circuits it so that the full signal strength from the hydrophones is delivered to the amplifier. Turning it to the left will decrease the signal strength to about what is necessary for the depth in question, after which fine variations may be made with the rheostat in the lower right-hand corner of the fathometer. As a general thing, one adjustment of the coarse-adjustment rheostat will suffice for depths from 15 to 100 fathoms. As the depth increases it may become necessary to turn it all the way to the right.

Detailed procedure for operating fathometer.—After the fathometer installation has been completed the operation to determine depths is as follows:

Turn line switch on the motor-generator switchboard to the " On " position and the oscillator switch to either " Port " or " Starboard." The motor-generator set can then be controlled from the fathometer. The hydrophone switch is mounted on the inside of the filter box, on the filter-box terminal board. This switch may be set to use any of the three hydrophones, although better results may usually be obtained by using the tuned hydrophone for deep water and one of the K tubes for shallow depths.

To make the fathometer read depths from the surface, the draft adjustment, which may be found on the back of the rotating dial, must be set to compensate for the draft of the ship and also for lag. Thus, if the ship is drawing 3 fathoms, the pointer on the adjustment should be set at 3. Lag correction is determined experimentally; the pointer is shifted enough to make the fathometer readings, corrected to proper velocity of sound, agree with measured depths. Turning the gear-shift knob on the left-hand side of the fathometer to a halfway position between "Shoal" and "Deep" will disengage the gears, so that the rotating dial can be turned by hand.

After the above adjustments have been made, pushing the start-stop switch button at the upper left-hand corner of the fathometer starts the fathometer motor and also the motor generator which supplies the power for the oscillators.

On the inside of the filter box, on the filter-box terminal block, a rheostat is provided shunted across the input circuit, which gives a coarse adjustment of the signal strength. Turning this rheostat all the way to the right gives maximum signal. With the fathometer running with the gears in the "shoal" position, a red flash should come twice a second at about 3 fathoms. This is the flash caused by the direct signal. Starting with the shunt rheostat set at maximum, slowly turn it to the left until the echo flash appears. Fine adjustments may be made with the series rheostat in the lower right-hand corner of the fathometer. Usually good operation can be obtained by turning the rheostat in the filter box about one-half inch to the left and then making final adjustment with the series rheostat. In this way a considerable range of depths may be covered with but one adjustment of the shunt rheostat, the necessary increases in signal strength as the depth increases being made with the series rheostat. As the depth increases the echo, of course, becomes somewhat weaker and the voltage delivered to the amplifier must be increased. This is done by turning either the series or shunt rheostat to the right.

With this system depths may be conveniently measured up to 200 fathoms. Beyond this point the white-light method, so-called, can usually be used to better advantage.

However, for depths between 100 and 115 fathoms a new scale must be provided, since the shallow-water scale begins at 5 fathoms and is incorrect from there to about 15 fathoms for use for depths greater than 100 fathoms. This is due to the fact that the fathometer measures the hypotenuse of the triangle of which the sides are the depth and one-half the horizontal distance between hydrophone and oscillator but records the actual depth. This is accomplished by reducing in correct proportion the length of each fathom division until a depth is reached at which the hypotenuse and the depth are so nearly of the same length that the difference can not be shown on the scale. It is, therefore, the practice to gum a paper scale just inside the inner scale, extending from 0 to 15 fathoms and divided into intervals of the length of those beyond 15 fathoms; this scale is for use when the depth exceeds 100 fathoms.

To utilize the white-light method turn the knob on the left-hand side of the fathometer to the "deep" position, which changes the gear ratio, so that one signal is sent out each three seconds, and a white light will appear on the outer edge of the rotating dial. With this system contact is made when the white light passes the zero position for its scale, which is at the bottom of the dial. Two signals will now be heard in the phones, one at the instant of making contact, which is the direct signal, and another a moment later, which is the echo. The time interval between the two will increase, of course, for increasing depths. Measurements are then made by observing the position of the white light at the instant when the echo is heard. A check on this depth may be made by observing the depth indicated by the red light, which is in operation at the same time, and multiplying its indication by six.

For depths greater than 600 fathoms the dial will make more than one complete revolution between signal and echo. In such depths the fathometer must be prevented from making further contacts until the echo has had time to return. To do this the button on the door at the right-hand side of the fathometer should be pushed in after contact has been made. This procedure holds the contacts open and prevents the transmission of any more signals until the echo from the first has been received. For depths greater than 600 fathoms the true depth is equal to 600 times the number of revolutions between signal and echo.

A vibratory tachometer in the upper right-hand corner of the fathometer serves to indicate whether or not the motor speed is correct. The motor speed should be such that the middle reed is vibrating. This corresponds to a sound velocity of 4,800 feet per second. The velocities corresponding to the other reeds are given in an accompanying table.

Location of faults in operation.—*Fathometer motor starts but no red flash with fathometer set on "shoal."* Trouble may be due to:

(*a*) Motor generator not running. See that line switch on generator is on.

(*b*) Defective hydrophone. Try switching to other hydrophone.

(*c*) Amplifier. If signal can not be heard in phones, see that the potentiometer at the lower right-hand corner of the fathometer indicator is turned all the way to the right. If signal is still not heard with fathometer running but amplifier does not sound dead, try touching phone tips to grid and filament terminals of each tube socket, beginning at the right. These terminals are the two terminals of the right-hand side of the tube sockets.

If signal is heard with increasing loudness as phones are touched on the grid and filament terminals going from right to left, trouble is probably due to relay being out of adjustment. This can usually be overcome by slacking up on the two thumbscrews at the back of the relay, which hold the lever arm in place, and moving the lever arm slightly to the right or left. When the red flashes begin to appear, the two thumbscrews should be tightened up. Adjustment should be made so that flash occurs for as small a signal strength as possible without bringing in too many strays.

If contacts on relay have to be removed for cleaning, or the contacts have been thrown out of adjustment for any reason, the complete relay adjustment may be made as follows:

(*d*) Relay adjustment. Center lever adjusting arm and lock with two thumbscrews. Back off on both armature stop screws and allow the tongue of the relay to come over against the left-hand pole piece. (By left-hand is meant the pole piece which appears on the left as the relay is installed in the filter amplifier.)

Now take up on the left-hand stop screw until the tongue just falls over to the right. The right-hand stop screw should now be screwed up until there is just room enough for the contacts to open. Final adjustments can then be made with the thumbscrews.

(*e*) Battery voltages down. Test both A and B batteries with a voltmeter, to see that they are at normal potential. The A battery should be 4 volts and the B (or plate) battery 72 volts. Any falling off in these voltages will result in poor operation and, if the decrease is great enough, may even cause the apparatus to refuse to function altogether. Inability to get satisfactory adjustment of the relay is often due to this cause.

Stray flashes on red-light method system.—Trouble may be due to:

(*a*) Relay set in a too sensitive condition. The plate-circuit relay, which may be seen on the left-hand side of the filter amplifier (just above the hydrophone switch), is a very sensitive instrument and may be set so as to operate on a very weak impulse. If it is adjusted to this state, it will be operated by any disturbance, such as water noise, coming from the hydrophones. As these noises are almost always present to a certain extent, particularly at high speeds, the relay may operate on impulses received from these disturbances as well as from those received from the echo.

The remedy is to move the lever adjusting arm slightly to the left by means of the thumbscrews on top of the relay until the stray flashes stop, and only the echo or possibly the echo and direct-signal flashes are present.

(*b*) *Other causes.*—Stray flashes may also be caused by arcing on the commutator of the motor generator, the motor in the fathometer, or by dirty or poor contacts at such points as the oscillator-contact points in the fathometer, the tube sockets, etc.

Irregular or weak operation on red light.—If the fathometer operates satisfactorily in shoal water, say 30 fathoms or under, but does not operate or operates very irregularly at greater depths and the echo sounds weak, the trouble may be due to one or more of the amplifier tubes having become worn out. The remedy is to try replacing progressively each of the tubes in the amplifier with a new tube from the spare-parts box. If no difference is noted in the intensity of the signal when one tube is replaced, the old tube should be put back and next one removed, and so on. When the bad tube is replaced, an immediate increase in signal strength will be noted.

A weak-sounding echo may also be due to the motor generator being off frequency. The armature should be revolving at 2,575 revolutions per minute when cold. After running until heated up, it should be revolving at about 2,625 revolutions per minute.

After a period of six months, more or less, depending upon the amount of use to which the fathometer is put, the dry cells, located in the battery box, which supply the microphone current will become worn out and should be replaced. This state will be manifested by the fact that the signal heard in the receivers will become weak and may be insufficient to operate the red light. Two new dry cells should then be put in to replace the worn-out dry cells.

Vibratory tachometer

Reed	Cycles	Revolutions per minute	Velocity		
			Ft./sec.	Fms./sec.	Meters/sec.
Left	28½	1, 710	4, 560	760	1, 390
No. 2	29¼	1, 755	4, 680	780	1, 426
No. 3	29¾	1, 785	4, 759	793	1, 450
Middle	30	1, 800	4, 800	800	1, 463
No. 5	30¼	1, 815	4, 840	807	1, 475
No. 6	30¾	1, 845	4, 920	820	1, 500
Right	31½	1, 890	5, 040	840	1, 536

Reeds are calibrated for not more than one-half of 1 per cent error, maximum.
Average error is ±0.2 per cent.

Sonic depth finder.—This apparatus, developed by the United States Navy, is similar in principle to the fathometer, but all depths are read by a method of synchronizing in split head phones the sound impulse and its echo. Depths can not be read by this method with sufficient accuracy for survey purposes in less than 100 fathoms.

Use of echo-sounding apparatus.—The general requirements for use of such apparatus are given in part 1. The method of correcting and reducing soundings is described and illustrated in chapter 6.

Velocity of sound in sea water.[2]—The use of echo-sounding apparatus requires knowledge of the velocity of sound in sea water. The sonic depth finder gives a time interval which is used with the velocity of sound to determine the depth. The fathometer is required to be operated at a speed corresponding to a standard sound velocity, so that a correction factor must be used to correct the sounding for the actual velocity existing under the conditions that prevail at the time of sounding.

The velocity of sound in water depends on the pressure, temperature, and salinity. The approximate pressure at any depth, of course, is known; temperatures and salinity must be determined by observations on the working grounds and are used in connection with tables published in the appendix to this manual to obtain the velocity. The use of these tables is explained under "Reduction of soundings" in chapter 6.

Temperatures.—Of all the physical conditions that affect the velocity of sound in sea water, temperature is by far the most important. An error of but 1° C. in the mean temperature of the water will cause an appreciable error in the adopted velocity of sound—about twice the error caused by an error of one salinity (one part per thousand of the salt content). It is, therefore, evident that the hydrographer must give special attention to this subject. He must know the mean temperature of the water through which the sound travels—that is, from the depth of the oscillator and hydrophone to the bottom—for every sounding. It is practicable to obtain this mean with an error not in excess of 1° C. if sufficient temperatures are taken during the season.

The temperature curves for the coast of Oregon and the Gulf of Alaska show a rapid drop in temperature from the surface to about 20 fathoms, below which the drop is gradual and uniform. The Lower California curve shows a constant decrease in the rate of change to a depth of about 120 fathoms and then a uniform rate to 500 fathoms. The Hawaiian curve shows that the surface temperature decreases less than 1° to a depth of 50 fathoms; the temperature then decreases rapidly to about 110 fathoms and from there decreases in a constantly diminishing amount to about 450 fathoms. How

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[2] For further discussion of this subject and description of experiments for the determination of velocity of sound in sea water, see Coast and Geodetic Survey Special Publication No. 108.

frequently then should temperatures be taken? This must be decided by the hydrographer in every case, since conditions vary so greatly in different localities that no formula can be stated that will apply to all places at all seasons. A few general rules, however, are suggested by the temperature curves given in Figure 21, which are fairly typical.

All curves meet approximately at about 450 fathoms. From these curves we see that the average of the temperatures at the surface and at the bottom, except for very shallow depths, will not give the true mean temperature within 1°. We also see that for some localities, in Oregon and Alaska, the mean temperature for the first 30 fathoms, obtained from the average of observations at 5-fathom intervals, if combined with observations at wide intervals, such as 50 or even 100 fathoms, would give a mean temperature close to the fact. On the other hand, for Lower California, and especially for Hawaiian waters, temperatures must be taken at short intervals, in the latter case to a depth of 300 fathoms, to get a true mean. Finally, we see that in depths greater than about 400 fathoms there is little difference in temperature between such extremes of latitude as Gulf of Alaska and Lower California or Hawaii. We may also infer from these curves, since the great temperature differences are in the upper strata (100 fathoms or less), that seasonal changes in temperature are confined to those strata. Observations at different seasons in the same locality confirm this inference and indicate that, in general, seasonal changes in temperature extend for a very short distance (much less than 100 fathoms) below the surface.

From these conclusions we may adopt the following general rules for observing temperatures for the determination of echo-sounding velocities:

1. Beginning at a depth of 2 fathoms (the approximate depth of oscillator and hydrophone), observe temperatures at intervals of 5 fathoms of depth as long as the difference between successive observations amounts to 1° C. or more. When the difference is less than 1°, increase the depth interval to 10 fathoms. If the next observation gives a temperature difference of less than 1°, increase the interval to 20 or 25 fathoms. Continue to increase the interval between observations as long as the temperature changes remain within 1°. Intervals may be increased to 100 or even 200 fathoms when successive observations show small changes in temperature (half a degree or so).

2. Take another temperature series in some other locality but within the area under survey and compare it with the first. If the second series gives a mean temperature within 1° of that obtained from the first series, it may be assumed that additional series are not necessary at that time unless there are reasons for suspecting that the condi-

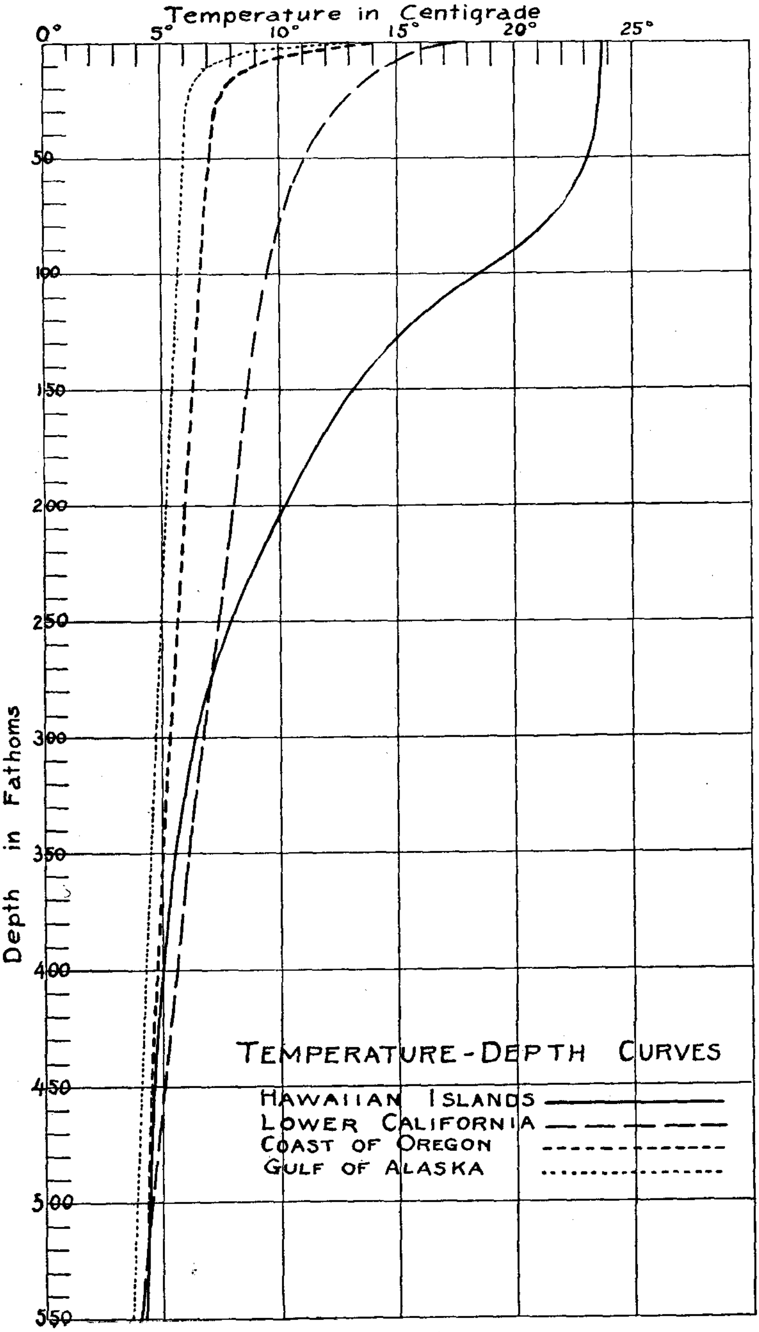

FIG. 21.—Temperature-depth curves

tions at these two stations are not typical of the whole area under survey. A glacial stream or the proximity of an oceanic current to the working ground would suggest the need for additional series in those localities.

3. At intervals during the season, as the surface water becomes warmer or colder, short series should be taken down to a depth at which the temperature conforms to the first series.

4. To obtain mean temperature from one of these series, it is necessary to make due allowance for the changing interval depth between observations; the arithmetical mean would give too much weight to the high temperatures of the warmer water of the upper shallow layers. Accordingly, temperatures must be weighted in the ratio of the distance between observations. The short series taken at different times during the season to test seasonal changes can be combined with the lower part of a long series in the same way.

5. A new mean temperature value should be adopted whenever the observations indicate that the old value no longer holds true, and especial care should be taken to show in the records when a change has been made and to give all data to support the temperature adopted.

A convenient method for recording temperatures and for working out and preserving the means, factors, and corrections resulting therefrom, is shown in the following table. The method of obtaining factors is explained on page 119.

Fathometer factors and corrections for soundings of 450 fathoms or less

[Locality, coast of Oregon. Mean salinity, 33. Standard velocity, 800]

Date, ... Location of station: Lat., ...; long., ...

Depth in fathoms	Temperature, ° C.	Mean temperature	Factor	Correction, fathoms	Depth in fathoms	Temperature, ° C.	Mean temperature	Factor	Correction, fathoms
2	12.0				87	6.8	7.6	+0.012	+1.0
7	9.5				92	6.7	7.5	+.012	+1.1
12	8.3	9.9	+0.018	+0.2	97	6.7	7.5	+.012	+1.2
17	7.7	9.4	+.017	+.3	102	6.7	7.5	+.012	+1.2
22	7.5	9.0	+.015	+.3	120 [1]	[1] 6.5	[1] 7.3	+.011	+1.3
27	7.3	8.7	+.014	+.4	140	6.3	7.2	+.011	+1.5
32	7.2	8.5	+.014	+.4	160	6.2	7.0	+.011	+1.8
37	7.2	8.3	+.014	+.5	180	6.0	6.9	+.010	+1.8
42	7.2	8.2	+.013	+.5	200	5.8	6.8	+.010	+2.0
47	7.2	8.1	+.013	+.6	220	5.7	6.7	+.010	+2.2
52	7.1	8.0	+.013	+.7	240	5.5	6.6	+.009	+2.2
57	7.0	7.9	+.013	+.7	260	5.3	6.5	+.009	+2.3
62	7.0	7.9	+.013	+.8	280	5.3	6.4	+.009	+2.5
67	7.0	7.8	+.012	+.8	300	5.2	6.4	+.009	+2.7
72	6.9	7.7	+.012	+.9	350	4.8	6.1	+.008	+2.8
77	6.9	7.7	+.012	+.9	400	4.6	5.9	+.008	+3.2
82	6.8	7.6	+.012	+1.0	450	4.4	5.8	+.008	+3.6

[1] Weighted mean from this point downward.

Temperatures are obtained conveniently by means of the Tanner-Sigsbee reversing case and deep-sea thermometer. The thermometer and case are lowered to the desired depth and held there for about one minute to allow the mercury to rise to the correct scale reading. It is then hauled up and read, the case reversing on the upward motion and breaking the mercury column at the reading at which the case begins to rise, or rather slightly above that level. (See p. 77.)

Salinity.—The salinity of sea water is considered to be the number of parts per thousand, by weight, of total dissolved solids and is expressed by this symbol, $\frac{0}{00}$. Salinity and relative density (specific gravity) may be determined in several ways, and the results may be converted from one term to the other by empirical formulas or by tables. Since velocity of sound tables have been prepared in terms of salinity, temperature, and pressure, it is necessary to convert density values to their salinity equivalents when observations are made in terms of density. Table 3 in the appendix is available for this purpose. For echo sounding and subaqueous sound ranging it is necessary to know the salinity of the sea water to 1 part in 1,000, corresponding to a relative density of about eight in the fourth decimal place.

Salinity by hydrometer.—The simplest method of determining density is by means of a hydrometer. Since hydrometers are usually calibrated in terms of specific gravity or density, it is necessary to refer to Table 3 for the salinity equivalent. The Coast and Geodetic Survey furnishes these instruments in sets of three, having scales of 1.0000 to 1.0110, 1.0100 to 1.0210, and 1.0200 to 1.0310, respectively. The value of the smallest division of each is 0.0002 of specific gravity, which division can be read to the nearest one-half by estimation. Densities can therefore be obtained to one in the fourth decimal place by these instruments, which is well within the requirements for hydrographic surveys.

Some difficulty may be expected in reading accurately a hydrometer on shipboard, and if there is much vibration and rolling, it will be impossible to get the requisite accuracy. In this case water specimens should be preserved in glass-stoppered bottles until they can be tested. If the motion of the ship is not too great, the hydrometer can be read satisfactorily if the top of the hydrometer jar is grasped between the thumb and first finger and allowed to hang freely, which will cause it to maintain a vertical position in spite of the motion of the ship. Temperature of the water specimen should be observed to the nearest tenth of a degree centigrade, which requires that the water be well stirred and temperature observation taken as nearly as possible at the same time the hydrometer is read. Hydrometers, thermometer, and beaker should be kept clean and free from salt deposit that would affect the sample; they should be washed in fresh water after the completion of observations.

In reading the hydrometer, look at the water surface from beneath (through the liquid and its glass container) and gradually lower the glass until the ellipse becomes a straight line, which is the bottom of the water meniscus in the hydrometer jar. The position of this straight line on the hydrometer scale gives the correct reading. It is well to take two or three readings, to make sure that the bulb is not sticking to the side of the jar.

Salinity by titration.—The salinity of sea water can be determined quickly, conveniently, and with sufficient precision by titration with silver-nitrate solution, even when the motion of the ship is too great for accurate hydrometer observations. Experiments have shown that experience is not essential; that with reasonable care any officer can get satisfactory results. This method depends upon the fact that the percentage of chlorine in the total dissolved solids in sea water is nearly constant the world over and may be taken as 55.25 per cent without serious error. The method consists in observing how much silver-nitrate solution of known strength must be added to a measured sample of sea water, to which a few drops of potassium chromate solution have been added, to precipitate as silver chloride all the chlorine in the water.

The silver-nitrate solution is prepared by dissolving 54.18 grams of *chemically pure*, dry silver-nitrate crystals in distilled water and then adding enough more distilled water to make 2,000 cubic centimeters of solution. The crystals should be kept in a dark place, as they undergo chemical change when exposed to light.

The potassium-chromate solution should be prepared as follows: Dissolve 5 grams of *chemically pure* potassium-chromate crystals in distilled water, add silver-nitrate solution slowly, drop by drop, stirring constantly, until a distinct red precipitate is formed. Filter and dilute the filtrate with distilled water to make 100 cubic centimeters of solution. This solution may be kept in a 4-ounce glass-stoppered bottle and can be taken from the bottle and dropped into the sample of sea water by means of a 1 cubic centimeter transfer pipette.

The following additional equipment will be found desirable for performing titration: A 50-cubic-centimeter burette, a 250-cubic-centimeter evaporating dish, a glass stirring rod, a 10-cubic-centimeter transfer pipette, and a 150-cubic-centimeter glass beaker. The success of the operation is dependent upon all apparatus being absolutely clean; all apparatus should be rinsed with distilled water after use.

The procedure for making a titration is as follows:

(1) Using the beaker, fill the burette to the zero mark with silver-nitrate solution, making sure that the tip of the burette is full.

(2) Rinse the evaporating dish, stirring rod, and 10-cubic-centimeter pipette with sea water and then shake them clear of all drops.

(3) Using the 10-cubic-centimeter pipette, measure out 10 cubic centimeters of sea-water sample into the evaporating dish. Add 1 cubic centimeter of potassium-chromate solution and place the evaporating dish under the burette. Allow silver-nitrate solution to run down into the evaporating dish from the burette, stirring constantly, until a pink tint appears that does not disappear upon stirring. The reading of the burette will then be the salinity of the sample in parts per thousand (by weight) of total dissolved solids.

The observer can usually estimate a minimum value for the salinity and let the nitrate solution run down rapidly to the corresponding mark on the burette. After that he should let the solution drip down slowly, stirring constantly. Probably some solution will drop from the burette after he has attempted to stop the flow. If so, he should count the number of drops after he detects the color change (including that left hanging from the tip of the burette) and subtract an amount equal to the number of drops multiplied by 0.05 cubic centimeter from the burette reading.

Other methods.—The dipping refractometer affords another means for determining salinity on shipboard with considerable precision, even in quite rough weather. The instrument is designed to measure the refractive indices of liquids at known temperatures but must be used in connection with calibration charts, since it gives values only in terms of an arbitrary scale. On account of the cost of this instrument and because two other relatively inexpensive methods are available to meet usual requirements of hydrographic parties, a dipping refractometer will be supplied only when the need is evident. Complete instruction and calibration charts will be supplied when these instruments are issued.

Electrical resistance of sea water varies in a definite ratio with its salt content, which offers still another method for measuring salinity. Special apparatus has been constructed and used successfully on shipboard to determine salinity with a very high degree of precision. This apparatus gives results considerably above the requirement for hydrographic surveying but is very costly. No electrical apparatus is known that will meet our required accuracy and can be obtained at a moderate cost.

There are several other means for measuring salinity, but it is doubtful if any of them are suitable for use on shipboard.

Frequency of observations.—Salinity observations should be made with such frequency as will enable the hydrographer to determine to 1 part in 1,000 (by weight) the mean salt content of the water through

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which he must know the actual velocity of sound for the work in hand. Ordinarily sea water remains constant within this limit over a considerable area. He should, however, take sufficient observations at the surface and at various depths to determine a correct mean value and to establish the fact that there are no important variations from this mean in any part of the area under survey. Special consideration should be given to salinity when taking echo soundings in the vicinity of fresh-water outlets and oceanic streams.

WIRE DRAG AND SWEEP

Surveys by the methods described above are sufficient except in rocky regions, where other means must be employed to make sure that all obstructions of small extent, such as pinnacle rocks, bowlders, and ledges, are discovered.

For the final examination of such regions the Coast and Geodetic Survey has developed an apparatus known as the wire drag. This consists of a wire maintained in a horizontal position at any desired depth by means of weights suspended by cables from floating buoys and by floats attached to the wire at regular intervals. The upright cables are wound on drums on the tops of the buoys, so that the depth of the wire can be changed as desired.

The wire drag is towed by a vessel at each end and will catch on any obstruction extending above the depth at which it is set.

A light wire drag in which the metal buoys are replaced by pneumatic canvas buoys is provided for use on vessels not regularly engaged in drag work.

The wire sweep is a modification of the drag for use in regions where the general depths are considerably greater than the depth to be verified and where few, if any, obstructions are believed to exist. The buoys are much farther apart than in the drag, and no provision is made for changing the depth of the sweep while in use or for preventing sag of wire between buoys.

The construction and operation of the wire drag and sweep are described fully in Coast and Geodetic Survey Special Publication No. 118.

OCEANOGRAPHIC DATA

Character of bottom.—In ordinary hydrographic work the character of the bottom is determined by filling the depression, provided in the bottom of sounding leads, with tallow or soap (called "arming the lead") and noting the material that adheres to it. Hard or soft bottom can be determined by the feel of the lead.

Information of this nature is very important, and the general requirements with regard to it should be followed carefully in all cases. In many regions the character of the bottom in connection with soundings is a valuable indication of approximate position when cruising in thick weather. When the bottom is noted at the top of the record page, it is understood to remain unchanged until a different bottom is recorded.

Such information given by the sounding lead may be somewhat superficial, and in harbors and anchorages, where it is especially important, a useful check is furnished by actual experiences in anchoring with an inspection of material brought up by the anchor.

Deep-sea data—Bottom specimens.—Instruments used to secure deep-sea data are illustrated in Figure 22. The Belknap-Sigsbee specimen cylinder, used with a detachable lead for deep-sea soundings, incorporates a device for obtaining a specimen of bottom material. In depths where the lead is recoverable, several types of specimen cups are available for attachment to the bottom of the lead. The Coast and Geodetic Survey generally uses a snapper type of cup in which two spoon-shaped jaws, closed by a spring, are held apart by a trigger that trips when the cup strikes bottom. This device works very well, but may fail from time to time if the bottom material includes small pebbles or shells that may be caught between the jaws, holding them open.

Temperatures.—The surface temperature may be determined by immersing a thermometer in a bucket of surface sea water, but a more convenient method is to use a registering thermometer and the thermometer holder of a Tanner-Sigsbee reversing case. The thermometer is placed in the holder and lowered overboard for a suitable interval of time by means of a lanyard. When the holder is hauled in, the thermometer is reversed and read. This method decreases the possibility of breakage of thermometers and probably gives a better determination of the temperature.

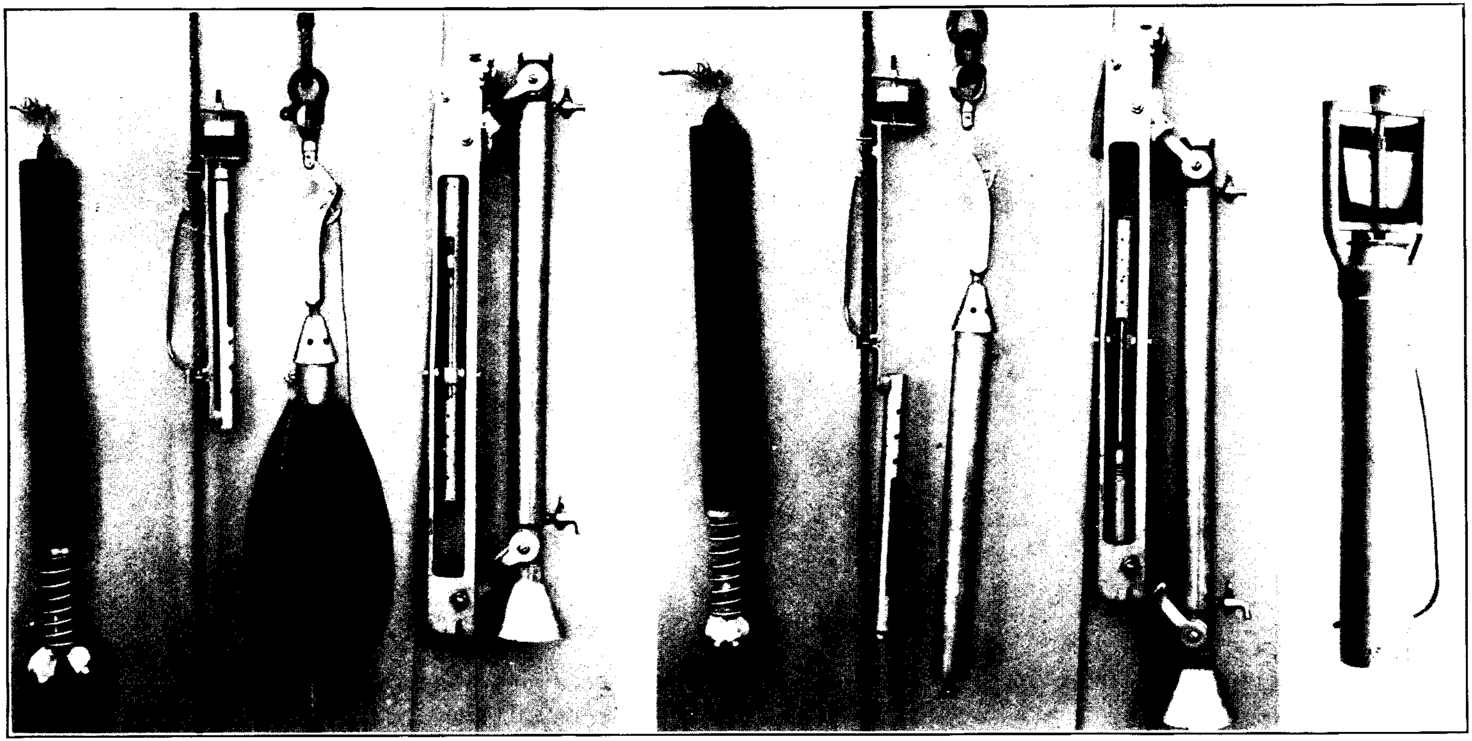
Temperatures at any desired depths may be obtained with Negretti-Zambra thermometers in Tanner-Sigsbee reversing cases. In using this type of case, care must be taken that the instrument reverses at the proper point. The thermometer holder is hinged to a rod at the bottom and is held in an upright position by a pin to which a small propeller is attached. When reeling out, the action of the water on the propeller forces the pin into a depression in the top of the case. As soon as reeling in is started the propeller should reverse and raise the pin. Unless the apparatus is adjusted properly, however, the case may rise some distance before it is released. The case should be tested by lowering it to a depth of 2 or 3 fathoms and observing its action when raised. If it does not release promptly, it should be adjusted by inserting one or more washers in the lower part of the propeller frame to check the descent of the pin. A thermometer should remain in the water at least one minute.

Water samples.—Water samples may be obtained by means of Greene-Bigelow watercups, which also have a registering thermometer in a reversing case and are operated at any desired depth by a metal messenger sent down on the wire. The Sigsbee watercup is also used for this purpose. This apparatus consists of a hollow metal cylinder with valves at each end so arranged and connected that external pressure on the top one closes both valves. At the top of the cylinder is a framework holding a screw and a propeller. To obtain a sample, the valves are opened and the cup sent down to the desired depth. When the cup is hauled in the water pressure closes the valves, and the propeller, which has no connection with the screw during the descent, now turns in an opposite direction, engages the screw by a ratchet arrangement and forces it down on the upper valve, thus locking the cup, which retains a sample of the water at the approximate depth from which the cup was raised.

The Belknap-Sigsbee specimen cylinder also has a device for obtaining a sample of water at the bottom, but its action is not always satisfactory, as some of the bottom material may hold the valve open. This material may be washed out during the reeling in of the wire, and the rod may come to the surface with no indication that the water contained therein was not obtained at the bottom. The most satisfactory method of obtaining a sample of water at the bottom is to attach a watercup a few fathoms above the lead, so that the former will not come in contact with the bottom.

Preservation of specimens.—Bottom specimens are described while in a moist condition and then sealed in glass bottles. Water specimens are also preserved in glass bottles sealed with glass or porcelain stoppers and rubber gaskets.

An account of deep-sea soundings in the Atlantic and Pacific Oceans and the Caribbean Sea, obtained in 1919 and 1922 by a number of Coast and Geodetic Survey ships while en route between the Atlantic and Pacific coasts, will be found in Coast and Geodetic Survey Special Publication No. 97.



a b c d a b c d e

Left: Ready to sound. Center: After sounding

FIG. 22.—APPARATUS FOR OBTAINING OCEANOGRAPHIC DATA

a, Improvised sinker equipped with snapper type of bottom-specimen cup; *b*, Tanner-Sigsbee reversing case for use with registering thermometer; *c*, Belknap-Sigsbee specimen cylinder, deep-sea sinker attached (in left-hand illustration); *d*, Greene-Bigelow watercup with reversing case for thermometer; *e*, Sigsbee watercup

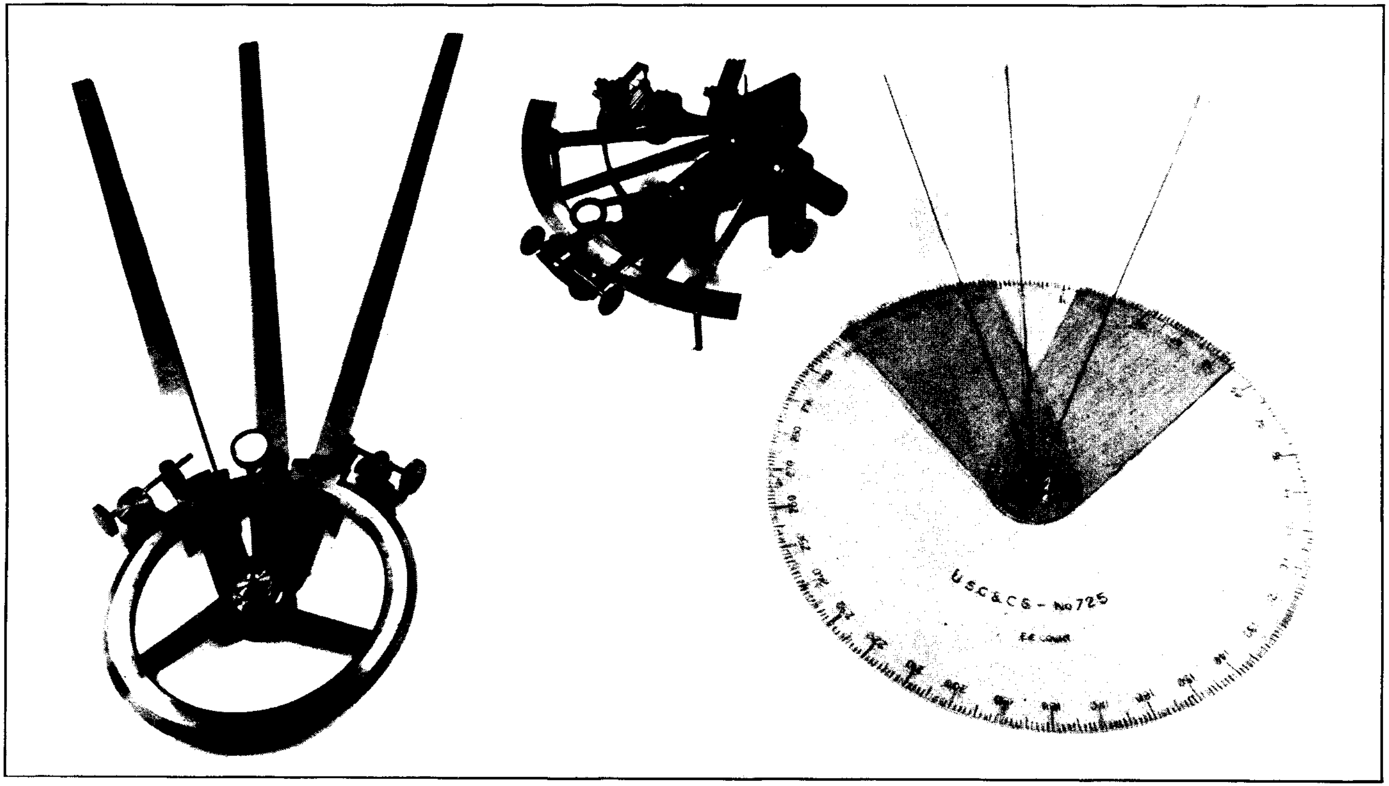


FIG. 23.—HYDROGRAPHIC SEXTANT; STEEL AND CELLULOID THREE-ARM PROTRACTORS

Chapter 5.—POSITION FINDING

To meet the various conditions encountered in hydrographic work, a number of methods of locating the sounding vessel are available. When within sight of land signals, positions may be obtained by theodolite angles to the vessel from two shore stations; by measuring distances on established ranges; by sextant angles, observed on board the vessel, between three stations; and by combinations of these methods.

Theodolite angles.—This method is the most precise and should be used when extreme accuracy is demanded, as in harbor-improvement surveys. Although not often employed in general coast work, it may be convenient in some cases. For instance, the signal at the masthead of a vessel may sometimes be distinguished at a greater distance offshore than the shore stations can be seen from the vessel. The two theodolities are set up at suitably situated triangulation stations. All the directions are referred to a known direction as zero, which it will be convenient in plotting to have to the left of any position of the vessel, when the theodolite is graduated clockwise. This zero should be verified, say at the beginning of each page of the record, by recording a pointing on the reference object.

A time ball or flag is shown from the vessel each time a position is required, and the instant it is dropped the direction of the foremast or other suitable mark on the vessel is observed at each station and the time recorded at the two stations and on board. Or observations may be made by a prearranged time schedule, in which case occasional signals should be made, if possible, for the comparison of clocks. The clocks should be set to agree and compared at the end of the day.

Ranges.—This method is sometimes used for very close and accurate work in the vicinity of wharves, slips, etc. Suitable ranges are set up and located, and soundings are obtained at various points on these ranges, measuring the distance of each sounding from the face of the wharf or other suitable reference point by means of a graduated line. This method may be modified by having the boat pass slowly along the face of a wharf, being kept a certain distance off by means of a line, while soundings are obtained at regular intervals.

SEXTANT POSITIONS

Position determination by sextant angles taken on board the sounding vessel is the most satisfactory and most commonly used method for coastal work. Two observers observe angles simultaneously, one between a right-hand object and a center object and the other between the center object and a left-hand object. The position of the vessel is then plotted by using a three-arm protractor to effect a graphic solution of the three-point problem. This method has the advantages that all operations are performed on board the vessel and that the position is known immediately.

Sextants.—Hydrographic sextants (see fig. 23) resemble those used for navigation but are of lighter construction and are read only to minutes. They can be used to measure angles up to about 140°. The telescope generally has a bell-shaped tube, so as to include as large a field as possible.

Adjustment of sextant.—In adjusting a sextant for hydrographic use the following procedure should be followed: Hold the sextant so that the reflection of the graduated arc can be seen in the index mirror (the larger mirror, on the movable arm) and, moving the arm slowly, see if the arc and its reflection appear to form a continuous unbroken arc; if not, correct by turning the adjusting screw at the back of this mirror with the small socket wrench. Next set the arm at zero and, holding the sextant in a vertical position with the arc down, sight at the sea horizon and see if the horizon and its image in the horizon mirror coincide; if not, correct by means of the screw at the side of this mirror, releasing the clamp screw with the knurled head for this purpose. Then rotate the sextant about 45° and see if the horizon and its image still coincide; if not, correct with the screw at the back of the horizon mirror. If this last adjustment is required, it may disturb the vertical adjustment. Both should be repeated until the horizon mirror is adjusted for any position of the sextant.

Use of sextant.—To measure an angle between two objects with a sextant, the observer looks at the one on the left over the top of the horizon mirror and moves the sextant arm until the reflection of the right-hand object in the horizon mirror is directly under the left-hand object.

When objects are definite and readily visible, many observers use the sextant without a telescope, especially if the angle is changing rapidly or the sounding vessel is unsteady. When a small error in the angle will affect the position considerably, or when observing on distant objects that are at all indistinct or indefinite, the use of the telescope is recommended. The distinctness of the reflected object can be regulated to some extent by raising or lowering the telescope.

As an angle generally is changing appreciably, the usual procedure is to hold the objects together by moving the unclamped arm until about time to take the angle and then to clamp the arm and use the tangent screw. It is often difficult to do this when an angle is changing rapidly, and in this case many observers set the clamp screw so that the arm will slide with a little friction and take the angle without using the tangent screw, adjusting the magnifying glass beforehand and taking care not to touch the arm until the angle is read. This requires care but is often preferable to clamping the arm at the moment of observation, which may cause the arm to jump a little. As a general rule, an observer, after taking an angle, should not move the arm of his sextant until the position is plotted, so that he can verify the vernier reading if necessary. If he wishes to use his sextant immediately to measure a cut or other angle, he should read the angle again before moving the arm.

Faint objects.—Facility in taking sextant angles between conspicuous objects can be acquired with a little practice, but when signals are faint the difficulties encountered may be discouraging to the beginner. The greatest trouble usually is in reflecting such signals, which sometimes can not be picked up, even though they can be seen fairly well when looking at them direct. In such cases it will be of material assistance if the sextant can be set close enough to the angle so that the signal will come within the field of the telescope. There are several methods of finding approximate angles. The rate of change of the angle may be noted and the sextant set accordingly or a conspicuous object or peculiarity of the sky line near the signal may be noted and reflected to bring the signal within the field of vision.

Every observer should ascertain the angle subtended between the ends of the thumb and little finger of one hand, outstretched at arm's length, so that by sighting over his hand and moving it along the horizon, he can step off an approximate angle between two objects. If the center object is hard to reflect, the observers may measure the right angle and the sum angle between the outside objects, subtracting one from the other to obtain the left angle.

Inexperienced observers sometimes have considerable difficulty in taking angles between distant floating signals and even in picking up the direct object unless they watch it constantly. For this class of work it is best to select a definite position on the bridge from which the direct object is in line, or nearly so, with a stay or some other part of the vessel. The reflected object may be followed by noting the rate of change of the angle or by setting the sextant a sufficient number of times between positions to keep the object always in the field of vision.

In using the above method of picking up faint objects, observers, and especially beginners, should be warned against getting an approximate angle and letting imagination do the rest. Such methods can, of course, be used only to aid in taking angles. If both objects can not actually be seen at the time of taking the angle, there is nothing to do but inform the officer in charge.

Sextant glasses.—A sufficient supply of spare sextant glasses should be kept on hand. When the glasses become unserviceable they should be returned to the office. Sextant glasses are expensive, and precaution should be taken against their being lost, broken, or scratched.

In case of emergency sextant glasses may be resilvered in the field by the following method: The necessary requisites are tin foil and mercury. Lay the tin foil, which should exceed the surface of the glass by a quarter of an inch on each side, on a smooth pad of paper; rub it smooth with the finger; add a drop of mercury about the size of a small shot, which rub gently over the tin foil until it spreads itself and shows a silvered surface; gently add sufficient mercury to cover the leaf, so that its surface is fluid. Prepare a slip of clean tissue paper the size of the tin foil. Brush the surface of the mercury gently to free it from dross. Take the glass, previously well cleaned, in the left hand and the paper in the right. Lay the paper on the mercury and the glass on it. Pressing gently on the glass withdraw the paper. Turn the glass on its face and leave it on an inclined plane to allow the mercury to flow off, which is accelerated by laying a strip of tin foil as a conductor to its lower edge. The edges may be removed after 12 hours, and in 24 hours give it a coat of varnish made from alcohol and red sealing wax.

The mercury-tin amalgam, while less readily affected chemically, is more liable to mechanical injury than silver, and caution is therefore necessary in handling the sextant glasses.

Metal mirrors.—The bureau is experimenting with mirrors of highly polished nonrusting metal, such as stainless steel and stellite. Reports from the field indicate that these have lower reflecting power than glass mirrors but are more durable. They will probably be used to best advantage in launch work where mirrors can not be protected so well as on shipboard and where signals usually are near by and easily picked up.

Protractors.—The two types of three-arm protractors in general use are illustrated, together with a hydrographic sextant, in Figure 23. The metal protractor is more accurate and durable. It is equipped with three centers—one with crosslines for plotting cuts, etc.; one with a small hole through which the position is marked with a pencil, which is generally used for field work; and one with a needle punch, generally used for smooth plotting. Extension arms are provided for distant signals.

Court's celluloid protractor is used for plotting when an angle is too small to be set on the metal protractor or when the signals are so close to the vessel that they fall under the frame of the metal instrument. It is also used to a considerable extent for general plotting on small launches where it may be more convenient to handle.

Testing protractor.—The testing and adjustment of protractors, as specified in the general requirements, applies to those used for field as well as smooth plotting and is very important, as an endless amount of trouble will result from using inaccurate protractors. Newer instruments generally hold their adjustments better and should be reserved for smooth plotting.

An aluminum plate with test lines is furnished by the office for testing purposes. If such a plate is not available, construct, on heavy paper, two lines perpendicular to each other and parallel with the edges of the paper. This, of course, must be done with extreme care.

To test a protractor, use the crossline center and make sure that it is flush, or nearly so, with the hub of the instrument in order to avoid parallax. Place the protractor on the plate or paper so that the crosslines of the center coincide with the intersection of the test lines and the fixed arm coincides exactly with one of the lines. Then clamp the two movable arms to coincide with the lines at right angles with the fixed arm. If the verniers do not read 90°, loosen the screws and secure the verniers in the proper position. Next test the right arm in line with the fixed arm; if the vernier does not read 180°, any appreciable error should be noted and corrected when setting off large angles. If a plate with diagonal lines is available, intermediate angles should be checked in the same manner.

Each extension arm is fitted and marked to correspond with a certain arm of the protractor. These should be tested for alignment and always used with the proper instrument arm.

Celluloid protractors can not be adjusted but should be tested for appreciable error.

Manipulation of protractor.—In plotting positions it is well for the sake of rapidity to have a uniform practice in placing the protractor. It is usually preferable to place the fixed arm on the center object, with the right and left arms about equally distant from the corresponding objects, and, keeping the center object on, to push the center of the instrument toward the objects, reducing the distances on either side equally until the fiducial edges of all three arms exactly bisect the station points. To avoid touching the movable arms, the circle should be held with one hand while the other is used to steady the fixed arm.

Protection against injury.—Sextants and protractors, especially when used on launches, should be placed in racks when not in use, so that they will not be thrown about by the movement of the vessel, Celluloid protractors are quite likely to be blown overboard unless secured by a lanyard of twine.

Strength of position angles.—The locus of the vertex of an angle between two fixed points lies on the circumference of a circle which passes through the two fixed points and the vertex. The two angles measured between three fixed points determine the position sought, as at the intersection of the two loci of the angle vertexes. When the circles on which the loci lie approach tangency the position becomes weak. The strength of a position determination therefore depends directly on the relative positions of the three fixed points and of the position sought. Due to possible distortion in the paper used for sheets, the strength of a position is also affected by the distance of the objects from it.

Selection of objects.—When there is a choice of objects those that will give the strongest position should be selected. For this purpose the following points should be considered:

A strong position will be obtained when the vessel is inside the triangle formed by the three objects; when the objects are nearly in line or the center object is nearer than the others and no angle is less than 30°; or when two objects some distance apart are in range and the angle to the third object is not less than 30°. In the latter case only a single angle need be observed, but a second angle on a third object may be taken as a check.

Small angles generally should be avoided, as they give weak positions in most cases and are usually inconvenient to plot. A strong position will be obtained, however, with one small angle when the vessel is a little off a range, as mentioned above, and the nearer of the two objects is the center object. It should be noted that, while such a position continues strong until the objects are in range, it may be very weak as soon as the vessel moves to a point where the more distant object is the center object.

Avoid any selection in which the vessel's position is on or near the circle passing through the three fixed points, as such a position is indeterminate. This is commonly called a "revolver," against which the hydrographer must be constantly on guard. If there is no choice of signals by which it may be avoided, as may sometimes occur near the inshore end of a line, a third angle should be taken, if practicable, to any definite feature, such as a tangent or point of land.

Avoid a selection in which two of the fixed points are close together as compared with their distance from the observer and, if practicable, avoid angles between objects having considerable difference of elevation, when either is near the observer. (See p. 85.)

If in running the sounding line both angles change slowly, the position will be weak. In plotting it should be noted that the position is strong if a slight movement of the center of the protractor throws the arms away from one or more points, and that the position is weak if such movement does not appreciably disturb the relation of the arms to the three points.

As slight errors in angles affect a position more with distant signals than when near objects are observed, preference should be given to the latter, other conditions being favorable. The uncertainties of plotting due to distortion of paper also make it preferable to use near objects. Thus, for inshore hydrography it is desirable that signals on the adjacent shore be used in preference to very distant signals, as, for instance, those on the opposite side of a large bay.

There are, however, numerous advantages in using off-lying signals or those on an opposite shore, providing they are not so far away as to affect the accuracy of the position to an appreciable extent. In many cases the angles are easier to observe and plot, it is not necessary to change objects so often as when those on the near-by shore are used, and the necessity for numerous, closely spaced signals is avoided. The extent to which such signals can be used is therefore important and requires good judgment. In general, for ordinary hydrographic work it is considered satisfactory and, in fact, preferable to use such signals to avoid the necessity for a large number of closely spaced signals on the near-by shore, provided that the former are well located, are so situated as to give strong positions in accordance with the principles outlined above, and are not so far away as to require the use of extension arms in plotting. Under these conditions, one or more distant signals can also be used in conjunction with other well-located signals on the near-by shore.

Angles to tangents.—In offshore hydrography it is sometimes desired, due to lack of a sufficient number of well-located objects, to observe an angle on a well-defined tangent to an island, cape, or other feature. In such cases an error may be introduced by the fact that the distance to the feature is so great that the observer can not see the shore line but actually sees a point on the feature that is some distance above the water. Such angles, therefore, should not be used unless necessary. If unavoidable, the angle should be plotted on the tangent of the contour that is probably on the observer's horizon, and the height of his eye above water should be noted in the record. If the feature is not well contoured, additional topographic work may be necessary to secure the desired degree of accuracy of the position. Scrutiny of the apparent tangent may disclose a feature that it may be desirable to locate for control.

Inclined angles.—If it is necessary to observe a sextant angle between two objects having considerable difference in elevation, the inclined angle may be corrected by means of the graph given in Figure 24. This graph is constructed by using the formula

$$\text{Cos } c = \frac{\cos o}{\cos e}$$

in which c is the correct angle, o the observed angle, and e the angular difference in elevation between the objects.

To find the correction to an observed angle, measure the angular difference in elevation (at the position of the observer) between the two objects, or the angular elevation of one if the other is at sea level. Enter the graph with this value as an ordinate and from the proper point of the scale on the left-hand margin extend a horizontal line to intersect the curve representing the observed inclined angle, obtained, if necessary, by interpolation between the curves provided on the graph. From the point of intersection drop down vertically to the scale at the bottom of the graph, which will give the correction to be applied.

Large-scale plotting sheet for offshore areas.—When engaged in offshore hydrography, plotted on a small scale, it is sometimes desirable to develop certain areas on a larger-scale sheet that can not be extended to include the stations required for control. To obviate this difficulty the method illustrated in Figure 25 may be used.

This figure represents an offshore, small-scale sheet on which it is desired to develop, on a larger scale, the area inclosed by the broken line. Having selected the three stations most suitable for control, the vertex loci of the right and left angles that fall within the area are plotted at intervals of 1° or less, as indicated.

This section of the sheet can then be enlarged to provide a plotting sheet on any scale desired, on which any position can be plotted, without using a protractor, at the intersection of the loci of the right and left angles, interpolating as necessary between the arcs drawn on the sheet. Thus, a fix of right angle 41° and left angle 28° is plotted at position 1A on the plotting sheet; and a right angle of 39° 28′ and left angle of 25° 42′ is plotted at position 2A.

This method may also be used conveniently, without enlargement of the plotting sheet, for small-boat work so far from the control stations that protractor-extension arms are necessary or the positions are otherwise difficult to plot. Preparation of the boat sheet in advance will permit accurate plotting of the loci of the angles over the area to be surveyed.

A photographic method of enlargement, if available, is convenient and economical; otherwise an enlargement may be made by other means, such as constructing a projection on the desired scale and transferring a number of points on each arc.

If the change in distance between successive arcs is slight, standard spacing dividers may be used for interpolating between the arcs drawn on the sheet.

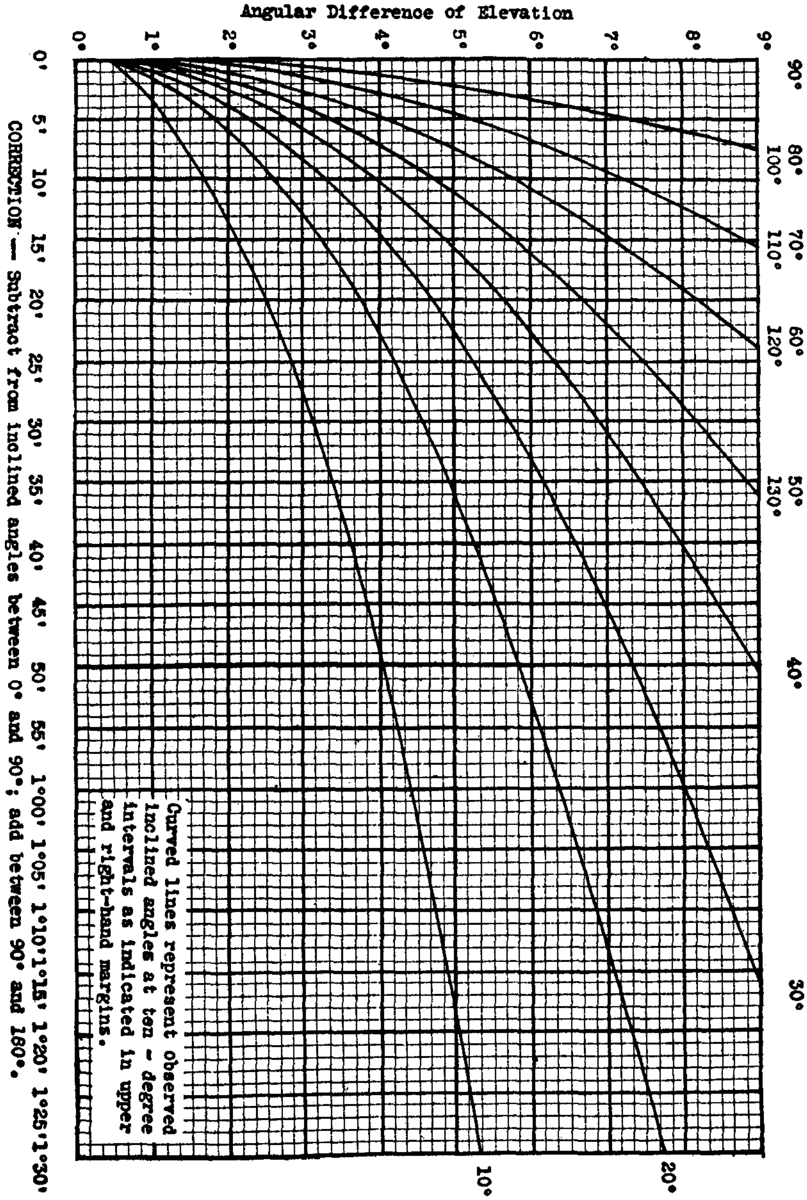


FIG. 24.—Graph for correcting inclined angles

USE OF FLOATING SIGNALS

In regions such as the South Atlantic and Gulf coasts of the United States, where the bottom slopes gradually and moderate

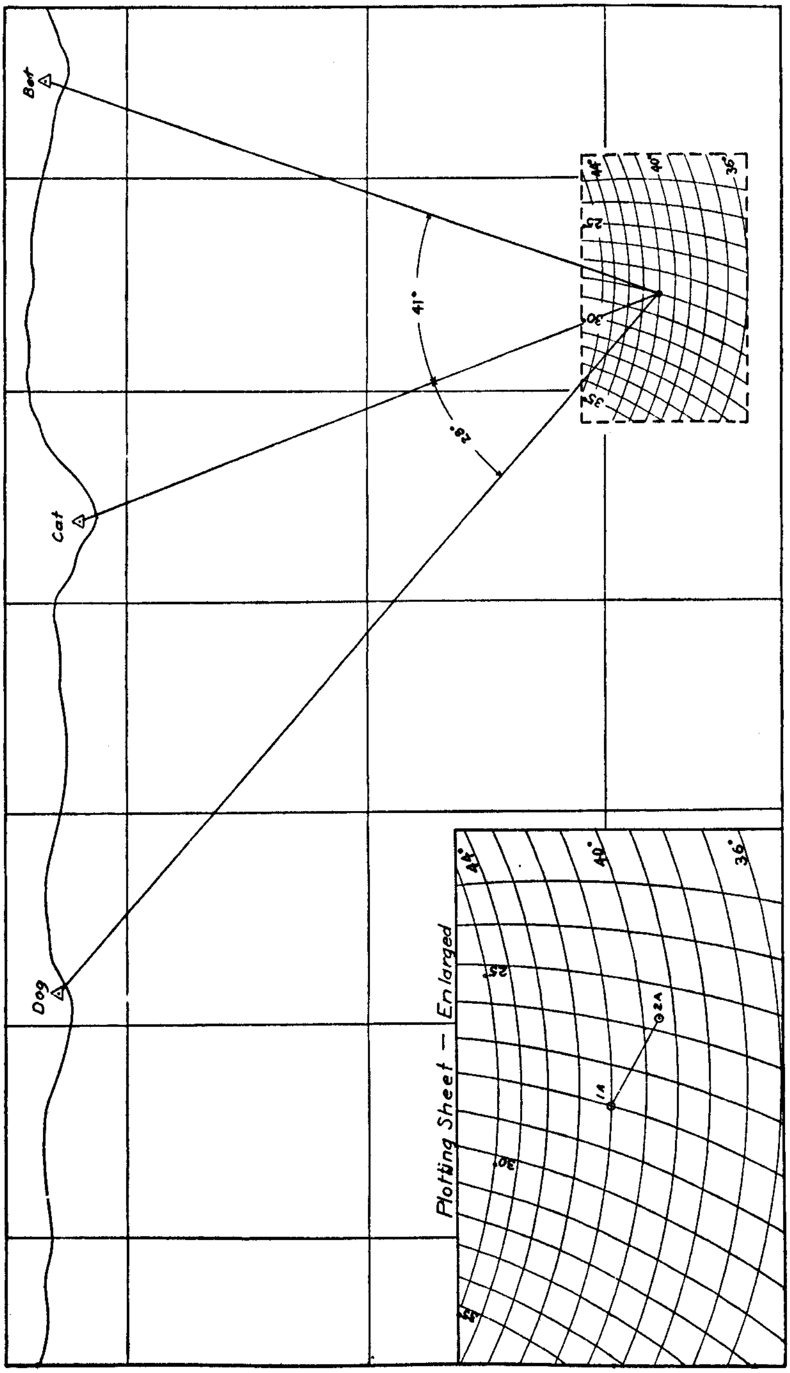


FIG. 25.—Large-scale plotting sheet for offshore areas

depths are found considerably beyond the limit of visibility of land signals, floating signals in connection with tall hydrographic signals are used to various extents for control purposes.

In such regions the general practice of the Coast and Geodetic Survey is to control sounding lines out to the 10-fathom curve by sextant positions on land and floating signals and, beyond this limit, to use floating signals for partial control in connection with dead-reckoning and other methods.

Placing signals.—For visual position control floating signals are usually anchored about 2½ miles apart in a line parallel to the general trend of the coast. The line of signals should be as far offshore as necessary or practicable, considering that, for the determination of their positions, they must be seen from the ship while the latter is still within the range of visibility of land signals. This distance will vary from 10 to 14 miles, depending on the general atmospheric conditions on the working ground.

The number of signals to be planted at one time will depend on circumstances. Under favorable conditions a floating signal may remain intact and in place for as long as two months, but their average life is much shorter. In general a sufficient number of signals should be planted to furnish control for from two to three weeks' work.

The extent to which floating signals are used depends on the depth and the amount of development required. In some regions a single line of signals as described above is sufficient to carry work to the 10-fathom curve, beyond which lines may be controlled by the dead-reckoning methods described in a later section of this chapter.

For control by floating signals, therefore, a single line may be considered the minimum use of such signals. The most extensive use of floating signals by the Coast and Geodetic Survey is exemplified by their use in offshore surveys of the coast of the Gulf of Mexico in the vicinity of Sabine Bank.

In this region closely spaced lines were required out to an average distance of 20 miles from shore; thence one-half mile apart to the 10-fathom curve, which is about 37 miles from shore; and thence 1 to 2 miles apart to the 25-fathom curve, which is about 80 miles from shore. For control of work out to the 20-mile limit, two lines of signals parallel to the coast were planted. Between this limit and the 10-fathom curve signals were planted about 4 miles apart in lines about 8 miles apart and normal to the coast. From the 10-fathom curve to the outer limit of work signals were planted from 6 to 10 miles apart in lines about 11 miles apart and normal to the coast.

Location of signals.—Signals in a single line are located by anchoring the ship at various points, between the signals and the shore, from which both tall hydrographic and floating signals can be seen. The ship is located by sextant positions and the floating signals by three or more sextant cuts giving good intersections from different anchorages.

This operation requires clear weather and great care in measuring and plotting angles. On account of the distances involved and possible distortion of the sheet it is at times almost impossible to obtain exact intersections. Information obtained while planting the signals as to their relative positions—that is, whether a signal is exactly in line with two other signals or a little off range—is of great value in determining the most probable position of a signal when the intersections are not perfect. When a second line is necessary the signals are located from the first line in the same manner as the latter is located from the shore signals.

Excellent results in plotting the positions of floating signals by eliminating distortion have been obtained by constructing a projection and plotting stations in pencil on an aluminum chart printing plate. The cuts to the floating signals are plotted on this sheet, and the positions of the signals are then transferred to the regular sheets. By erasing the projection when it is no longer needed the same plate may be used indefinitely. An aluminum plate with one side roughened so that it will hold pencil marks may be obtained from the office upon requisition.

The location of floating signals beyond a second line by sextant positions and cuts is usually difficult, and such signals, therefore, are generally located by the following method: Signals are located in consecutive order in a seaward direction. Two full-speed runs, in opposite directions, are made between a signal to be located and the next inner and previously located signal. Each signal is passed close enough abeam so that its distance can be obtained by a horizon angle (see p. 91), altering course, if necessary, for this purpose.

The distance run through the water is obtained from the mean reading of two patent logs, one streamed on each quarter and each read every 15 minutes in order to detect any possible fouling or errors in reading. The course steered for each run is obtained from the mean of the standard compass headings read at 15-second intervals throughout the run. The factor for each log and the deviation of the standard compass must be determined carefully, as described in a later section under the heading "Precise dead reckoning."

Location runs should be made in comparatively calm weather to eliminate the leeway element, and the second run must follow immediately after the first. As these runs require only a short time, it is assumed that the same current conditions are encountered on both runs.

Corrections for deviation and variation are applied to the nearest tenth of a degree. To facilitate the application of variation, isogonic lines, showing every tenth of a degree change, are plotted on the boat sheet from the best information available.

The azimuth and distance between two signals are obtained graphically by plotting the double run on a sheet having a 1:40,000 scale projection. Assume a position of the known signal and lay off the starting point from the distance of the signal when abeam. Plot the position of the end of the run from the true course and mean reading of the two logs, and the first position of the unknown signal from its distance abeam at the end of the run. Lay off the end of the second run from the distance of the known signal when abeam and plot a second position of the unknown signal from the second course (reversed), the distance run, and the distance of the unknown signal when abeam at the beginning of the return run. Then determine the position of the unknown signal with relation to the known signal by plotting it on line between its first and second trial positions, the distance between the accepted position and each trial position being in proportion to the time required for each run.

Positions and cuts used to locate floating signals should be recorded, and log readings and compass headings for full-speed runs should be tabulated in such a manner that the corrections may be applied readily and all work shown in a clear manner. The following form is satisfactory; it illustrates the tabulation of one run only:

MARCH 4, 1924.

Runs to locate signal "B" from signal "A"

Time	Log 138	Log distance	True distance	Log 136	Log distance	True distance	Course mean	Remarks
6.37	49.68	0.00	[1] f=.945	82.43	0.00	[1] f=.880	79.8 psc	"A" 72 meters starboard beam.
6.52	51.90	2.22	2.10	84.84	2.41	2.12	+7.6 var	"B" 115 meters starboard beam.
7.02	53.50	1.60	1.51	86.50	1.66	1.46	+2.5 dev	
Time=0.42 hour			3.61			3.58	89.9 true	

[1] Log factor.

Distance by horizon or vertical angle.—The distance between the ship and an object at sea may be obtained by measuring the angle, with a sextant, between the water line of the object and the horizon beyond; computing the distance from the formula

$$D=H \cot (a+d)$$

in which D is the distance in feet, H the height in feet of the eye above sea level, a the observed angle, and d the dip of the sea horizon.

The latter may be taken from a dip of the sea horizon table which will be found in any epitome of navigation or computed from the formula $d=59'' \sqrt{H}$. The height of the eye and the sextant angle should be measured with great care. Tables or curves showing the distances in meters for various angles and heights of eye may be prepared to facilitate the computation. The accuracy of this method increases with the height of the eye above the water. It should not be relied on in hydrographic work when the observed angle is less than about 1°, which will correspond approximately to a distance 50 times as great as the height of the eye. When the horizon is indistinct or there appears to be abnormal refraction, distances to near-by floating signals may be obtained by vertical angles between the water line and top of the signal, the height of the signal being known. In this case the accuracy of distances is increased by having the eye as close to the water as practicable. If the signal is too far away for a distance by vertical angle, bow and beam bearings may be used.

Control by floating signals.—Sounding lines from the limit of visibility of shore signals out to the 10-fathom curve are controlled by sextant positions on three floating signals. Beyond this limit the wider-spaced signals may be used to supplement dead reckoning in order to obtain more accurate offshore distances, to coordinate adjacent sounding lines, to serve as tie-in points when it is necessary to break a sounding line, and to eliminate numerous current observations.

In the Gulf coast survey, however, it was found that when weather conditions permitted accurate bearings to floating signals the resulting positions were more accurate than dead reckoning. Dead-reckoning methods, therefore, were used only at night, in thick weather, or when the rolling of the ship prevented accurate bearings.

Positions by bearing.—In this method the sounding line is parallel, or nearly so, to a line of floating signals. As soon as a signal is picked up on the bow, a log reading and bearing are taken, and these are repeated at intervals of 10 or 15 minutes (always including a bearing and log reading when the signal is abeam) until the signal drops from sight astern. All bearings are plotted on the boat sheet.

When the sounding line has passed from a position abreast one signal to a position abreast the next signal the log distance is compared with the actual distance and a log factor computed for the run between the two signals. Using this log factor, the true distance over the ground is computed for each run between bearings, and these distances are plotted progressively along the edge of a sheet of paper. The points on the sheet of paper are then placed on the corresponding bearings between the signals on the sheet and the positions fixed.

To check the positions obtained by this method the lines are frequently tied into a signal by a full-speed run.

Three bearings taken on a signal are generally sufficient to establish very closely the course made good, provided the angle passed through is not less than 45° and also provided the current is not undergoing a rapid change. Therefore it is usually possible to determine the new course to be steered by the time the ship arrives abreast each signal, and if necessary to alter the course the change is made at that time. The plotting is simplified if the course is not altered between signals. If it becomes necessary to alter the course between signals, this change of course should be shown on the edge of the paper on which the distances between bearings are plotted.

If the current is undergoing an appreciable change during the passage from one signal to the next, the points plotted on the edge of the distance scale will not coincide with all the corresponding bearings on the sheet, since the log factor obtained by comparing the actual distance with the log distance represents the average distance over the ground per log-mile.

Figures 26 and 27 show three examples of runs between signals when the current is changing. In these illustrations the signals are referred to as buoys. Case 1 shows a current setting against the vessel and gradually increasing. In this instance, by using the average log factor for determining the true distance between bearings, the resulting distances will be too short for the first half of the run and too long for the last half of the run. Consequently, when the distance scale is applied to the bearings, the plotted course will be drawn too far in toward signal "T" and thrown out too far from signal "U," resulting in the condition shown in the sketch. The most practical method of adjustment in this case or a case where the plotted line shows a change in the component of the current setting with or against the vessel is to apply the distance scale to several bearings midway between the signals and fix one or two intermediate points, as, for instance, points 5 and 6 in case 1.

Having fixed these points, new log factors should be computed for each of the adjacent sections and these sections plotted independently. A knowledge of the effect of the change in the component of the current setting with or against the vessel on the plotted line is necessary in order to analyze the current and assists materially in making the adjustment. In cases where this change is considerable and the adjustment is uncertain, the sounding line should be tied in with a signal by full-speed run and the line adjusted by throwing the closure onto the intermediate bearings.

Case 2 shows a current setting to the westward and uniformly increasing during the run between signals. In this instance, since there is no current setting with or against the vessel, the log factor for the

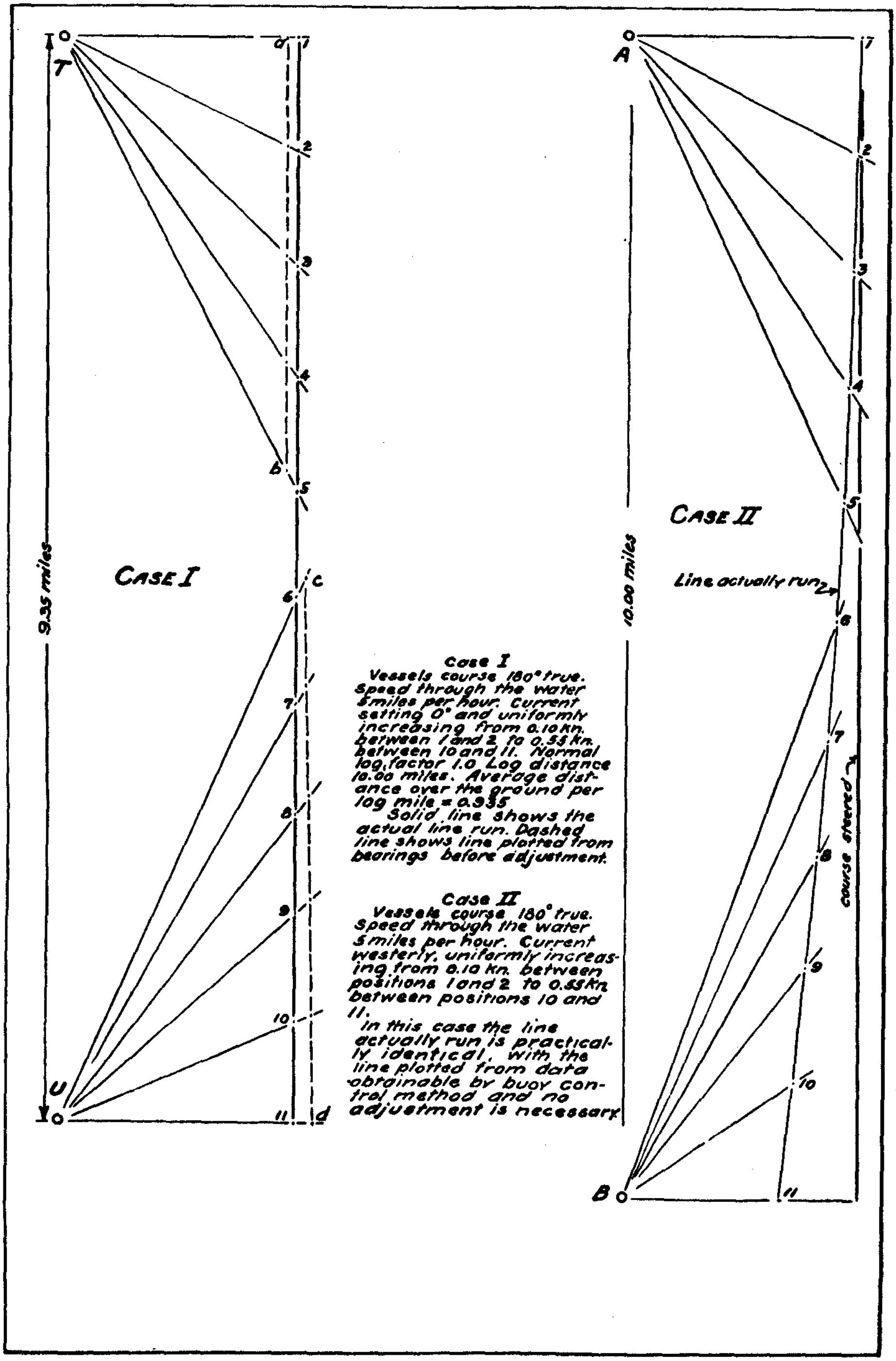


FIG. 26.—Positions by bearings on floating signals

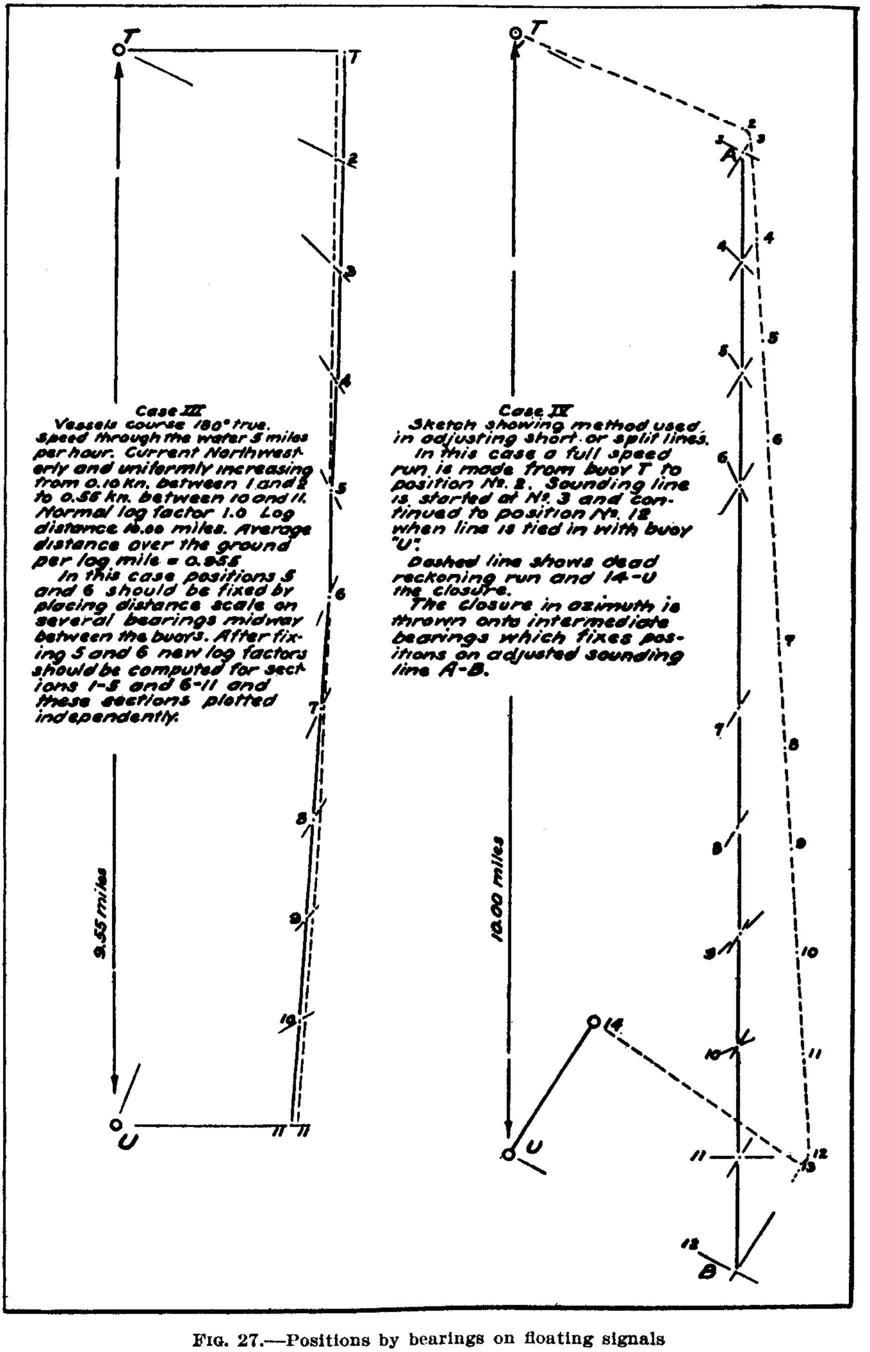


FIG. 27.—Positions by bearings on floating signals

run between signals is the same as the normal log factor, and the plotted points on the distance scale, when placed on the corresponding bearings, show closely the increasing set to the westward.

Case 3 shows a current setting northwest with uniformly increasing velocity. In this case the most practical method of adjusting the plotted line is to fix one or two positions midway between the signals, as described under case 1, in which the component setting with or against the vessel's changing.

Case 4, Figure 27, shows the method of giving positions, adjusted by the precise dead-reckoning method, additional strength by throwing the closure in azimuth onto the corresponding bearings. It is apparent from the figure that little weight should be given to this method in cases where the closing azimuth and the bearing form an acute angle. In the figure, for instance, positions 7, 8, 9, and 10 should not be fixed by this method. These positions will be stronger if placed on the intersection of the bearings and the line drawn from 6 to 11 after these latter two points have been adjusted by the above method.

For this method of position finding a log should be kept in the following form. The tabulation shows a part of a sounding line from a position abreast one signal to a position abreast the next signal.

Position No.	Time	E. T. (hours)	Log	Log distance	True distance	C., psc.	V.	D.	C., true	Bearings			
										Psc.	S. H.	True	Signal
9	3.09		91.98	SS	f=.98					260½	171	268	X
10	3.27	0.30	93.49	1.51	1.48	173	+7.5	−0.1	180.4	309	173	316.4	X
11	3.57	.50	96.01	2.52	2.47	173	+7.5	−0.1	180.4	188½	173	195.9	Y
12	4.13	.27	97.44	1.43	1.40	173	+7.5	−0.1	180.4	193	173	200.4	Y
13	4.28	.25	98.66	1.22	1.19	173	+7.5	−0.1	180.4	201	173	208.4	Y
14	4.43	.25	99.94	1.28	1.25	173	+7.5	−0.1	180.4	217	173	224.4	Y
15	5.01	.30	1.43	1.49	1.46	173	+7.5	−0.1	180.4	258½	173	265.9	Y

Actual distance 9 to 15=9.25 miles.
Log distance 9 to 15=9.45 miles.
Log factor, 9 to 15=0.98.
Abbreviations used in above table: E. T., elapsed time; C., course; psc., per standard compass; V., variation; D., deviation; S. H., ship's head; SS, sounding speed; f, log factor.

Use of ship's mast.—When sounding from small boats it may sometimes be desirable to use the foremast of the ship as a signal, either in conjunction with other signals or for positions by bearing and vertical angle. In such a case the ship should be anchored with a short scope and her position determined whenever there is any change, due to change in direction of wind or current. The position angles by which the mast is located and the time when such angles are taken must be noted and copied in the sounding record.

PRECISE DEAD RECKONING

This method of controlling the positions of sounding lines beyond the limit of visibility of signals has been developed by the Coast and Geodetic Survey and used to a considerable extent for surveys out to the 100-fathom curve on the south Atlantic coast of the United States.

Departure is taken either from a floating signal or a position determined by sextant angles on such signals, and a continuous sounding line is run offshore to the desired limit, over to the next proposed line, and inshore to a position fixed in the same manner as the starting point. From positions at the beginning and end of the line, and at approximately two-hour intervals on it, the set and drift of the current and the velocity and direction of the wind are measured.

At each position the course to be steered to the next position is determined by applying to the desired bearing of the line certain corrections, including the probable effect of the current and wind, based on previous observations. At the conclusion of the run to the next position the most probable location of the latter is obtained by applying the corrections to the actual course steered and distance logged. In the latter case, however, the corrections for current and wind are the average effects of these forces based on observations at the beginning and end of the run.

After the line ends it is adjusted to its most probable position by apportioning the closing error between the various runs according to the time required for each.

Details regarding this method of control are given in Coast and Geodetic Survey Special Publication No. 73. Additional information, together with some changes now considered advisable, are given below.

Compass.—A careful determination of the errors of the standard compass, using a tested azimuth circle, is extremely important, and the ship should be swung often enough to detect any change. To facilitate the application of variation, isogonic lines showing each degree of change, from the best information available, should be plotted on the boat sheet. The course steered should be obtained from the mean of headings observed and tabulated at one-minute intervals throughout each run. An adding machine may be used conveniently for this tabulation.

Coast and Geodetic Survey Special Publication No. 96, Instructions for Compensation of Magnetic Compass, is recommended for study.

Patent logs.—The following method of rating logs is considered more accurate and satisfactory than that described in Special Publication No. 73 and should be used whenever practicable.

The runs to rate the logs are made on a sensitive range of two triangulation stations. This range should be as nearly parallel with the shore as practicable in order to avoid cross currents. The course should be about 1 mile in length, and its ends must be determined accurately. This may be done conveniently by taking as the inshore end of the course a point on the range where the angle between the range stations and a third and near-by station is 90°. The proper resection angle for the outer end of the course can then be computed.

To rate a log, a run in one direction over the course is followed immediately by a run in the opposite direction. An observer sets his sextant at the first angle and reads the log at the proper point, then sets off the second angle and reads the log at the end of the course. At least three double runs should be made.

It is assumed that, over a short course, the ship encounters the same current on both runs. After three double runs have been made it is possible to determine the action of the current. If the logged distances are nearly equal, there is no appreciable current with or against the ship, and the factor may be computed by dividing the length of the course by the mean of an even number of logged distances, otherwise the factor is obtained by solving simultaneous equations derived from each double run, using the formula

$$Ry \pm Tx = D$$

in which R is the log reading, y the factor, T the time required for the run, x the current, and D the length of the course.

In the comparatively rare case where the current changes during the time required for a double run the equations can be solved for x and the mean current for each run computed.

Logs should be rated both at full and sounding speed and, if the ship is equipped with an engine-revolution counter, this also should be rated.

In general, better results will be obtained by using two logs for measuring the distance run. They should be watched rather carefully and read at 15-minute intervals. The mean of the two log distances should be used unless there is a large discrepancy between them. In the latter case the log reading to be rejected may be determined by any unusual action noted on the run, by comparison with the distance by revolutions, or by rerating the logs.

Currents.—Currents are usually observed from a ship anchorage, or when the depth is too great for convenient ship anchorage by mooring a barrel buoy with a steel cable and using a small boat. When the current at a ship anchorage is slight, however, accurate observations are difficult to obtain on account of yawing of the ship.

In such cases better results have been obtained by anchoring a marker buoy instead of the ship. The current pole is set adrift at the buoy. The set is obtained from a bearing with the buoy and pole in line. The drift is measured by cruising close to the pole and observing a horizon angle (see p. 91) to the buoy, noting the time when the pole is set adrift and when the angle is taken.

Wind measurements may be obtained while drifting or by holding the ship close to the marker buoy.

The methods of sounding given under the heading "General remarks" in Special Publication No. 73 have been modified by recent developments. Lead-line sounding with machine has superseded the trolley rig to a large extent, as noted previously, and ships equipped with the fathometer have available the vastly superior method of echo sounding to supplant other methods in depths over 15 fathoms.

Extent of use.—The principal difficulty encountered in precise dead reckoning is that very few logs will hold a uniform rate at the slow speed required for ordinary methods of sounding in moderate depths. Also, when it is necessary to stop for soundings with wire, the corrections for log loss and transfer are uncertain.

The facts that the position of a sounding line is not fixed exactly by this method and that its most probable position is not known until the closing error is determined limit the use of precise dead reckoning to regions where widely spaced lines are sufficient. The usual spacing of lines where this method has been used has been 1 to 2 miles from the limit of visibility of signals to the 15-fathom curve and thence 2 to 4 miles to the 100-fathom curve. In general, its use should be confined to sections where the required spacing of lines or the depths are so great that the use of floating signals for partial control, as described previously, is not economical.

RADIO-ACOUSTIC SOUND RANGING

This method and the apparatus used have been devised by the Coast and Geodetic Survey and the Bureau of Standards for position finding under conditions when visual positions can not be obtained. The development was based on the subaqueous sound-ranging work of the United States Army and, during its preliminary stages, was greatly facilitated by the advice and assistance of Army officers familiar with the apparatus and principles involved.

In this method the position of the ship is fixed by its distance from the hydrophones of two suitably located shore stations, the distances being determined by the time required for a sound to travel under water from the ship to each station.

At each station a suitably inclosed hydrophone is anchored a short distance offshore, usually about 4 or 5 feet from the bottom, in 7 to

10 fathoms. This hydrophone is located by sextant angles and is connected by cable, through filters, an amplifier, and a metronome, with the transmitter of a temporary radio station.

On board ship a hydrophone, attached to the hull, and a radio-receiving set are connected electrically with a chronograph so that the time of receipt of underwater sound waves or radio signals is recorded on the chronograph tape.

To obtain a position, a small bomb is dropped overboard from the ship while under way. This bomb is timed by a fuze to explode 20 to 30 seconds after striking the water. In this time it will sink to a depth of 20 to 30 fathoms. If the depth of water is such that the bomb will reach the bottom before exploding, it may be supported at

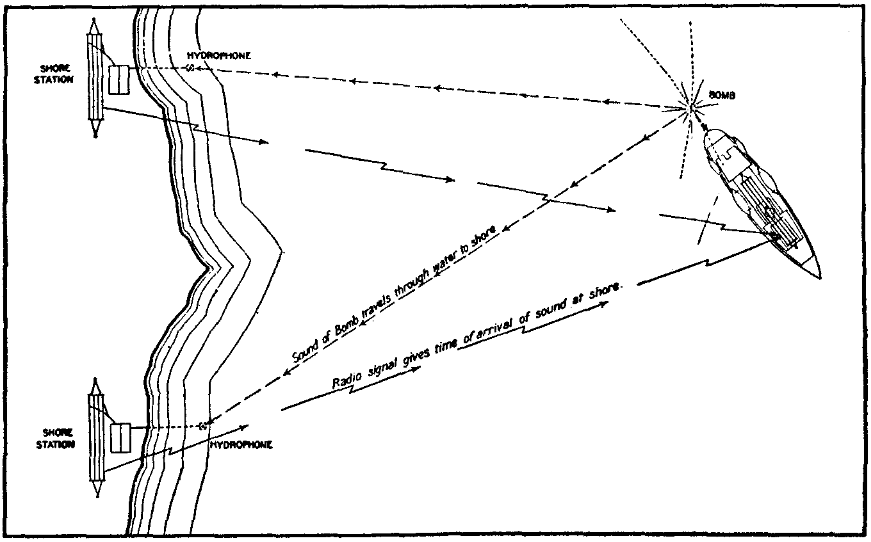


FIG 28.—Radio-acoustic position finding

any desired depth by a small cord and temporary buoy; an inflated paper bag will serve for the latter.

The time interval between dropping the bomb and its explosion may be determined with a stop watch or by marking the chronograph tape at the instant the bomb is dropped, either with a pencil or by tripping a relay, and scaling to the mark caused by the bomb explosion. The chronograph next marks the time of receipt of the sound of the exploding bomb by the ship's hydrophone, and, knowing the distance of the ship from the bomb, from the elapsed time and speed of the ship and the velocity of sound in water the time required for the sound to reach the ship, and consequently the exact time of the explosion, can be computed.

The sound also travels to each control station, where the vibrations of the hydrophone cause an electrical impulse to travel to the metronome relay through a circuit containing amplifiers and filters. The closing of the metronome relay causes the radio transmitter to send out three dashes, the intervals between dashes, governed by the metronome, serving to identify the station.

It is also possible to provide a second electrical connection at a shore station, independent of the metronome circuit, so that a dash is transmitted at the instant the sound reaches the hydrophone.

The radio dashes are received by the ship's set, the exact times of receipt being recorded by the chronograph, and the distance from each station is computed from the elapsed time and the velocity of sound through the water. When the shore apparatus has the additional circuit mentioned above, the chronograph tape shows the time of receipt of the instantaneous dash, followed by three additional dashes at intervals after the first, due to lag in the metronome circuit.

The method used for recording and computing radio-acoustic positions is described in chapter 6. To facilitate the plotting of such positions it is customary to lay off, on the boat and smooth sheets, distance arcs at intervals of 10,000 meters from each hydrophone. A small square with the station dot in its center is generally used as a symbol for a hydrophone station. Colored ink is used for each station symbol and name, a different color being adopted for each station. The distance arcs from each station are inked with the color used for the station.

The velocity of sound through the water is determined from tests made while within range of visibility of signals. If sounding work is started before these tests are made, a velocity may be assumed and final distances computed later after the tests have been completed.

Full details regarding radio-acoustic sound-ranging methods and the apparatus used are given in a publication on this subject issued by the Coast and Geodetic Survey.

ASTRONOMICAL POSITIONS

The development of the control methods described in this chapter has, in general, limited the use of astronomical observations for hydrographic position finding to deep-sea soundings at a considerable distance from land, and to the reconnaissance of unsurveyed regions. Recently, however, the development of echo-sounding equipment, whereby soundings can be obtained at full speed with resulting increase in the accuracy of log readings and decreased effects of wind and current, has opened up an interesting field of experimentation in the use of astronomical control to supplement or supplant the dead-reckoning methods that have been previously described in this chapter.

Star-control echo sounding.—Extracts from a recent report from one of the survey ships of the bureau, describing the use of astronomical positions for hydrographic control, are given below. The methods described were used on the Atlantic coast to fix the offshore points of lines run from a fixed inshore position out to the 100-fathom curve (approximately 50 miles from the starting point) and then back to another fixed position. Soundings were obtained with the fathometer while running at full speed. The part of the report relating to star sights is applicable to all hydrographic work controlled by astronomical positions.

Star-control echo sounding is based on the considerations, first, that soundings can be taken at full speed with no stops on the line and, second, that sounding lines are run in very clear and comparatively smooth weather.

From an inshore position, fixed by angles to shore or floating signals, a sounding line is run to the desired offshore limit where a series of star sights are taken to fix the offshore point of the line. The line is then run inshore to another fixed position. Single sun sights and occasional moon sights (in daytime) are taken on the line.

The offshore point of the line must be reached at dawn or dusk. If less than an all-night run, the ship should anchor before dark at the starting point, obtain a position, and then start the line at the proper time. The inshore line can be started as soon as the star observations are completed, as the ship can anchor at the inshore end of the line, if reached during darkness, and obtain a position after daybreak.

It is necessary to judge the weather nicely in order to have reasonable assurance, when starting the line, that it will be clear when the offshore point is reached. A failure to get a location of this point may necessitate the rejection of the entire line.

Logs.—These must be carefully rated, checked frequently, and rerated as soon as there is any indication of a change in rate. Two logs must be streamed, as one may foul at any time. It is the practice on this ship to stream the logs from the bridge, so that they can be read by a responsible officer. Logs are read every 10 minutes, at each change of course, and at times of sights.

Star sights.—Following are the principal requisites for obtaining a good star fix:

(*a*) *Experienced observers.*—An inexperienced observer can not do good work. Practice is essential not only to obtain accurate sights but to obtain them without delay as soon as stars are visible.

(*b*) *Suitable instruments.*—Well-made navigating sextants, in good condition and equipped with excellent mirrors, are required.

(*c*) *Correct index error.*—This is very important. If stars equally spaced around the horizon are observed, index and personal errors may be compensated to some extent by taking the mean position. If, however, a complete set of stars can not be observed, due to clouds or a poor horizon in one direction, the index error can not be eliminated.

(*d*) *Distinct horizon.*—This is probably the most essential requirement. To obtain it, very clear weather is required, and it is necessary in the evening to observe the stars as soon as they are visible in the telescope of a sextant set to the proper altitude, and to wait as long as possible before taking morning sights. When two very bright objects, such as Jupiter or Venus and Sirius, will give a good intersection of lines of position, and are available for observations while there is considerable light, it is probably more accurate to accept an intersection from two bodies than to take a mean with other stars. In this case, however, accurate knowledge of the index error and great care to avoid personal error are especially important.

(*e*) *Stars at suitable altitudes.*—Stars at high altitudes are undesirable, even though they appear when the horizon is distinct, as considerable error in obtaining perpendicularity in the observation is likely. On the other hand, very low stars are usually invisible with the best horizon and are subject to greater errors of refraction. Stars at altitudes of from 10° to 40° are desirable, and those at 20° will usually give the best results.

(*f*) *Stars in all directions.*—It is very desirable to obtain a complete set of four stars approximately equally spaced around the horizon.

Methods of observation.—It is desirable to have two or more officers take independent sights, not necessarily on different stars. These sights taken by different officers must not be combined, but each officer's sights must be used to obtain an independent position and the positions compared.

When the sights are taken they should be rated by the observer as "poor," "fair," "good," or "excellent," taking into consideration the clearness of the horizon, the elevation and visibility of the body, and the steadiness of the vessel. These ratings should be taken into consideration in finding the most probable position of the vessel.

On each body at least three or four observations in succession should be taken and the mean of these used. Before working the sight, if the differences of times and altitudes between separate observations are compared, a good idea will be obtained of the accuracy of the observations.

It will sometimes happen that one sight of a series will not prove correct, although rated by the observer "good" or "excellent." For this occurrence there is no explanation, but when it occurs and is proven by comparison with the other observers' sights, it should be unconditionally rejected.

Star sights taken when the horizon is dark or gloomy should not be considered; because of a large probable error, they are more apt to confuse than aid when adjusting the line.

Probable position of ship.—When the lines of position are plotted there will usually be a triangle or other figure of error rather than an intersection of all lines at one point. A symmetrical rather than a small figure of error is desirable. In determining the most probable position of the ship it is always necessary to consider the directions of the bodies observed. The mean position should in most cases be equidistant from the lines of position and should lie either toward or away from all the stars of the set and not away from some and toward others. The illustrations in Figure 29, showing various figures of error, will be of assistance in this respect. The arrows point from the position lines toward the observed bodies, and the circles show the most probable position of the ship.

Cases A, B, and C are obvious. Case D is one of the most ambiguous cases, in which good judgment of the value of the sights must be used. If the two sights *a* and *b* are considered of equal value, a mean line *c* should be drawn and the adjustment made as in case C. Note in case E that the position is outside the triangle of error.

Records.—Three records are used—(*a*) The regular sounding record in which only the position numbers, in addition to the sounding data, are entered; (*b*) the dead-reckoning book, for entry of courses, log readings, etc.; and (*c*) the sight book, for entry of all data relative to the taking and computation of sights. Each observer should have his own sight book.

Adjustment of sounding lines.—The lines are adjusted to the three fixed points. In adjusting each half of the line, sun and moon sights are given consideration as single lines of position. Under no considerations should a single line be run up to another and the intersection used as a position.

Remarks.—The principal disadvantage of this method is that it does not provide for check soundings and does not permit of taking current observations except at the beginning, offshore point, or end of line. Observations of current by this vessel have been of little value to date. It has been found advisable in laying off courses to ignore rather than to estimate the current. It is advisable to run long lines during the neap tides when there is less current.

Standard methods of taking and computing astronomical positions will be found in any epitome of navigation.

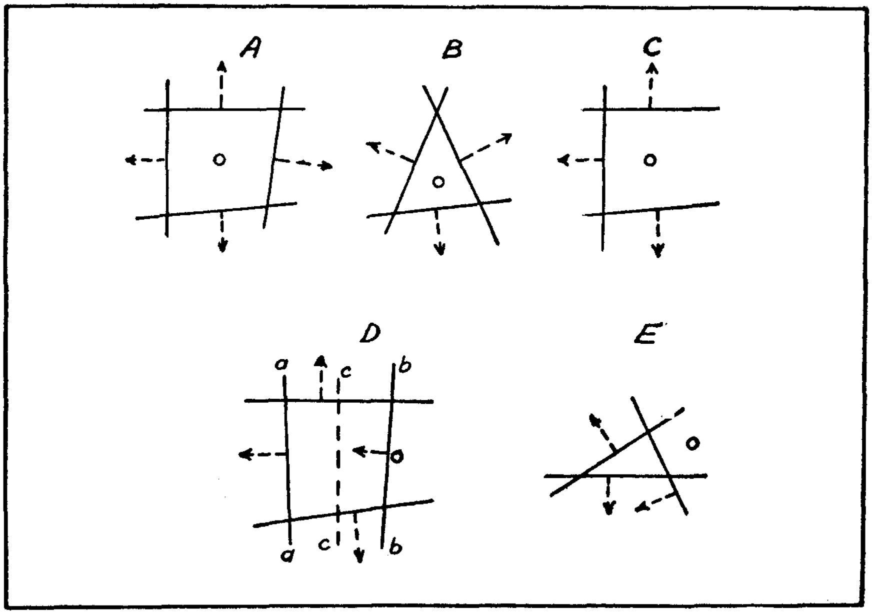


FIG. 29.—Probable position of ship; observations on celestial bodies

RADIOCOMPASS BEARINGS

Radiocompasses have been installed on a number of ships of the Coast and Geodetic Survey for navigational purposes and in order to determine whether or not radiocompass bearings can be used in hydrographic surveying.

Experiments to date have been unsatisfactory. The radio bearings have lacked the precision required for surveying purposes but may be used, as a last resort, when no other means for obtaining a position are available. This method may be used to fix the offshore end of a sounding line if good star sights can not be taken, due to unexpected cloudiness or failure to arrive when the horizon is visible. It should, however, be regarded as a makeshift for saving a line which otherwise would be lost or which could not be run.

Chapter 6.—RECORDS

The importance of a clear and comprehensive record of hydrographic work can hardly be overemphasized, for the value of a survey, no matter how complete and satisfactory the actual field work may be, is impaired if the record is unintelligible or inadequate in any respect. A satisfactory record can be secured only by the exercise of good judgment and constant care on the part of all concerned.

The recorder must be sure that he hears and records all data correctly and that the record is complete and in accordance with the general requirements. He should call back soundings, angles, and object names and must not hesitate to ask for repetition when necessary. He should request confirmation of unusual soundings, marking them "O. K." if confirmed. Care must be taken that all entries are made in a legible manner. The recorder should have several pencils and should keep them well sharpened. A No. 3 pencil is generally preferred for recording. The record should be protected while in use by a cover of paper or other material.

The hydrographer should exercise close supervision over the recording and be especially careful that clear explanatory notes are entered wherever necessary. The reason for rejecting a shoal sounding, for example, may be obvious to the hydrographer, but, unless a logical explanation is given, the cartographer who reviews the work has no authority to omit the sounding from the sheet. He should guard against defects in the record, such as questioning an entry for future investigation and then neglecting the matter while the question mark remains to confuse everyone who has any subsequent business with the record.

The final responsibility for the proper recording of all hydrographic operations carried on under his direction rests on the chief of party. He must make sure that those under him are familiar with the requirements and assure himself by frequent inspection that all work is being recorded in a systematic and otherwise satisfactory manner.

METHODS OF RECORDING

In this chapter a number of record pages are reproduced to illustrate the methods of recording and reducing hydrographic work. In the cases where reductions of soundings are shown the entries are

Form 275

Locality

SOUNDINGS Coast of Massachusetts

Year 1927 *Month* June *Day of Month* 21

POSITION NUMBER	TIME Mer. 75 a. M.	SOUNDINGS Fathoms	SOUNDINGS Feet	LEAD-LINE COR. Feet	RED. FOR TIDE Feet	REDUCED SOUNDINGS Field Feet	Field Feet	Office Fathoms	Office Feet	BOTTOM
	h. m. s. No. 14									
	In charge J.A. Smith									
	R angle J.A.S.			Sextant H209				No. 20		
	L angle A.A. Nelson			~~Sextant H306~~				Weather Fair		
	Plotting J.A.S.			Protracter H199				Wind Lt. E'ly		
	Recorder P. L. Jones			Clock H155				Sea Smooth		
	~~Automatic~~			~~gauge No.~~						
	~~Auto-portable~~	tide								
	Plain			staff		at Gloucester				
	~~No 18~~						No. 16			
	~~Left anchorage at~~	7 30				Sextants OK.				
	Distance to working grounds		3 mi.			~~Clock~~ OK				
						Leadline corrections on page				OK
						Sheave No.		tested		, 19
							~~Corrections on page~~			~~Vol.~~
11	8-02-00		3	0	1½	1	½			S
	15		3			1	½			
	30		4			2	½			
	45	1	0*			4	½			M
12	03-00	1	2			6	½			
	20	1	4		2	8				
	40	1	5			9				
	04-00	1	1 OK			5				rky
	20		5			3				
	40	1	3			7				M
13	05-00	2	0			10				
	20	~~1~~ 2	~~3~~ 3*			13				

FIG. 30.—Sample record page; lead-line soundings

28

Sublocality

Cape Ann

Boat used Launch #44 ; d day

HEADING BY .... COMPASS No. 2	ANGLES AND RANGES		REMARKS AND GENERAL DIRECTION (TRUE) OF LINES

LEAD LINE CORRECTIONS

Mark on lead line Fms M	True length by standard Feet =L	Correction to soundings Feet =L-M
1	6.0	0
2	12.0	0
3	17.9	-0.1
4	23.8	-0.2
5	29.7	-0.3

HEADING	ANGLES AND RANGES		REMARKS
132°	✓ Bet	70-40	Line begins
	Cat		42°37' / 70°-36'
	Dog	89-20	50 m. from beach.
			*Rk. bare 1 ft., 20 m.
			on stbd. beam.
	✓ Bet	55-20	Regular sdg. speed.
	Cat		
	Rim	~~000~~	S. Cox - leadsman
c.c. 125°	✓ Bet	42-10	
8^05	Cat		
	Dog	63-20	*leadsman's error -
			corrected at once.

Fig. 31.—Sample record page; sextant positions

inclosed in a heavy border to distinguish them from the entries made during the progress of field work. It will be noted that rubber stamps are provided for entry of information required at the beginning and end of each day.

In these illustrations the limited space available has been conserved as much as possible. In recording hydrographic work, while space in the record should not be wasted, no attempt should be made to save it by crowding the positions and other data. In some cases it may be necessary to leave a number of blank lines between soundings in order to provide plenty of room for positions, explanatory notes, etc.

Abbreviations for character of bottom.—The abbreviations used for recording the character of the bottom are given in Table 1, page 158.

Lead-line soundings—Sextant positions.—In Figures 30 and 31 the left and right hand sides of a record page are reproduced to illustrate the recording of lead-line soundings and sextant positions. It will be noted that one of the subheads of the "soundings" column is crossed out so that the other will show the units in which soundings are recorded.

There will seldom be corrections to a properly prepared wire-center lead line, but the stamp and comparisons should be entered to indicate that the line has been tested. Should there be appreciable corrections, the algebraic sign of the "L–M" entry will show whether the correction is to be added to or subtracted from the soundings.

For position No. 1, Bet, Cat, and Dog are the right, center, and left objects; No. 2 illustrates the method of recording a position where two objects are in range and an angle is taken between a right-hand object and the range.

Tube soundings.—The method of recording tube soundings and tests is illustrated in Figure 32. The two uncorrected tube soundings are entered in the "soundings" column on the two lines next below that on which the time is recorded, the tube number being entered in the time column on the same line as the tube reading. The mean of the two is entered on the following line and is separated from the others by a pencil line. When the soundings are taken to half fathoms, the mean is entered to the nearest lower half fathom. A tube should always be identified by its instrument number and not by a letter of the alphabet or other means of identification.

If, during the progress of work, a vertical cast is made for a single comparison with a tube sounding, the vertical cast corrected for sheave or lead-line error is entered above the tube soundings (on the line in the "soundings" column opposite the time, which otherwise is left blank) and is denoted by the abbreviation V. C. in the next column.

POSITION NUMBER	TIME Mer. 120 A M.	SOUNDINGS		[redacted] COR. Sdg.	RED. FOR TIDE	REDUCED SOUNDINGS				BOTTOM
						FIELD		OFFICE		
		[redacted]	[redacted]			[redacted]	[redacted]	FEET	TENTHS	
		FATHOMS	[redacted]	FMS [redacted]	FMS [redacted]	FATHOMS	[redacted]	FATHOMS	FEET	
	h. m. s.									
	10-46-00									
	532	36	1/2							
	744	36								
		36		36½	1/2	36				S. brk. Sh.
	47-30									
	439	38								
	440	38	1/2							
		38		39		38	1/2			gy. S.
124	49-00	39	1/2	V.C.						
	532	39								
	744	38	1/2							
		38	1/2	39½		39				
			TUBE TESTS							
		Vertical cast (wire)		Number		Tube Reading FMS.	Tenths	Cor. Fathoms		
	11-00-00	20	fms	439		20	5			
				440		20	9			
				532		20	8			
				744		20	4			
				mean		20	6	-0	1/2	
	11-06-00	30	"	439		29	7			
				440		30	2			
				mean		30	0	0	0	
	11-10-00	40	"	532		39	4			
				744		39	0			
				mean		39	2	+1	0	

FIG. 32.—Sample record page; tube soundings

Tube tests are recorded in tabular form immediately after the last sounding before such tests or on the following page. The tube readings are entered to the nearest tenth of a fathom and the corrections to the nearest half fathom. The sheave error should be considered in running out the wire, so that there is no correction to the depth by wire.

Fathometer soundings—Radio-acoustic sound-ranging positions.—In Figures 33 and 34 the left and right hand sides of a record page are reproduced to illustrate the method of recording fathometer soundings and radio-acoustic positions. The same record is used, whether the fathometer is used exclusively during the day or alternated with other methods of sounding, proper notation being made when changing from one method to another.

Soundings are recorded in the first division of the "soundings" column, the second division being used to enter the sounding corrected for slope when this correction is necessary.

If inconvenient, because of the location of the fathometer, to record immediately in the sounding-book positions and other data obtained from outside the fathometer compartment, such data may be recorded in a separate book and later copied into the fathometer-record book. In that event the clocks used in connection with both records must be set to agreement at the beginning of the work and compared hourly and records made of such comparisons. At the end of the day's work all notes and records must be copied into the fathometer-record book and verified. Care must be taken in recording fathometer soundings, so that there will be ample space to admit of all other data without crowding the record.

It should be noted that the maximum interval of 10 minutes between recorded positions (see par. 100, p. 11) will occur only when the bottom is quite even. In rocky regions and when crossing such features as sand ridges, channels, etc., the interval will be decreased considerably, to show 5 per cent variations in depth, and may even be much shorter and more irregular than illustrated in Figure 33.

As each sounding is read the fact that the middle reed of the tachometer is vibrating at maximum amplitude must be noted and indicated in the record by a check mark on the same line as the sounding at the right-hand edge of the left-hand side of the page.

When a sounding by other means is taken to check the fathometer it is recorded immediately below the fathometer sounding, with a note as to the method used to obtain the check sounding and any correction to be applied to the latter. In such cases both soundings should be read and recorded to tenths of a fathom, if practicable.

The method illustrated for recording salinity indicates parts per thousand. Temperature observations are given in temperature-depth curves and in factor tables and do not appear in the sounding record.

The stamps for data required at the end of the day also are illustrated in Figure 33. For lead-line surveys the lead-line correction stamp also is required.

When soundings are obtained with the fathometer or when radio-acoustic control is used statistics for each method should be given at the end of the day, each statistical number being preceded by a letter or letters indicating the method used, in accordance with the following scheme:

Statute miles of sounding lines.—F, with fathometer; T, total for all methods.

Number of soundings.—FR, soundings obtained and recorded by the fathometer red-light method; FW, by the fathometer white-light method; S, by all other methods; T, total by all methods.

Number of positions.—B, bomb positions; T, total for all methods.

For radio-acoustic positions the name of call letters, or each station, the distance in meters between the ship and station, and the log and revolution-counter readings are recorded. Intermediate positions are provided by recording the time, log, and revolution-counter readings. The latter are noted whenever there is a change in speed or course and at such other times as may be desirable. Rubber stamps are provided for recording radio-acoustic and intermediate positions.

Bomb record.—A bomb record, for which a standard form is provided, is used for recording data relative to radio-acoustic positions and the computation of distances. The bomb record for position No. 37, Figure 34, is shown in Figure 35. Each page of this record is divided into alternate four and two line spaces by heavy lines, each four-line space being used for recording the data for one station. For convenience in following the explanation given below, the columns of this sample record page have been numbered.

Referring to Figure 35, the position number, time of dropping bomb, and the names or call letters of the stations are recorded in the first two columns.

The time intervals in the next two columns are scaled from the chronograph tape. On this tape the chronograph pen draws a base line in which it makes a small jog or offset for each second of time. The time of receipt of the sound of a bomb explosion or of a radio signal from a shore station is shown by a longer offset made, on the opposite side of the base line, by another pen. As explained on page 100, the first long offset of a position determination is caused by the bomb explosion. For convenience in scaling time intervals, the offset denoting a second of time next preceding the offset caused by the bomb explosion is used as an initial point from which all time intervals are scaled.

POSITION NUMBER	TIME MER. 120 P M.	SOUNDINGS FATHOMS	Slope Cor.	Velocity COR. fms.	RED. FOR TIDE fms.	REDUCED SOUNDINGS FIELD FATHOMS	FIELD	OFFICE FATHOMS	OFFICE FEET	BOTTOM	
	h. m. s.	Fathometer Soundings Read by R. R. Poe									
137	5-00-00	45½	0	1	1½	45					✓
	03-15	49		1		48	½				✓
	09-10	46½		1		46					✓
138	5-15-00										
	18-25	42½		1	1	42	½				✓
	20-15	47½		1		47	½				✓
139	5-29-10	48 2/10		1	1.2	48					✓
	V.C.	48 5/10								S	

~~No. 17~~

STATISTICS M DAY

Statute miles of sounding lines F98 T110

Number of soundings FR120 S240 T360

Number of positions B18 T39

No. 16

Sextants O.K.

Clock O.K.

~~Leadline corrections on page~~

Sheave No. H 92 tested 5/16, 1927

Corrections on page 14 Vol. 1

No. 19

Days' work ends at 139

Distance to Hove-to mi.

FIG. 33.—Sample record page; fathometer soundings

HEADING BY Std. COMPASS	ANGLES AND RANGES	REMARKS AND GENERAL DIRECTION (TRUE) OF LINES
	No 23	
	Position No 37	Distances
	Assumed	Final
	Station Orford 144705 m.,	144901 m.
248°	Station Hunter 131039 m.,	131216 m.
	Station m.,	m.
	Log 53.90	R. C. 786098
	No. 24	
	Position No. 38	
	Log 56.50	
	R. C. 787603	
	No 23	Sheave correct
	Position No. 39	Distances
	Assumed	Final
	Station Orford 151803 m.,	152003 m.
	Station Hunter 138533 m.,	138713 m.
	Station m.,	m.
	Log 59.10	R. C. 789203
		Line ends
		Density = 1.0238 @ 14.7°C.
		Salinity = 32 ‰

FIG. 34.—Sample record page; radio-acoustic positions

BOMB RECORD

Locality *Coast of Oregon*

Year 19*27* *Month* *June* *Day of Month* *10* *U. S. C. and G. Survey Ship* *Guide* ; *M* day

1	2	3		4		5		6		7		8			9	10	11	12	13
POSITION NUMBER	TIME OF DROPPING BOMB AND NAMES OF STATIONS	TIME IN SECONDS TO TWO DECIMAL PLACES: INITIAL INTERVAL / RUN / INITIAL COR.		SCALED TIMES		LAGS		TIME FROM INITIAL		MEAN OF METRONOME SIGNALS		ELAPSED TIME			VELOCITY OF SOUND METERS PER SECOND: ASSUMED	FROM TESTS	DISTANCES IN METERS: ASSUMED	FINAL	DESCRIPTION OF BOMB / SPEED OF SHIP / FUSE INTERVAL / REMARKS
37	5-00-00	0	90	98	67	—	—	98	67	—	—	97	84		1479	1481	144705	144901	1-pint can
	Orford	0	07	105	57	6	88	98	69										10 knots
		0	83	107	06	8	38		68										20 secs
				108	55	9	91		64	98	67	97	84						
	Hunter			89	43	—	—	89	43	—	—	88	60				131039	131216	
				97	18	7	75	89	43										
				97	85	8	43		42										
				98	57	9	11		46	89	43	88	60						

No. 22

Times scaled by *J. P. Smith*
Times checked by *A. R. Jones*
Computations by *J. P. S.*
Checked by *A. R. J.*
Velocity tests recorded on page *3-6* vol. *1* of *Bomb* record.

This information inserted at end of each day.

FIG. 35.—Sample record page; bomb record

In the third column are entered the following in the order named: (1) The "initial interval," which is the time interval between the offset caused by the bomb explosion and the initial point; (2) the "run," which is the time required for the sound of the explosion to reach the ship, computed from the speed of ship, time interval between dropping the bomb and its explosion (see p. 100), and the velocity of sound in water; and (3) the "initial correction," which is obtained by subtracting (2) from (1) and is, of course, the interval between the initial point and the actual time of the bomb explosion.

In the fourth column are entered the intervals between the initial point and the offsets caused by the radio dashes from the shore station. The time interval of the instantaneous dash (see p. 101) is recorded on the first line, followed by the intervals of the three metronome dashes. If the apparatus is not equipped to transmit a dash at the instant the sound reaches the hydrophone, or if any of the metronome dashes are missed, the appropriate lines are left blank.

In the fifth column the lags of the metronome dashes are recorded. Means of a series of observations of lags are used and may differ slightly from the lags indicated by the difference between the instantaneous and metronome dashes of any one position.

In the sixth column the lags are subtracted from the scaled times of the metronome dashes to obtain the time intervals between the initial point and the receipt of the sound by the shore hydrophones. The mean of the metronome-dash intervals is recorded in the seventh column.

In the eight column the "initial correction" (from third column) is subtracted from the instantaneous and metronome dash intervals to obtain the time required for the sound to reach the shore hydrophone.

The velocity of sound in sea water is entered in columns 9 and 10. If field work is started before tests are made, a velocity may be assumed until tests are completed.

The distance in meters between the ship and shore station, entered in columns 11 and 12, is obtained by multiplying the velocity of sound by the elapsed time (from column 8).

The last column is used for entry of data listed in the heading. The fuse interval is the interval between the time of dropping the bomb and the time of its explosion.

Succeeding four-line spaces are used for the two or more control stations from which distances are obtained.

When it is desirable in the field to determine the location of the ship as quickly as possible, a position can be computed from any one of the radio dashes. In this case it is convenient to use a template to check the operation of the shore stations and to identify the offsets on the tape. A template for this purpose is constructed by plotting, along the edge of a strip of boat-sheet paper or other durable material, offsets corresponding in length to those on the tape and spaced in accordance with the lags determined by tests and with the scale of the tape.

For a final record, however, the complete data noted above are carefully determined, entered, and checked, thus obviating the neces-

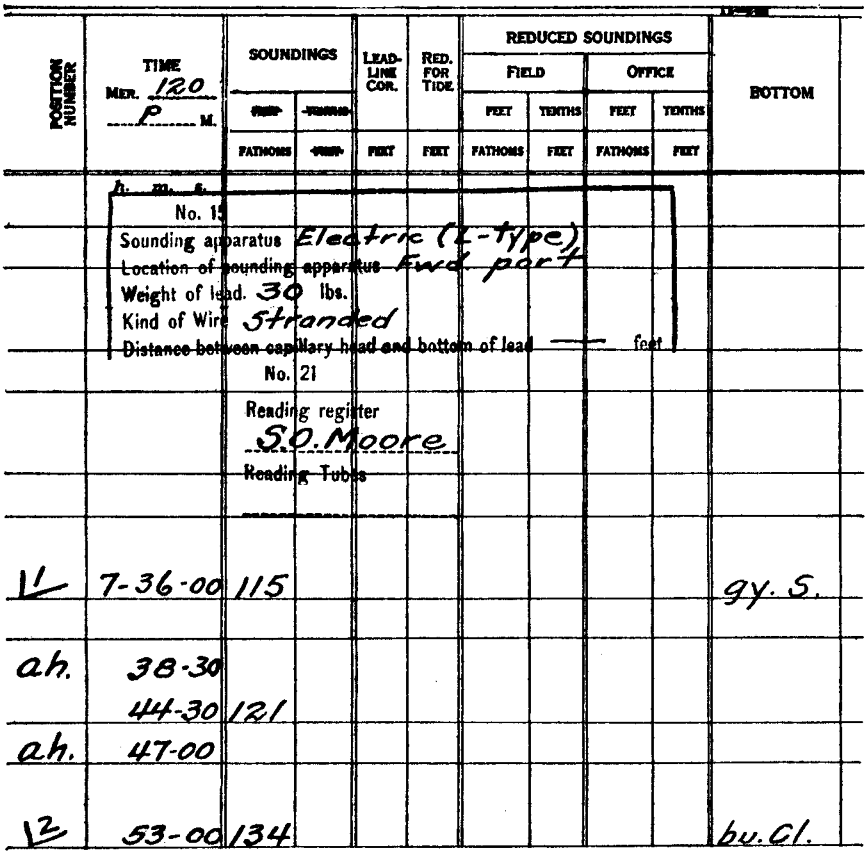


FIG. 36.—Sample record page; wire soundings

sity of forwarding chronograph tapes to the office. A rubber stamp is provided for the names of persons that perform the various operations.

Wire soundings.—The method of recording soundings obtained by sounding machine and wire with the vessel stopped is shown in Figure 36. The information indicated by the two stamps in this illustration is given for wire and pressure-tube soundings and is *in addition* to data shown in Figure 30.

"No bottom" soundings are recorded in the form of a fraction with zero as the numerator and the depth reached as the denominator. Thus, $\frac{0}{19}$ indicates no bottom at 19 fathoms or feet, depending on the sounding unit.

Recording cuts.—When a considerable number of signals are located by sextant cuts, as when floating signals are used, it is well to record all cuts in a special angle record, properly indexed. A sounding record with its cover label altered may be used for this purpose.

Record of floating signals.—When a floating signal is planted it will be found desirable for future reference to record the date, depth of water, length and bearing of anchor cables, and identifying mark of the signal.

REDUCTION OF SOUNDINGS

The reduction of soundings in accordance with paragraphs 130 to 139 of part 1 is indicated in the various sample record pages. The tide reducers are taken from the tidal record when a plain staff is used or are scaled from the marigram of an automatic gauge. In most cases the tabulation of marigrams to determine the gauge reading corresponding to the plane of reference is done in the field. It is sometimes desirable, however, to forward the marigrams to the Washington office for tabulation, in which case the gauge readings for days when hydrography is done may be scaled and recorded in a tidal-record book to be reduced to the plane of reference and used for reduction work after information relative to the gauge reading corresponding to the plane of reference is received from the office.

In some cases, when the gauge is a considerable distance from the work, it may be necessary to apply a time and height correction. The above operations are fully described in the Instructions for Tide Observations.

Lead-line corrections and tide reducers are usually entered at the top of each page and wherever a change occurs.

For tube soundings the heading of the "lead-line correction" column is changed to show the corrected sounding in fathoms. The latter is obtained by applying the correction obtained by tests to the mean of the two tube readings. The same correction is applied to either pair of tubes. For examples, the correction to one pair of tubes at 30 fathoms is also applied to the other pair for the same depth, and the correction to either pair at 35 fathoms is obtained by interpolating between the correction for one pair at 30 fathoms and the other pair at 40 fathoms.

For fathometer soundings the second division of the "soundings" column is used to enter the sounding corrected for slope. The slope correction, which in most cases is negligible, is obtained by means of a graph furnished by the office. The heading of the "lead-line correction" column is changed to show the velocity correction to the sounding in fathoms. The latter, which is applied to the sounding (unless a slope correction is necessary, in which case it is applied to the sounding corrected for slope), is obtained by means of a factor representing the relation between the assumed velocity of sound and the difference between the assumed and actual velocities.

For soundings of 450 fathoms or less this factor is taken from Table 4a or 4b in the appendix. Table 4a is used for instruments with a dial speed of 240 revolutions per minute, corresponding to an assumed velocity of 800 fathoms per second, while Table 4b is used for instruments with a dial speed of 246 revolutions per minute, corresponding to an assumed velocity of 820 fathoms per second. (See description of fathometer, p. 55.) These tables are entered with the mean temperature and the mean salinity.

A convenient form for working up these velocity factors is shown on page 72. By using this table and making small interpolations, the corrections can be entered directly in the record in the column headed "lead-line correction." A form of this nature should be prepared for each station at which temperatures are observed, and included in the abstract of temperatures for the season. (See par. 170, pt. 1.) If a second temperature series or the shorter series that may be taken from time to time during the season (see p. 72) agree with the first series, factors and corrections, of course, need be computed only for the first series.

Each form should be identified by a number or letter, and the descriptive report for each sheet should contain a reference to the factor tables in the abstract of temperatures that apply to that sheet.

For depths over 450 fathoms a factor must be computed for each 200-fathom layer of depth, using the observed salinity and serial temperatures. Thus, a factor is computed and applied to soundings within the 450 to 650 fathom range, another factor is computed for soundings within the 650 to 850 fathom range, etc. In computing these factors the actual velocity of sound for any depth is considered to be the mean of the velocities of successive 200-fathom layers down to the depth range in which the sounding lies. The velocity for each 200 fathom layer is taken from the tables for the middle of the layer. For example, the velocity for the 200 to 400 fathom layer is taken from the tables for 300 fathoms.

Factors are usually computed in the following tabular form. This form is essentially the same as that shown on page 72, and is included in the abstract of temperatures and referred to in descriptive reports in the manner described above. The principal difference is that the factors must be computed instead of being taken from a table.

Fathometer factors

[Salinity, 31 0/00]

Date, ... Location of station: Lat. ....; long. ....

Depth, fathoms	Temperature, °C.	Velocity per second	Adiabatic correction per second	Corrected velocity per second	Mean velocity per second	Depth range	Factor
		Fathoms	*Fathoms*	*Fathoms*	*Fathoms*	*Fathoms*	
100	16	819	3	822			
300	8	809	2	811			
500	5	806	1	807	813	450– 650	+0.016
700	3	807	1	808	812	650– 850	+0.015
900	3	810	1	811	812	850–1,050	+0.015

NOTE.—Factors are computed for an assumed velocity of 800 fathoms per second. Temperature observations and factor computations are extended to include the maximum depth at which soundings are taken.

The serial temperatures entered in the second column are those observed at the depths shown in the first column. Velocities in the third column are obtained from Table 5 in the appendix. The adiabatic corrections are obtained from Table 6 in the appendix and are added to the velocities from Table 5 to obtain the corrected velocities. The mean of the corrected velocities for 100, 300, and 500 fathoms is considered to be the velocity for the depth range 450 to 650 fathoms, and so on.

The factor is computed from the formula

$$\frac{D}{V} = \pm F$$

in which D is the difference between the assumed velocity, depending on the dial speed of the fathometer, and the actual velocity from the above table; V is the assumed velocity; and F is the factor. The sign of the factor is plus if the actual velocity is greater than the assumed velocity, and minus if the contrary is true.

The factor (for soundings over 450 fathoms) is entered at the top of each page in the record and wherever a change occurs, to two decimal places only. If the figure in the third decimal place of the factor as tabulated is 6 or more, the figure in the second decimal place is increased by one; 5 or less in the third decimal place is disregarded. Each sounding is multiplied by the factor to obtain the correction, which should be entered in fathoms to agree with the sounding unit. A slide rule may be used conveniently for this operation. The correction is applied in accordance with the sign of the factor.

The method described in the preceding paragraph may also be used for soundings less than 450 fathoms if desired, but the entry of corrections by inspection from a table should be more convenient.

In Figure 36, illustrating the recording of wire soundings, no reduction is made, as the soundings are over 100 fathoms.

A stamp (stock No. 4—not illustrated) is provided for entering the initials of the persons who reduce and check the record and who plot sounding lines and soundings.

The sheet and volume numbers should be entered on the cover label of each record when it is first used; the remaining data on cover label and title page (see par. 138, p. 17) being entered whenever convenient before the records are relinquished.

List of signals.—The list of signals required in paragraph 139, part 1, is generally prepared in the following form:

List of signals on hydrographic sheet No. —

Hydrographic name	Location
Hal	Halls Mills, 1923.
Bat	Topographic signal, sheet C.
Red	Hydrographic signal, page 45, Sdg. record, volume 2.

A date after a name identifies the station as a triangulation or traverse station located during the year stated. The field letter of the sheet on which a topographic station is located and the page and volume of the record on which cuts to a hydrographic signal are recorded should be given.

Chapter 7.—HYDROGRAPHIC SURVEYING

After the completion of such preliminary operations as are necessary, a party is ready to begin actual hydrographic work. This should be based on a general plan, formulated in advance from a consideration of the results desired, the various units available, and other conditions that may affect the work. Such a plan, of course, is subject to change and often will be changed to some extent as the work progresses.

Under ordinary conditions it is desirable that all classes of work be completed to the same general limit at the end of the season. An exception to this occurs when the hydrographic party executes the greater part of the control surveys for work that will extend over more than one season. In such a case it will be advantageous to have the triangulation or traverse far enough ahead of other work at the end of the season so that the latter can be resumed without delay at the beginning of the next season while the control is being extended.

The division of work between the various units of the party should be made with the idea of securing the greatest possible progress consistent with economy and safety in the use of the ship and launches. In laying out the launch work consideration should be given to the location of shore quarters and ship anchorages, so that the time required for runs to and from the working grounds may be reduced to a minimum.

A chief of party working in a region with which he is not familiar should obtain as much information as possible regarding prevailing weather conditions from a study of meteorological data and from persons with local knowledge. As the season advances he will acquire familiarity with local weather conditions which, together with knowledge as to the relative progress of the various units, will be of great assistance in planning the continuation of work.

Special attention should be given to sections of the work requiring unusually favorable weather conditions. Even if it is thought that the best weather will occur later in the season, preparations for such work should be completed as soon as practicable in order that advantage may be taken of suitable weather whenever it occurs.

When radio-acoustic control is used it is not economical to have the shore stations so close together as to give good intersections of the distance arcs for any considerable distance inside the range of visibility, under favorable conditions, of shore signals. In work of this nature clear weather must therefore be utilized for the inshore work controlled by visual positions. Exceptionally smooth weather is usually required for the installation of hydrophones and cable laying.

Careful study should be made of the order in which work is to be taken up, with the idea of developing a logical sequence of operations so that all work accomplished will give as much information as practicable of additional work required, and the project thereby will be completed not only without neglect of any essential work, but also without waste of time or effort.

For example, assuming that sounding lines are to be spaced 200 meters apart to the 5-fathom curve and 400 meters to the 10-fathom curve, in most cases it will be more economical to run the 400-meter lines first and then to split them out to the 5-fathom curve. By this method the 5-fathom curve is well defined by the 400-meter lines and the hydrographer knows just where to split the lines. Otherwise he may run the 200-meter lines too far out in order to make sure that there is no shoaling after a depth of 5 fathoms is first reached or be confronted with the necessity for additional work if shoaling is disclosed by the subsequent extension of the 400-meter lines to the 10-fathom curve.

An example of wasted effort sometimes occurs in the survey of a river or similar passage by crosslines and channel lines. The logical order of work, of course, is to run the crosslines first in order to determine the location of the channel. Cases have been known, however, where the channel lines have been run first, following the supposed location of the channel as defined by aids to navigation or other features, subsequent crosslines disclosing the fact that the supposition was far from correct. Such a survey, involving exactly the same amount of work as the proper method, is, of course, unsatisfactory and can only be remedied by such additional work as is required for rerunning the channel lines.

It is sometimes economical, before beginning the survey of a bay, river, or other indentation, to run a few widely spaced trial lines of soundings in order to obtain general information from which the bearing and spacing of lines and other details of the work can be planned more intelligently. This is especially desirable in resurveys for the purpose of getting an idea of the extent of changes that have taken place. If the trial lines are carefully placed and are run in accordance with standard practice, they usually can be fitted into the final survey so that no work is wasted.

A study of the nature of the country adjacent to the work is always of value, for the characteristic land forms are likely to be repeated under water. Thus, in certain water areas along the New England coast sunken bowlders, corresponding to those that dot the fields along the shore, are found in great numbers, while in southeast Alaska the sharp mountain peaks, that are so noticeable while cruising along the coast, form submerged pinnacle rocks, often rising from great depths to within a few feet of the surface. On the South Atlantic coast of the United States the low, even, sandy coasts give assurance that dangers, such as rocks and reefs, do not exist, but here it will be found that, corresponding to the constant movement of the sand dunes along the shore under the effect of the wind, there are frequent changes in the bottom due to the action of waves and currents.

Organization of units.—The organization of a launch unit engaged in lead-line sounding usually consists of two officers, a recorder, an engineer, and two men who alternate as leadsman and helmsman. The officer in charge ordinarily takes right angle and plots while the second officer takes left angle and supervises the operations of recording and sounding. When a sounding machine is used, one of the officers generally records and an extra man is provided at the machine.

On shipboard several men are usually required for work on deck, so that there is considerable latitude in arranging a system of relieving the leadsman and helmsman or for providing extra men if they are required for other methods of sounding. For hand-lead sounding it is usually desirable to station a seaman on the deck below the sounding chair to assist in hauling in the line. For radio-acoustic control the bomb firing should be under the direction of an officer with considerable experience. Echo soundings also should be read by an experienced officer, and in deep water it may be necessary to detail officers with special qualifications for this work.

Predicted tides.—One of the first requirements of the hydrographer is a knowledge of the predicted tides for the region in which he is working. This information is required for reducing soundings to the approximate plane of reference before they are plotted on the boat sheet (see par. 83, pt. 1) for planning work that should be done at a certain stage of tide, etc. The times and heights of high and low water at a near-by point can usually be obtained from Table 2 of the Tide Tables. A convenient method of obtaining the predicted tide at any time during the day is illustrated in Figure 37. The procedure is as follows:

(*a*) On cross-section paper plot the high and low water points A and E in accordance with the time and height coordinates.

(*b*) Quarter the connecting line AE at points B, C, and D.

(*c*) Take points B′ and D′ above and below B and D, respectively, at a distance equal to one-tenth of the range of tide.

84668°—28——9

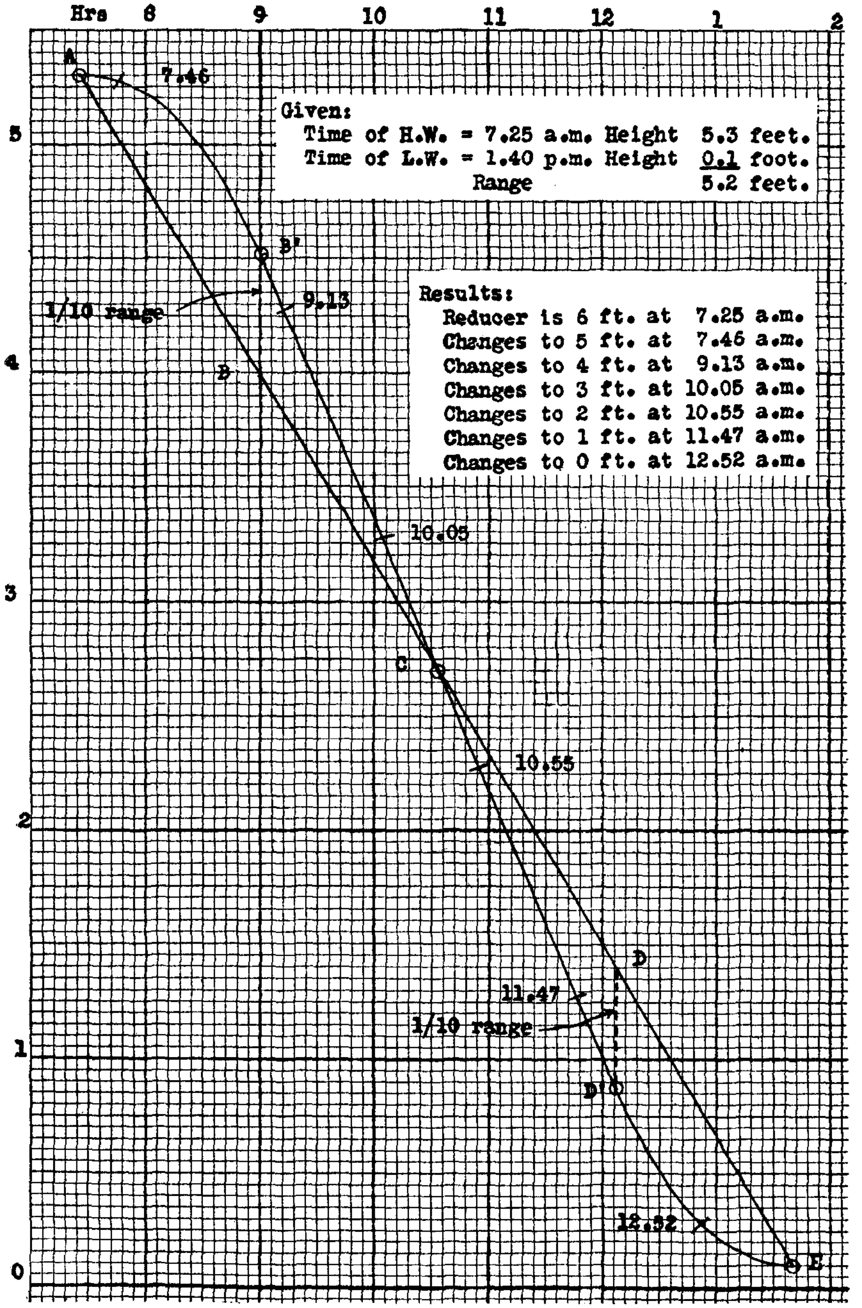


FIG. 37.—Construction of predicted tide curve

(*d*) Draw an approximate sine curve through points A, B′, C, D′, and E, which will give the information required.

The tide curve constructed in this manner can be marked to show the points at which changes in reducers occur. Thus, when reducers are desired in integral feet, the curve should be marked at points between 0.2 and 0.3 of each foot (between 0.7 and 0.8 when the tide is below the plane of reference) and the corresponding times noted. A tabulation of reducers and times of change can be taken from the curve and furnished to each unit before starting the day's work.

Offshore limits of surveys.—Until recent years depths greater than 100 fathoms have been regarded as of little concern to navigators, since that depth was about the limit at which they could obtain soundings. The development of echo-sounding apparatus, however, now enables ships equipped with such apparatus to measure the greatest depths of the oceans, with the result that they are always "on soundings." It is therefore considered that hydrography should be carried as far seaward as practicable. Where the bottom gradient is small, as on the Atlantic and, especially, the Gulf coasts of the United States, the 100-fathom curve lies so far seaward that it is difficult to control hydrographic surveys to that depth. For this reason surveys on these coasts usually are not carried much beyond the 100-fathom curve.

On the coasts of the Pacific Ocean, however, the gradient is usually so steep that a depth of 100 fathoms is found comparatively close to shore, with the 1,000-fathom curve no great distance beyond. In these waters it is therefore the general practice to extend surveys to the 1,000-fathom curve.

Direction of lines.—In the absence of specific instructions on the subject, the general requirements permit the hydrographer to run sounding lines normal or parallel to the coast or to use a combination of these directions. The most suitable bearing depends so much on local conditions that, in general, it is necessary to depend on the judgment of the chief of party for the selection of a system that will accomplish the desired results in the most economical manner. In laying out a system of lines along an open coast a consideration of the following points may be of value.

Lines normal to the coast have been used more often in the past, especially for inshore hydrography. Their principal advantages are that, when well located, they are especially suited to the determination of the depth curves; that positions are more easily obtained, as fewer changes in objects are required; that positions so close to shore that three signals are not available can be obtained by prolonging the line between strong positions farther offshore; and that they permit the use of ranges and leading marks on shore for running the lines.

In running such lines in toward the shore or other danger or when getting under way at the inshore end of a line, however, it is very difficult to record all variations in speed, with the result that inshore depth curves are frequently displaced to some extent. There is also less flexibility in spacing. If two parallel lines are run in the direction of depth change, it is obvious that, if they are spaced correctly according to the depth at one point, they will be too close together or too far apart at other points.

These difficulties may be obviated to a considerable extent by the use of lines parallel to the general trend of the coast, especially in an even, gradually sloping bottom. It is also probable in many cases that soundings can be obtained closer to shore, as the boat is running along, instead of toward, the danger line, and that time can be saved by starting and ending work closer to the ship anchorage or headquarters of a shore party.

Lack of the advantages mentioned above for lines normal to the coast may be considered to be the disadvantages of a system of lines run in the alternate direction. When the coast has many indentations, so that the shore line is very irregular, it would appear to be more satisfactory to run lines normal to the coast or to use a combination of normal lines running out a short distance to a junction with lines parallel to the shore. In some cases lines parallel to an irregular shore might be satisfactory, but it will usually be difficult to provide a sufficient number of signals for the numerous positions at irregular intervals that would be required for the changes in course.

Spacing of lines.—The spacing of lines depends on the depth, character, and relief of the bottom and the importance of the region. In general, the spacing should be such as to give sufficient development, for navigation and fishing purposes, of all areas out to the offshore limit adopted for the project. In important anchorages and channels lines are usually spaced 50 meters apart, or even closer if necessary for complete development. In general coast work, with even sand or mud bottom and without indications of banks or dangers, lines normal to the shore are generally spaced 200 to 300 meters apart to the 10-fathom curve, thence one-half mile apart to the 15-fathom curve or to the limit of visibility of control objects, and thence from 1 to 4 miles apart to the 100-fathom curve. When the bottom is broken or uneven it is necessary to decrease this spacing.

For work between the 100 and 1,000 fathom curves lines are spaced from 2 to 5 miles apart, the closer spacing being used out to the limit of fixed-position work and the wider spacing for lines controlled by astronomical observations when the outer limit of work can not be reached by other methods of control.

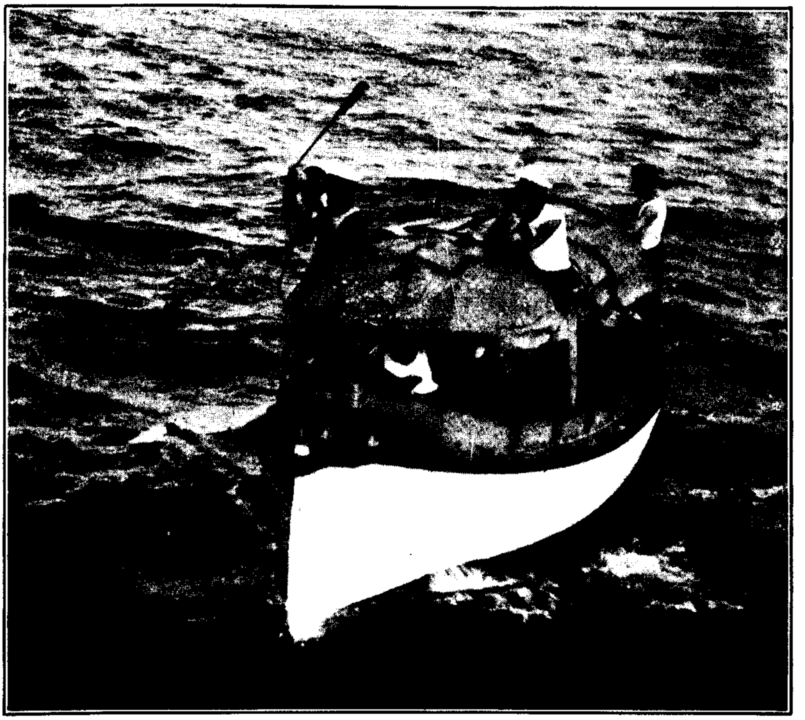


FIG. 38.—LAUNCH HYDROGRAPHIC PARTY

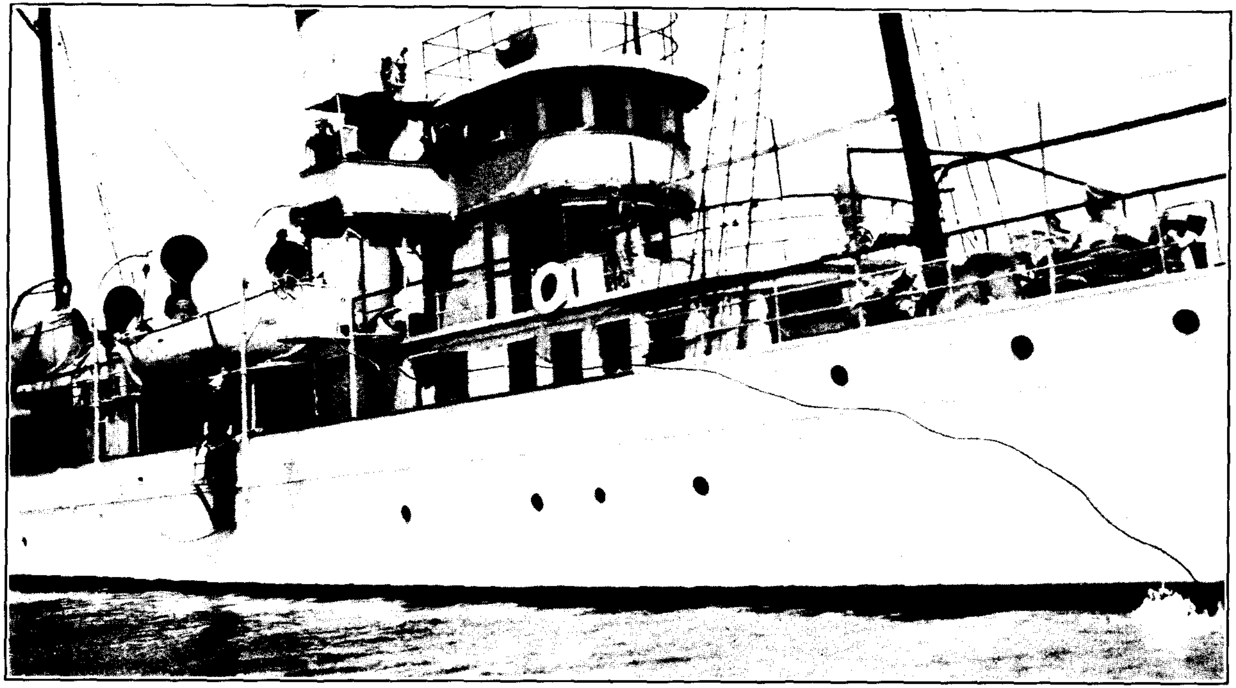


FIG. 39.—LEAD-LINE SOUNDING WITH SHIP

For a system of lines parallel to the shore the spacing will vary with the depths, increasing gradually from the minimum distance used for the inshore lines. Thus the successive spaces, outside the 6-foot curve, may be 50, 100, 100, 200, 300, and 400 meters.

Crosslines for any system should be spaced four or five times as far apart as the main lines.

In rocky regions two surveying methods are available. One is to decrease the above spacing considerably and to develop thoroughly all shoal indications with the lead line or wire drag. The other is to run only a sufficient number of sounding lines to ascertain the general depths and configuration of the bottom, and then to cover the entire region with the wire drag to the depth required for navigation.

The spacing of lines is prescribed in special instructions covering each project, but the responsibility of the chief of party is not confined to compliance with such instructions. He is required to decrease the prescribed spacing in certain cases and to investigate all shoal indications without regard to the system of lines in use. (See pars. 105 and 109, pt. 1.)

The method prescribed for the survey of a rocky region may be subject to change. For example, a locality to be surveyed by a combination of soundings and wire drag may be found to be subject to conditions, such as a heavy and continual swell, that will interfere with the economical use of a wire drag. On the other hand, a survey by soundings alone may develop so many, and possibly unexpected, shoal indications that a change in method to include the use of a wire drag may be advisable.

In such cases the chief of party should inform the office promptly of the conditions encountered and recommend any changes that may seem desirable. He should not, however, change the method of survey until so authorized.

Laying off the lines.—Proposed sounding lines, in accordance with the bearing and spacing decided upon, are laid off in pencil on the boat sheet. As it may be desirable to shift the entire system slightly from time to time, due to the possibility that the actual lines may not coincide with those laid off on the sheet, only a few lines should be drawn at one time.

Running lines.—To run a sounding line the hydrographer places his vessel at the desired starting point, heading approximately on the course to be steered. The helmsman is given the course, the recorder is given the starting data, a position and sounding are taken, and the vessels get under way. The taking of lead-line soundings at any desired interval is directed by the recorder by the word "sound," or by whistle or other signal. This order should be given a sufficient number of seconds before the expiration of the time interval (based on observations of the actual time required to get soundings in various depths), so that the sounding will be obtained as closely as possible at the expiration of the interval.

When sextant positions are taken at regular intervals the recorder notifies the observers about 30 seconds beforehand by an expression such as " stand by " or " position on the next sounding." The observers then set their sextants on the control objects and take the angle, as the lead line comes vertical, on the order " mark," given by the recorder or officer in the best position to observe the sounding operation. Special positions are taken on order from the officer in charge.

Sounding lines ordinarily are run on compass courses, following the proposed lines on the boat sheet as closely as practicable, but except when running lines parallel to the coast, without taking time to make them coincide exactly with the latter. In many cases, if the position plots some distance from the desired line, it may be desirable to change course only enough to parallel the latter and then to shift the system of proposed lines to agree with those actually run. When running lines with graduated spacing parallel to the coast, however, greater care must be taken to keep on the proposed line and to return to it as soon as practicable if the position plots off the line.

Ranges of shore objects should be picked up, if practicable without delaying the work, and will be especially useful when there is a cross wind or current. When a range is desired the angle between some signal and the proposed line may be taken from the sheet with the protractor, and with a sextant set to this angle, a search may be made for suitable objects on shore that are in range with the line.

When ranges are not available and there are objects both ahead and astern, as when working in a bay or passage, an improvised instrument, called a 180° mirror (see fig. 40), may be used to keep the sounding vessel on line between two selected objects. This instrument consists of a thin board shaped about as shown, with a grooved sight " C " and two grooves for holding two sextant index mirrors at right angles to each other and about 5 inches apart. A part of the silvering on the upper part of mirror "A" is removed, and a cover is provided to exclude from mirror "A" objects not reflected to it from mirror " B."

To use this instrument, an object on the near shore is selected as described above for a range, and an object on the far shore is picked up as soon as the vessel is on line and course. The vessel is kept on line between these objects by so directing the course that the double reflection of one object remains under the second object as viewed direct through the grooved sight and the clear part of mirror "A."

At the end of a sounding line the vessel turns and runs over to the next line. In running from one line to another of any close system of parallel lines, soundings are not required, and there will be less confusion if they are not taken.

The procedure for tube soundings is practically the same except that the machine is released at the expiration of the time interval. For machine soundings the recorder is informed as to the time interval between soundings and notifies the officer in charge when it is time to reverse the engine.

As a sounding vessel approaches the shore or other shoal water a sharp watch must be kept ahead for rocks and other dangers, and the helmsman and engineer must be ready to carry out orders promptly. In some regions, and especially in coral bottom, a lookout aloft on a

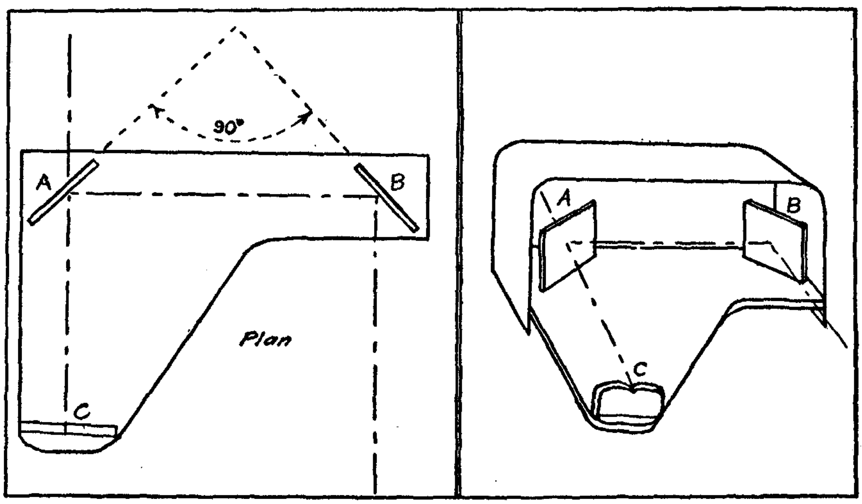


FIG. 40.—180° mirror

survey ship will be able to detect shoaling by the appearance of the water.

Sounding speed.—The approximate maximum sounding speed practicable for lead-line and tube sounding is 5 knots, but this must be decreased when running with a fair current to avoid large sounding intervals or overrunning the lead line. The proper sounding speed can be determined after a short period of observation. Echo-sounding lines and the intervals between wire soundings are run at full speed.

The use of funnel-shaped canvas drags, with a simple arrangement of lines for towing and spilling, will be found effective to obtain a short turning radius or to reduce the speed of motor launches when the minimum engine revolutions for satisfactory operation give an excessive sounding speed. They may also be used to assist in stopping for wire soundings in order to reduce wear on the clutch.

Sounding interval.—The desired interval between soundings may be obtained by adjusting the time interval between soundings, the speed of the vessel, or both. Under normal conditions and the proper sounding speed the following time intervals will usually be satisfactory for lead-line soundings:

Depths under 2 fathoms	15-second interval
Depths from 2 to 4 fathoms	20-second interval
Depths from 4 to 7 fathoms	30-second interval
Depths from 7 to 10 fathoms	40-second interval
Depths from 10 to 15 fathoms	1-minute interval

Tube-sounding intervals will vary somewhat, depending on the type of machine and the skill of the operators. Suitable intervals can be determined with a little experimentation. The use of two machines will, of course, decrease materially the interval required for tube soundings. The general requirements regarding sounding intervals for all types of sounding apparatus are given in part 1.

Position interval.—With regard to this subject, very little need be added to the general requirements given in part 1. Special attention, however, should be called to the importance of taking a position as soon as the vessel gains full headway at the beginning of a line and when slowed down on approach to shoal water at the end of a line; otherwise serious errors in spacing soundings on the plotted sheet will be likely to occur. The irregular and improbable depth curves, as well as poor crossings, sometimes seen on plotted sheets near the shore are generally due to unrecorded variations in sounding speed.

The maximum interval between radio-acoustic positions is about 30 minutes. A shorter interval will usually be required for a system of closely spaced lines. At the present time about four minutes are required to obtain a radio-acoustic position.

When there is considerable distance between sextant positions, as in the case of offshore wire soundings, unrecorded trial positions to check the course and distance run may, of course, be taken at any time.

Depth curves are of much value in interpreting and examining the results of the field work. The depth curves will often indicate areas of shoaler depths requiring further examinations. Also abnormal and improbable curves are a strong evidence of probable uncertainties or inaccuracies in the hydrographic survey. Depth curves correspond to contours on land, and in nature are therefore generally of graceful sweeping form, free from sudden changes in direction and from corners. Ordinarily they can not cross or abruptly run into each other; on approaching they tend toward parallelism. Any departure from probable natural conditions is an indication of error either in field work or in plotting, or it may be an indication of shoaling that will require further examination. A study of the characteristic bottom forms in any region is of value in the interpretation of hydrography, as such forms are apt to repeat themselves in similar regions.

Development.—Extent of development will vary from a maximum on shoals in important locations and in channels and anchorages having depths near the draft of vessels to be accommodated to a minimum on extensive flats of much less depth and in clear areas of much greater depth than is required for navigation. Careful attention also must be given to the development of shallow channels and waters that are likely to be used by light-draft vessels or motor boats. In regions where changes are continually taking place, development ordinarily need not be so detailed as in regions of little change.

The requirements given in part 1 and the methods heretofore described, if carefully followed, will suffice for ordinary hydrographic work. Methods of development in a few special cases are given below.

Work on large scales.—When working on large scales (usually larger than 1:10,000) special precautions must be taken to guard against errors that would not be appreciable on smaller scales. The observers should stand close to each other and be careful to mark their angles at the same time. Great care should be taken to note the exact times of soundings and positions and to keep sextants and protractors in adjustment.

Sounding in strong currents.—It had been definitely established that accurate soundings and their locations can not be obtained with hand lead or machine when sounding lines are run across or against strong currents. The depths obtained will be invariably greater than the true depths, the error being in direct proportion to the strength of the current and increasing greatly with the depth. (See fig. 41.) In strong currents, therefore, sounding lines should be parallel to the axis of the current with the vessel running at slow speed in the direction of the current.

Development of shoals.—Development of all shoal indications is one of the most essential details of hydrographic work. In order that all soundings indicating possible shoals may be noted, close cooperation between the hydrographer, recorder, and leadsman is essential. Such soundings should be plotted on the boat sheet and marked in a distinctive and conspicuous manner (usually by ringing with red pencil) *at the time they are obtained.* Shoals should be developed by a closely spaced system of crosslines to determine the high points, which may be examined further by drifting over them and feeling them out with the lead. A marker buoy, anchored at a suitable point on the shoal, will often be of value for such development. This work may be largely avoided if conditions are such that a wire drag can be used for the examination.

In exposed regions reefs or shoals may be located during heavy weather by obtaining cuts to the breakers from shore stations or from different positions of the vessel. The depths on such obstructions should be determined during smooth weather if possible; if always breaking, a sounding line should be run just outside the breakers and distances from vessel to breakers noted at numerous points.

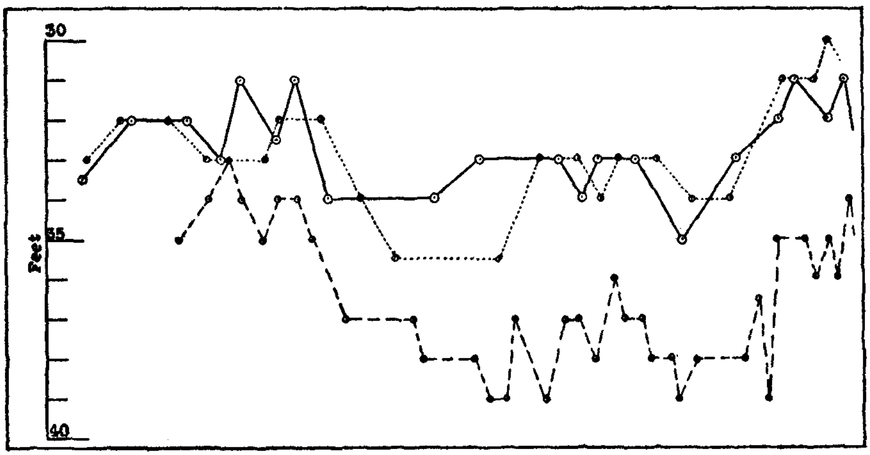


FIG. 41.—Sounding in strong current

This illustration shows the results of an experiment to determine the accuracy of obtained by crosslines normal to a 1½-knot current. Circles connected by broken lines show depths obtained by lead-line soundings while running on a range in the direction of a 3-knot current. That accurate soundings were obtained was indicated by subsequent crosslines run under favorable conditions. Circles connected by dotted lines show depths obtained by crosslines normal to a 1½-knot current. Circles connected by broken lines show erroneous depths obtained while running on the range against a 3-knot current.

Development of channels.—The first system of lines should be across the axis of the channel, either normal or diagonal thereto. In narrow channels or where the slope is abrupt the lines should be diagonal and at such an angle that the change in depth will be gradual enough to permit taking a sufficient number of positions to locate the channel limits and usual depth curves. Care must be taken to show all variations in sounding speed by a sufficient number of positions and either to take each position simultaneously with a sounding or to record the exact time of each. The crosslines will serve to locate the channel, which must then be developed thoroughly by a system of lines parallel with its axis.

Channel development is illustrated in Figure 42. Based on the information given by the crosslines as shown, the broken lines indicate a proposed system of channel lines that will complete the development. The crosslines start at A and are run in the directions shown by arrows to end at B. As the first line indicates three channels separated by flats, two additional lines, starting at A′ and ending at B′, are run to fill in the wide space between the beginning of the first line and the ending of the second and thereby define the limits and trend of the two lower channels. The proposed channel lines are to begin at C and continue, in the directions shown by arrowheads, to end at D. Dotted lines connecting ends of channel lines are the courses run by the sounding vessel, without sounding, from one line to another. If the proposed lines do not establish a sufficient number of points to define the limits of the flats, additional lines must be run until the sides of the channels are reached.

In the development of channels and similar narrow passages near-by signals should be used wherever practicable. If a distant signal is used with two near-by signals, the position usually will be affected considerably by even a slight error in the location of the distant signal or in measuring the angle.

Development of bars and reefs.—In many regions the submarine relief is characterized by a succession of more or less continuous ridges trending in a common direction, such as the submerged glaciated areas in Maine and Alaska, the fringing coral reefs of the Florida Peninsula, and the common sand waves and banks in rivers and their estuaries and in certain coastal waters. In such regions the trend of the ridges should be ascertained by a general system of lines, and final development made by lines run at an acute angle with the direction of the ridges.

Development of flats.—On extensive flats bare at low water the low-water line may be determined economically by zigzag lines run back and forth across it. When a sounding line approaches a bare flat specific note should be made in the record. This will often eliminate doubt regarding the extent of the flat and avoid sounding over it at high water. When convenient, flats of less area may be sounded over when covered, the minus soundings subsequently plotted on the sheet showing the height of the flat above the plane of reference and the low-water line, drawn outside of all minus soundings, showing the extent of the area that is bare at low water.

Running surveys.—The hydrographic methods described heretofore are based on the assumption, which is usually the case, that accurate control is available. Valuable information concerning unknown regions where there is no control, however, can be secured, if desired, by a so-called running survey. Sounding lines obtained by a survey

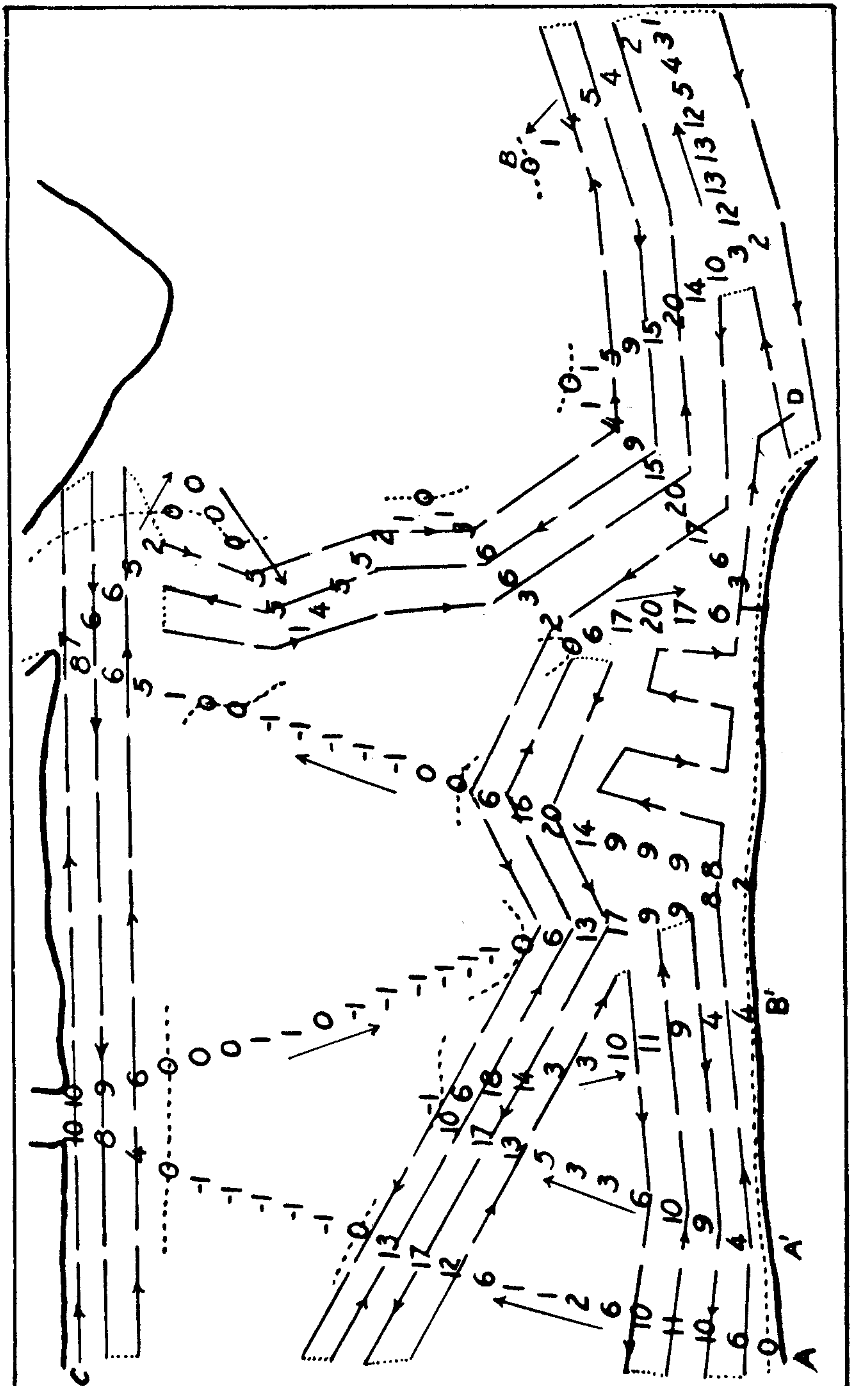


FIG. 42.—Channel development

ship while cruising at a safe distance off the coast are located by astronomical observations, while the general configuration of the coast is determined by bearings and angles to prominent headlands and other features.

It is sometimes desired to survey an anchorage in an unknown region for use as a harbor of refuge or other purpose. A method of establishing local control by plane-table triangulation is described in the Topographic Manual which may be adapted to sextant triangulation, if desired. The stations thus provided may be used for the development of the harbor and its approaches to any extent desired. The data so obtained, when located as accurately as practicable by astronomical observations, will serve very well for the construction of a preliminary harbor chart. The stations, of course, should be carefully marked for later recovery when accurate control is extended into the region.

Current surveys.—A knowledge of the action of tidal and other currents is of great importance to the mariner. Current surveys are usually made by special units and are not included in the usual work of a hydrographic party except by special instructions. It is desirable, however, that current observations be obtained at various points on the working ground when this can be done without interfering with other work. If a ship is anchored in a known position over night or during thick weather, such observations can be obtained with little effort and may furnish valuable data for current prediction. They will generally be made with a current pole and line. Instructions for current observations will be found in Coast and Geodetic Survey Special Publication No. 124.

Cost data.—Each chief of party is required by the regulations to submit cost sheets covering his season's work. It is convenient to keep a memorandum of the various items involved as the work progresses, as this will save extensive examination of the records and considerable memory work at the end of the season.

Care of property.—Every effort should be made at all times to maintain instruments and other property in proper condition. Each officer using an instrument should personally see that it is kept in good order, and an officer should be detailed to supervise the care of equipment in general use.

The arc of a sextant or protractor may be cleaned by wiping lightly with chamois skin or a soft rag dipped in weak ammonia. Such surfaces should never be polished with paper, cloth, or a rubber eraser, as this may deface the graduation. Instruments should be carefully dried after exposure to water or dampness, with special attention given to lenses and sextant mirrors.

All surveying instruments should be cleaned from time to time. Surfaces that are liable to stick together when left in place for a long time should be moistened slightly with oil or tallow after cleansing and before assembling; this applies to the cells holding object glasses.

A lens may be dusted with a camel's-hair brush and when necessary may be cleaned by rubbing gently with soft tissue paper, first moistening the glass slightly by breathing on it. A lens should be examined occasionally to see that it is tight in its cell.

Sounding wire, even when galvanized, is subject to rust if not well cared for. The reel should be wrapped round with oiled cloths and well covered from rain. When the sounding machine is idle for a short period the wire should be dried by running through cloths and oiled, and this should be repeated once a month when the machine is not in use. The machine itself should be protected by a cover of canvas or other material when not in use. Lead lines should be properly coiled and stowed.

New methods and equipment.—All members of parties should be encouraged to study the principles involved in hydrographic surveying and to experiment with new methods and apparatus. Descriptions of new methods and apparatus and suggestions for the improvement of those in use should be furnished as separate reports. as these are preserved in a special office file.

Changes of this nature may be divided into two classes—those that will have no effect on the accuracy of operations, such as the design of a new type of floating signal; and those that may affect the quality of work, such as a new type of sounding tube. Those falling in the latter class, of course, should not be used for actual survey work until approved by the office.

Seamanship.—Skill in hydrographic work will be of little value and in fact can hardly be attained unless an officer is also proficient in seamanship. Knowledge of how to handle and care for his ship or other craft under all conditions and of the use of lines, anchoring gear, and similar equipment is especially essential for the hydrographer, for in many regions he is required by the nature of his work to meet, almost daily, conditions that the average mariner will encounter only in emergencies.

Every officer engaged in hydrographic work should endeavor to improve himself in seamanship by study of standard books on the subject and by observation and practice.

Chapter 8.—SMOOTH SHEETS AND MISCELLANEOUS SUBJECTS

PLOTTING SMOOTH SHEETS

The general requirements for plotting smooth hydrographic sheets are given in paragraphs 140 to 162 of part 1. The protective cover should be held in place securely by weights or thumb tacks. A convenient method is to secure the cover along the edge of the sheet farthest from the plotter with a sufficient number of tacks to hold it in position and to use only a few tacks elsewhere, as this will facilitate lifting the cover for inking positions.

A small hole should be cut through the cover at the position of each station used for control, the hydrographic name of the station being lettered legibly on the covering material. The holes should be round, so that there will be no corners to fray and catch the protractor arms.

The protractor should be carefully tested before use and manipulated as described heretofore.

In plotting positions, sufficient pressure should be applied to the center punch of the protractor so that the needle will prick through the cover and indent the sheet with a hole no larger than is required to hold the position ink dot. (See pars. 144 and 145, pt. 1.)

Positions may be encircled and numbered in pencil on the cover to aid in later identification. The cover may be lifted as often as desired while the positions are being inked and numbered on the smooth sheet in accordance with the general requirements. The pencil lines connecting successive positions are usually drawn so that there is a short space, with the position dot in the center, between successive lines.

Sounding lines are generally plotted in the order in which they were run, but lines in critical areas can, of course, be plotted at any time in order to give immediate information as to additional work that may be required.

The records and boat sheets should be examined for notes that may affect the smooth plotting and for information regarding features that are to be plotted on the sheet in accordance with the general requirements. It is the general practice to check mark each position in the record with colored pencil as it is plotted.

Plotting soundings.—In plotting soundings it will be found convenient to use a large sheet of blotting or other paper with a hole in its center large enough to span several positions. By moving

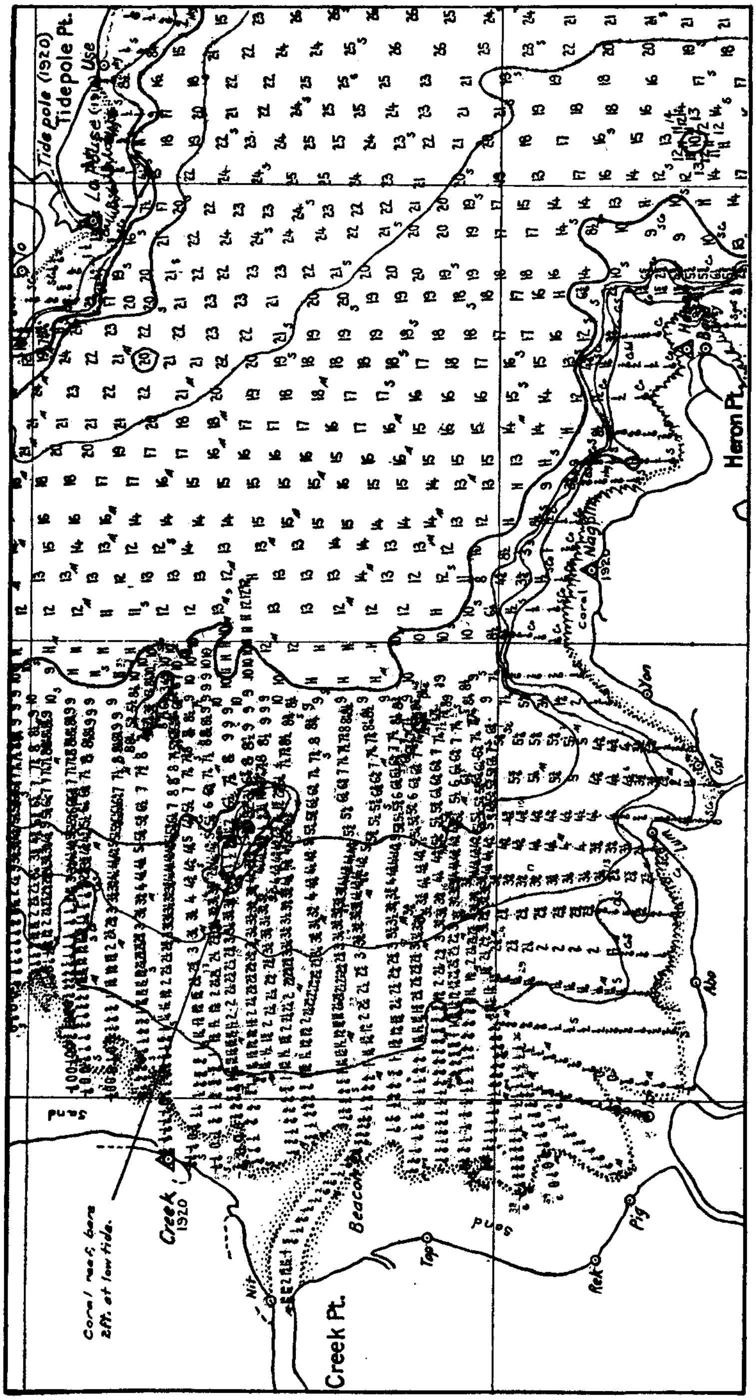


FIG. 43.—Section of completed hydrographic smooth sheet

this cover on the sheet only a small area of the latter, on which soundings are being plotted, will be exposed at one time.

The beginner will usually experience some difficulty in plotting soundings neatly with vertical even-sized numerals, but skill in this work will be acquired with a little practice.

Use of symbols.—The symbols ordinarily used on hydrographic

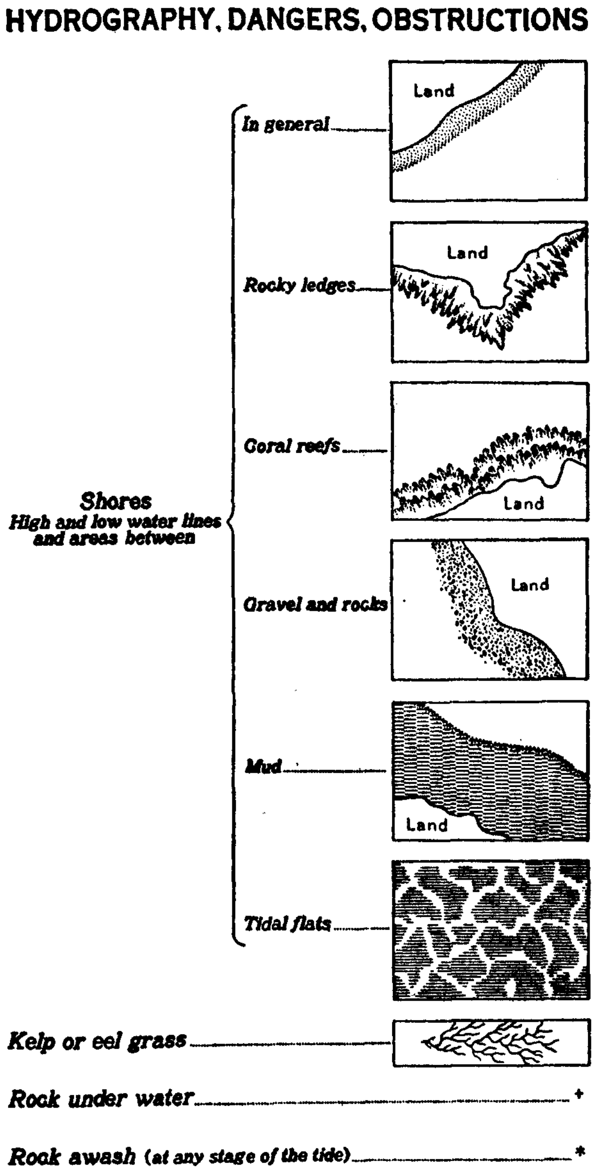


FIG. 44.—Standard hydrographic symbols

sheets are illustrated in Figures 44, 45, and 46. In deciding whether the features mentioned in paragraph 160, part 1, are to be shown by symbols or legends, the field draftsman should be governed by the simple rule that a method should be selected whereby each fea-

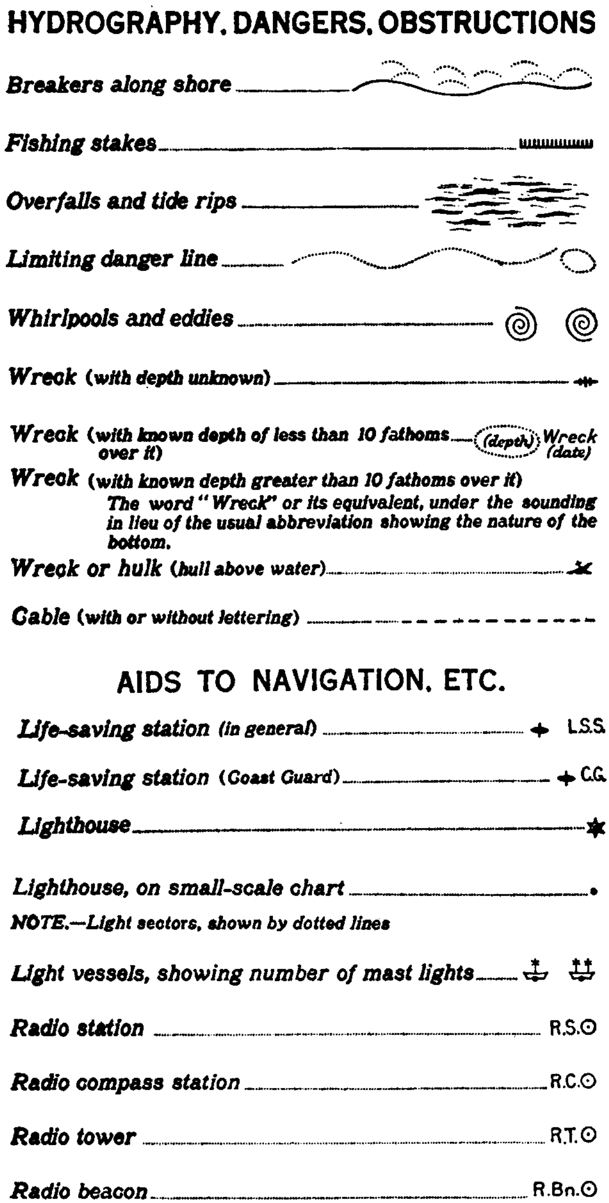


FIG. 45.—Standard hydrographic symbols

ture will be shown correctly and clearly with the least amount of work. A small off-lying reef or a small ledge making out from the shore, for example, might be shown by symbols, while a large reef or a ledge extending a considerable distance along the shore may be indicated more economically by showing the limits by a broken line with appropriate legend.

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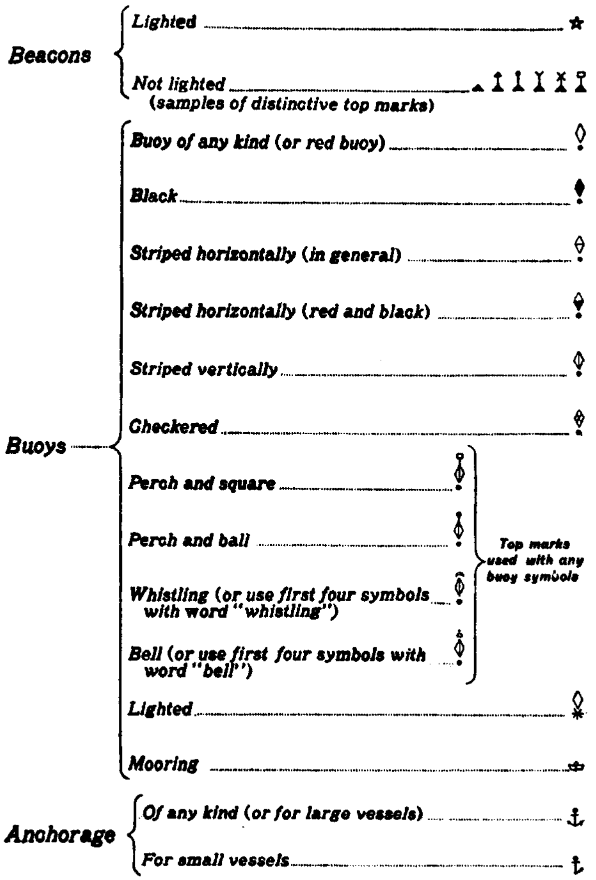

FIG. 46.—Standard hydrographic symbols

Symbols for lighthouses and beacons will rarely be used on hydrographic sheets, as these almost invariably are located for control purposes and are shown by the standard station symbols. Buoys of all kinds may be shown conveniently by the "buoy of any kind" symbol illustrated in Figure 46, with the nature and number of the buoy shown by the abbreviations commonly used on nautical charts.

Errors, omissions, and discrepancies.—When for any reason only a single angle is available (as when a mistake has been made in reading one angle), the locus of the angle vertex may be plotted and the location fixed by the intersection of this locus with the course made good, or by plotting on it the distance from either adjacent position according to the time interval. If two angles have been observed but without a common object, the locus of the vertex of each may be plotted separately, and the position will be at their intersection.

Mistakes in angles or record may sometimes be detected by estimating the position from time and course and testing the angles with the protractor. In field work the officer who plots sets off the angles as called by the observers, without reference to the record. Errors in recording angles or objects, therefore, can often be detected by placing the center of the protractor on the boat-sheet position and testing the angles and objects.

The following discussion of discrepancies that may appear in plotted soundings will suggest methods of investigations and adjustment as well as precautions to be taken in field work in order to avoid them:

Discrepancies at crossings should be recognized as evidence of some fault in apparatus, method, or record which requires a study to discover its source and indicate the most probable correction, and possibly a reexamination in the field. The following typical errors are likely to produce large discrepancies which are most readily detected by such a study: Careless protracting or spacing of soundings; errors in applying lead-line correction; confusion of numbers, such as 7 for 11; miscalled sounding; reversed angles, left for right or right for left; misreading sextant 5° or 10°; confusion of signals; sextant badly out of adjustment; erroneous tide reduction.

The following are typical of errors which will require a more careful analysis of all available data: Spacing of soundings when affected by unrecorded variations of speed and course; unrecorded errors in length of lead line; large clock errors; plane of reference, when the soundings of one line at a crossing depend on a tide gauge blocked by shoals from the free access of the tide; tide gauge too distant, or otherwise not well located in relation to the hydrography; abrupt changes of slope, especially those due to the existence of ridges formed by wave action on bars; difference in state of the sea, when the soundings of one line are more affected by rough water than those of another; soundings affected by the existence of a bight in the lead line when running with or against wind, sea, or current; very soft or ooze bottom, a condition which permits of a considerable latitude of judgment as to what is the bottom.

Most of the errors in the first list will have the effect of displacing the sounding line from its true location, and a study of the data should bring out the fact that the divergence is inconsistent with the record and lead to the discovery of the error.

Unrecorded variations of speed most frequently occur at the start or finish of a line; a comparison of time intervals and distances between positions should indicate the trouble. A faulty plane of reference will produce discrepancies where lines of soundings reduced by it cross other lines of soundings reduced from a different gauge.

Curves of equal depth afford useful evidence of the source of several discrepancies, among which is that of a tide gauge poorly located with reference to the hydrography. Under this condition curves located by means of adjoining parallel sounding lines, run at different stages of the tide, will have a jagged unnatural appearance.

The existence of sand ridges on a bar should be apparent from an inspection of the whole area of the bar. A slight difference in the position of the vessel at a crossing might result in a sounding being taken on the crest of a ridge and one on the side or bottom of the steep inward slope. The possibility of an underwater bight in the lead line should be capable of inference from the notes in the record.

If the study does not result in an actual correction of one of the lines, yet it may plainly show good reasons for the rejection of one of the lines and, in consequence, warrant the adoption of the other. When the data do not afford a reasonable explanation of the difference, and the latter amounts to as much as 5 per cent of the depth in critical parts of the water area, the work should be revised in the field.

And here it is pertinent to once more stress the importance of full notes in the record. It should be obvious from the foregoing how necessary they are in clearing up discrepancies. Sufficient notes may save from rejection an apparently unreliable sheet. As the smooth plotting and especially the plotting of soundings may not be started for some time after the field work, the importance of accurate boat sheets and of care in plotting sounding lines and soundings thereon should also be obvious.

Following are the principal defects found in hydrographic sheets that have been reviewed in the past:

(*a*) Incorrect plotting of positions due to protractor being out of adjustment.

(*b*) Defects in plotting soundings such as incorrect spacing, omission of soundings due to failure to utilize all space available, and repetition of soundings so that more are plotted than were actually taken.

(*c*) Failure to record and plot a sufficient number of bottom characteristics.

(*d*) Confusion in recording time of positions and soundings, especially when stopping for vertical casts.

(*e*) Careless placing and excessive size of position numbers and letters.

(*f*) Lack of explanatory notes in the sounding records.

PROGRESS SKETCHES

Following are the standard specifications for the preparation of progress sketches:

Progress sketches should be made on tracing vellum, using a black ink only, and so drawn as to be suitable for blue printing. They must not be of excessive dimensions, usually not over 18 by 24 inches. Unless otherwise directed, the scale of a progress sketch should correspond to that of the published chart covering the entire area outlined for the season's work, and must be stated in the title.

The progress sketch should give the approximate area of the topography by parallel ruled lines, not closely spaced, the approximate area of the hydrography by widely spaced dots, the approximate area of wire-drag work by a limiting dash-and-dot line filled in with widely spaced parallel broken lines, and the triangulation as indicated below, including the various operations of a single party for one season on one sketch. No attempt need be made to show actual sounding lines by dots or dotted lines; only information as to area covered is required.

Principal triangulation schemes should be in heavy lines, and base lines should be of double width. A line observed at both ends should be full throughout. A line observed at one end should be full at the observed end and broken at the other. Reconnoissance lines should be dotted if shown on the sketch with triangulation. When the sketch contains reconnoissance only, the lines should be full if they are to be observed at both ends. A line should be broken at the end from which it is not to be observed. Old stations recovered, including spires, stacks, etc., should appear thus: ◬⃝. New stations should appear thus: ◬.

All important points determined, including mountain peaks, should be shown as far as practicable. Lines to intersection stations should be drawn lighter than those of the main scheme. A confusion of lines may often be avoided by indicating with short lines radiating from intersection points the stations from which they were observed.

In the Philippines progress sketches of general coast work should, if practicable, be on a scale of 1/100000 (the scale of the Philippine coast charts); for harbor surveys a larger scale may be used if necessary to show the triangulation clearly. The stamped title form is to be used on such sketches, giving the following information: Class of work, island, locality, scale, dates, chief of party, vessel.

Monthly progress sketches will be returned for use in further reports after the information on them has been transferred to the office progress charts.

TERMINOLOGY FOR SUBMARINE RELIEF

The following terms have been adopted by the Coast and Geodetic Survey and should be used hereafter in referring to unnamed features that conform with the definitions and when suggesting names for such features:

Primary forms—*Continental shelf.*—Zone of the continental margin extending from the line of permanent immersion to the continental talus.

Continental talus.—The declivity from the lower edge of the continental shelf into deeper water. This declivity is characterized by a pronounced change in gradient and usually occurs at a depth of about 100 fathoms.

Insular shelf.—Zone of the margin of an island or group of islands from the line of permanent immersion to the insular talus.

Insular talus.—The declivity from the lower edge of the insular shelf into deeper water. This declivity is characterized by a pronounced change in gradient and usually occurs at a depth of about 100 fathoms.

Basin.—A large submarine cavity of more or less circular, elliptical, or oval form.

Trough.—A long and broad depression with gently sloping sides.

Trench.—A long and narrow depression with steep sides.

Deep.—The well-defined deepest area in a submarine depression.

Rise.—A long and broad elevation which rises gently from the ocean bottom.

Ridge.—A long and narrow elevation with steeper sides than those of a rise.

Plateau.—An extensive elevation with a more or less flat top and steep sides.

Secondary forms—*Crest.*—A narrow rise of irregular longitudinal profile which constitutes the top of an elevation of the sea bottom.

Bank.—(*a*) An area, detached from shore and composed of any material, over which the water is relatively shallow, which does not as a rule constitute a danger to surface navigation; or (*b*) an area, connected with the shore and composed of any material except rock or coral, which is a menace to surface navigation and which may uncover.

Shoal.—A shallow place in any body of water, detached from the shore and composed of any material except rock or coral, which is a menace to surface navigation.

Reef.—A rocky or coral elevation, dangerous to surface navigation, which may uncover and which is detached from the shore unless of coral, when it may or may not be connected with the shore.

Ledge.—A rocky formation connected with and fringing the shore.

Pinnacle.—A rocky column dangerous to surface navigation.

Spur.—A prolongation of a mountain ridge onto or across the continental or insular shelf.

Caldron.—A small deep of more or less circular, elliptical, or oval form.

Furrow.—A fissure which penetrates into a continental or insular shelf in a direction more or less perpendicular to the coast line.

Valley.—A prolongation of a land valley into or across the continental or insular shelf.

GEOGRAPHIC NAMES

Distinct names of harbors, towns, points, islands, shoals, rocks, mountains, etc., are necessary to the intelligent use of charts and coast pilots, and the surveyor should ascertain and use accepted or local names in all possible cases. When there are no local names, appropriate names, especially for all important features, should be recommended. When topographic work is carried on, this information, for features extending above water, will usually be furnished by the topographer, but the hydrographer will often have opportunities to cooperate with the former. Further details with regard to this subject will be found in the topographic manual. (See also pars. 160*j* and 166*i* of pt. 1.)

OFFICE REVIEW OF SHEETS AND RECORDS

Sheets and records are received by the library and archives section and checked against the transmitting letter. They are then forwarded to the chart division, where a file number is stamped on each sheet and its records and each sheet is entered on a sheet diagram which is a chart on which the limits of the sheet and its number are shown.

The records then go to the division of tides and currents, where the tide reducers are verified. If errors are found in the reducers, the reduced soundings are corrected accordingly. This division prepares a report, as to whether or not the tidal work has been done properly, which is filed with the sheet.

Each sheet and its records are next subjected to a critical review by the section of field records of the chart division. A sufficient number of positions are replotted to make sure that this work has been done correctly. The plotting of all soundings is verified, after which the soundings and depth curves are inked. In reviewing a sheet special attention is given to the notes in the record with a view of ascertaining whether or not the information recorded is sufficient to warrant any action that may have been taken in correcting or rejecting positions and soundings. Comparison with previous surveys and other charted data is made to ascertain whether previously reported dangers are shown or their nonexistence adequately proved. (See pars. 121 and 122, pt. 1.) When the review is completed a report as to the adequacy of the work, failure to comply with the general requirements or with special instructions, etc., is prepared and attached to the sheet.

Each sheet and the office reports thereon are then inspected by the chiefs of the sections of field work and field records, who note any additional work that may be necessary and recommend approval or nonapproval of the sheet by the chiefs of the divisions of charts and of hydrography and topography. Final action is taken by the director based on the recommendations of the chiefs of divisions.

Chapter 9.—COAST PILOT

Coast pilots are published for the purpose of supplying all information not furnished on charts or in other readily available forms that may be of use to the navigator. New editions of Coast Pilot volumes are issued from time to time as conditions require, and during the periods between editions each pilot is corrected at intervals of about one year by means of a supplement.

A new edition of a Coast Pilot is usually compiled by an officer especially assigned to coast-pilot work. Preparation for this work should be made in the office by examining all information concerning the region covered by the pilot that has been received in the office since the date of the edition that is under revision, special attention being given to information received since the date of the last supplement.

The data examined should include sheets and reports of surveys that have been made by the bureau, annual reports of the Chief of Engineers, United States Army, blue prints and reports of surveys by the United States Engineers, Notices to Mariners, and general correspondence. Note should be made of localities requiring special investigation on account of lack of complete or recent information, increase in commercial importance, or for other reasons. Various divisions in the office should be consulted relative to information in their files and to ascertain their need for special investigations in the region to be examined.

Field work.—After completion of preliminary work a field examination as thorough as practicable should be made of the region covered by the pilot. The methods used for this work will vary considerably, depending on the nature of the country, facilities for transportation, etc. In some regions the most satisfactory method will be to use a vessel large enough to afford living accommodations for the party for all travel and field work. In other sections it may be advisable to travel by other means to certain points along the coast where a launch or other transportation can be hired for short periods for the examination of near-by territory. In the latter case passenger or other vessels should be used for local travel, whenever possible, in order to collect data from local masters and pilots making the runs.

Equipment.—In addition to the Coast Pilot and notes collected in the office, the party should carry a complete set of charts and other nautical publications covering the region under examination. In some cases bromides of original sheets may be of value. Instrumental equipment should include a sextant, lead line, three-arm protractor, boat compass, parallel rulers, binoculars, dividers, and steel tape. In some regions a small theodolite and a plane-table outfit may be useful.

Other sources of information.—While in the field every opportunity should be taken to consult with governmental and private organizations and local authorities. These may include superintendents of lighthouse districts, masters of lightships and lighthouse tenders, United States engineers, United States local inspectors, chart agents, port commissions, State authorities or others engaged in the development or operation of waterways, municipal engineers in charge of water fronts, engineers departments of railroads controlling water terminals, yacht clubs, mariners, and other individuals interested in maritime affairs.

Such consultations should be carried on, in so far as practicable, with three main objects in view:

(*a*) To obtain all available information for the compilation of the Coast Pilot.

(*b*) To ascertain the needs of the organizations or individuals that can be supplied by this service or through reference to other bureaus and to obtain suggestions for improving the nautical publications of this bureau.

(*c*) To establish relations whereby the Coast and Geodetic Survey will be advised as promptly as possible of all changes affecting navigation that should receive consideration in the office or attention in the field.

Whenever possible, plans showing changes or improvements, such as new terminals, dredging operations, bridges, etc., should be obtained for use in compiling the Coast Pilot and for chart correction. Control points should be identified or established, so that the plan can be oriented and located with respect to the chart. Such plans should be inspected in the field and clearly marked to distinguish between details that actually exist at the time of the examination and those that are projected only.

Coast Pilot information.—The nature and amount of detail to be gathered and compiled in a Coast Pilot require considerable judgment, as overminute details or unessential matter tend to obscure more important information and to impair the usefulness of the volume. It is obvious that certain classes of information that are of value for a little-known region may not be necessary in a pilot covering a well-charted coast. It should also be borne in mind that the pilots published by the Coast and Geodetic Survey are used not only by professional navigators but also by navigators of a large number of pleasure craft and other small boats and that careful consideration must be given to the requirements of small craft as well as larger vessels. With these considerations in mind, the main objects of a Coast Pilot party should be to verify or correct all statements, descriptions, and directions in the pilot under revision; to note information no longer of value, and to obtain such new information as may be necessary.

General information, published in the first section of each Coast Pilot, should include such subjects as are pertinent, in the sequence adopted for recent Coast Pilot editions. Information on a few subjects, such as facilities for repairs and supplies, must be obtained in the field, but the greater part of the information in this section and in the appendix is obtained from other bureaus or from private organizations after completion of field work.

Descriptions and sailing directions.—In this section of each Coast Pilot detail descriptions and directions for the coast and harbors of the region covered by the volume are given. The following points, usually covered in Coast Pilot publications, will suggest, in so far as they apply to the region being examined, the subjects on which information should be obtained both for the preparation of original pilots and in revision work:

General description of the coast, following the geographic sequence of the published Coast Pilots, and including the aspect or appearance of the coast on making the land; describing prominent objects, as, on a bold coast, the headlands, peaks, etc., with their form, color, and height; or, on a flat coast, the water tanks, spires, beacons, etc. Especially describe the first landfall and objects useful as guides to navigation.

Outlying dangers and islands, the limits of tide rips and breakers, and their relation to wind and tide.

Landmarks.—Description of all prominent landmarks likely to be useful to navigation or to future surveying operations. If mountains, state whether summits are often clouded. Give measured or estimated heights of mountains, hills, cliffs, islets, or rocks referred to. Describe ranges in use by pilots and means of identifying them. Suggestions should be made as to other ranges that would be useful.

Directions for passing outlying dangers.

Refuge.—In case of stress of weather the best anchorage or the nearest harbor of refuge to run for; or in extreme cases of damage the best place to beach a ship. Give character of beach.

Pilots.—Information as to their station or cruising ground, any special regulations or signals, their charges, the possibility of obtaining tugs, etc.; anchorage while awaiting pilot or tug.

Approaches.—General remarks, usual course from alongshore or from sea, dependence on lead when approaching in thick weather.

Bars.—Describe principal marks and aids. Give directions for approach, with description of outlying and other dangers and how to avoid them. Least depth and width at best place for crossing bar; most favorable time to enter. Does bar break in ordinary or only in heavy weather? How far out do breakers extend? Give velocity and direction of wind and stage of tide producing these conditions. Can entrance be made while bar is breaking; and, if so, for what draft? Give character of bottom, and usual allowance made for squat, pitch, and tide under different conditions on the bar. To what change in depth and position is the bar channel or approaches subject; if any, give magnitude and direction of change.

Channels.—Give minimum available depth throughout and, where necessary, the minimum width. Give character of bottom and describe all aids and natural objects. Are channel banks defined by grass or other growth, color of shoals, spoil deposits, or in any other readily recognizable manner?

State maximum draft possible and greatest draft entering or leaving. Where maximum draft differs from minimum depth in channel, state reasons for same, as swell, squat, tide, and rocky or soft bottom. Note depth and character of approaches to wharves, piers, dry docks, marine railways, and coal stations. Manner of approaching them and why. Are channels permanent, subject to considerable or frequent change, under improvement, or maintained?

Description of the shore, with characteristics (as height, color, wooded, cultivated, bold, sandy) of each important headland, point, island, and rock.

Inshore dangers.—Extent and nature, least depth over them; whether visible; if breaking, at what stage of tide; how much, if any, is bare at low water; marks or ranges for clearing them by day or night. In regions where dangerous shoal areas or pinnacles are marked by kelp or other growth, state the ordinary significance of such growths, at what stage of tide they show at surface, and when, if ever, they are towed under.

In regions where bowlders, ledges, coral heads, or similar dangers probably exist it is very desirable to examine the suspected areas at extreme low water, at which time important features may show above or near the surface.

In the examination of entrances and approaches for off-lying dangers, advantage should be taken of heavy weather to locate any shoals marked by breakers. The existence of rock or other shoals in localities of considerable current is often indicated by rips and swirls; such disturbances should be noted at strength of current and investigated. Fishermen and other persons with local knowledge should be interviewed relative to the existence of uncharted dangers.

Ports.—Commercial importance, character, and magnitude of trade; chief exports and imports; facilities for coaling and watering vessels; supplies and provisions obtainable; facilities for repairs to hulls and machinery; marine railways or dry docks (length, draft forward and aft, and tonnage hauled); wharves, piers, and docks, and depth of water and character of bottom alongside and in approaches, whether public or private, and rules for use; harbor regulations; means of communication; and hotel accommodations.

Locate and describe customary anchorage, customhouse and landing, time ball, station for reporting vessels, storm warning and small-craft warning display stations, quarantine stations, hospitals for mariners; and obtain copies of all published pilot, harbor, and anchorage rules and regulations, where possible. Note harbor improvements in progress or projected. Give location of submarine cables and water mains. Define limits and give regulations for forbidden anchorage. Locate and describe aeroplane landing fields.

Sailing directions for coasting, approaching, entering, and leaving channels and harbors; special care should be taken to verify sailing directions for newly surveyed regions or for localities not covered by adequate charts, and such directions should be actually tried under different conditions before they are adopted or recommended for use. Previously published directions should be verified in connection with recent field sheets or the latest editions of the charts, and all changes should be investigated in the field.

Verify ranges and determine and describe any natural ranges or leading marks, defining sailing lines, points of change of course, dangers, and other features.

Check bearings or obtain azimuth of dredged-channel axes. Wherever possible locate the more important aids by means of ranges, bearings, or angles for use as checks on their positions. Add any useful details not given in light list, reliability of lights and buoys, visibility of lights, and audibility of fog signals. Note localities of unusual sound reflection. Locate and describe marks and aids, whether natural objects or others, used in connection with works of improvement which may serve as navigational guides. Locate and describe general limits of fish weirs, oyster stakes, and similar constructions; also describe day marks and lights maintained on them. Give rules and regulations relating to them.

Courses and bearings should be given in degrees, true, followed by the magnetic course in points. In writing magnetic courses in points the system of boxing the compass from north and south toward east and west shall be followed. All directions should be as clear and definite as possible. "Pass east of this beacon" is a better direction than "leave this beacon on the port hand," for example, as it is definite and applies to navigation in either direction.

Aids.—Lights, lighthouses, buoys, beacons, and other aids should be verified on the ground for location, description, depth alongside, and in relation to the features they are intended to mark. Note buoys which tow under or do not watch properly. Where the distinctive characteristic of an aid is its color, state whether it is generally clearly distinguishable.

Currents, tidal or nontidal.—General conclusions from observations or other information. Give velocity, direction, duration, and relation of time of slack to that of high water or low water. Note set with reference to axis of channel and openings through bridges and at other contractions of the fairway, across bars, and in entrances; approaching docks and piers; occurrence of rips, swirls, and eddies. Effect of wind and freshets on currents, and if flood current is ever entirely overcome. Describe fully all abnormalities in currents or marked variations from usual phenomena. The notes should cover the entire field of operations, both inshore and offshore, and include all horizontal movements of surface waters, whether tidal or nontidal, or both. Where the currents are due to winds or other meteorologic cause or are greatly modified in velocity, direction, and duration thereby, the variations produced should be determined and their relation to the conditions that produce them should be developed, if possible, such as velocity and direction of wind.

Tides.—Collect all available data bearing upon tides, excessive or abnormal rise and fall, duration of stand, and time of high and low water. Where gauges are in operation, make special effort to obtain records of such conditions, whether due to wind, flood, or other causes.

In shoal areas, especially inclosed waters, give variation of surface level due to storms and, if possible, develop relation of velocity and direction of wind to locality and magnitude of resulting changes in surface elevation.

Practically all the above information relative to tides and currents can be furnished by the division of tides and currents. All additional information secured in the field should be referred to that division for discussion before publication.

Bridges, contractions, and obstructions.—Note kind of bridge, horizontal and vertical clearance at mean high water[1] of openings through fixed spans, draws when closed, and at other contractions; also depth in openings. Length, beam, and draft accommodated by locks and similar structures. Vertical clearance of aerial cables and trolley wires. Which side of draw or opening of bridge should be

[1] When the plane of reference used on the chart is mean lower low water, the clearance at mean higher high water should be noted.

used and, if only one, state for what reason. Obtain copies of rules and regulations governing the operation of bridges and locks and signals in use.

Ice.—Season during which it is encountered. Its form of occurrence; movements under influence of winds and currents; extent to which it affects navigation. Season of navigation as affected by ice, flood, fog, low water, storms, and in addition, in the case of canals and other artificial waterways, give period of navigation fixed by law or regulation.

Rivers.—Give draft and class of vessels which can enter; point to which tide reaches; depth on bars and permanency of channel; strength of current; effect of freshets; distance to head of navigation for steamers and other craft.

Canals.—Describe location and approaches, give total length of each lock, capacity of locks, controlling vertical clearance under overhead structures, passing points, tie-up points, local contractions, variations of surface elevation, period open to navigation, toll charges, signals, and regulations governing operation.

Anchorages, with descriptions relative to their capacity, holding ground, amount of protection, and circumstances of weather under which tested. Character of bottom, marks, and rules and regulations for use, if any.

Landing places, especially on a coast exposed to swell.

Watering places for vessels—Rivers, streams, or springs.—At ports state whether water is piped to wharves or supplied by water boats, and charges; convenience for watering ships. Give distance upstream that salt water extends at different seasons or under other varying conditions; state also when overboard water is sufficiently fresh for drinking or boiler purposes.

Weather.—Under this head state briefly only new and important facts, as prevailing winds and their seasons, directions from which gales come and how they affect anchorage, land and sea breezes, rainy seasons, fogs, and freshets, and seasons or conditions when prevalent.

Wrecks, where usually occurring; tendency of wrecks to break up or remain in position. Information bearing upon the occurrence of wrecks is exceedingly desirable. It is of first importance that inquiries be made and investigations instituted for the purpose of developing the various causes contributing in any way to marine disasters, such as little-known currents, additional aids required, misleading or deceptive bottom relief in approaches, shifting shoals and channels, imperfect or inadequate charts.

Change of coast line or depths.—Mention any reliable evidence as to recession or growth of shore line or change of depths. Note any important facts regarding changes observed. Give evidence, if any, of subsidence or emergence of shores. Locate and outline limits of dumping ground for dredged or other materials. Report all obstructions and temporarily obstructive operations. Note especially localities where changes of any sort affecting navigation are likely to occur and report those which should receive frequent attention in order to keep publications up to date.

Important information.—Information of importance affecting navigation, such as rocks, reefs, shoals, sunken wrecks, aids omitted or incorrectly charted, errors or omissions on charts or in Coast Pilots, changes in depth, channels, coast line, and currents should be forwarded to the director without delay for insertion in the Notice to Mariners or other immediate publication. Where aids are involved a report should be forwarded, without recommendation, to the superintendent of lighthouses for the district involved and a copy sent to the director. Suggestions or recommendations in regard to aids shall be sent only to the director.

Inside Route Pilots.—These pilots, covering certain sections of our coasts, are published for the guidance of navigators of small craft who desire to avoid open waters by making use of such inside passages as are available. In general, they contain descriptions and sailing directions for the through route, with brief mention of connecting waterways, and are condensed by omitting such information usually published in Coast Pilots as is not essential for this class of navigation.

These pilots are compiled or revised in the same manner as the regular Coast Pilots. The following points should receive special consideration in this class of work:

(*a*) Note extent of routes and period of navigation; draft that can be accommodated at low water and at high water; width of opening and vertical clearance under both fixed spans and drawbridges; rules and regulations for operating of drawbridges; draft in canals; length and width of locks; obstructions; tolls; period of navigation; attended or unattended bridges; rules, regulations, and signals.

(*b*) Navigability of tributary rivers, creeks, and other waterways, and distance from mouth to falls, rapids, dams, or other head of navigation, including depths and distances to various points.

(*c*) At points where boats must wait for the tide the time of local high water referred to some known point should be given. Character of bottom should be determined generally, especially at local shoalings such as crossovers, bars, oyster reefs, etc. Outline and describe snag-infested and stump-infested areas.

(*d*) The extent to which the tide affects the inland waters and variation of surface due to winds and floods should be noted. Localities of strong currents should be mentioned, with at least approximate velocities and relation of time of occurrence to that of local or other high or low waters. Note points where navigation depends upon freshet conditions or high water due to rain.

(*e*) Locate and describe, in relation to the channels or other features they are intended to mark, all aids to navigation, including private aids such as pointers, poles, bush stakes, beacons, buoys, etc. Note buoys which tow under or do not watch properly. Where the distinctive characteristic of an aid is its color, state whether it is generally clearly distinguishable.

(*f*) Give points where services of pilots are necessary, where they can be obtained and rates, extent of traffic, development or settlement of region, and mention places where supplies, provisions, gasoline, oil, water, ice, and hotel accommodations can be obtained; also facilities for watering vessels and coaling, where small craft can be repaired, hulls, machinery, or both; give location of marine railways and the length, beam, draft forward and aft, and tonnage they can haul.

(*g*) In remote districts telegraph, telephone, railroad, steamboat, or other lines of communication and postal facilities should be described.

(*h*) Occurrence of obstructive growths such as hyacinth, grass, kelp, etc., and season in which they are found, occurrence of ice, and to what extent and for what period navigation is affected.

(*i*) Note especially localities where changes of any sort affecting navigation are likely to occur and which should receive frequent attention in order to keep publications up to date.

(*j*) *Entrances and inlets.*—Describe principal marks and aids; directions for approaching entrance, with description of outlying or other dangers and how avoided; least depth and width in entrance, across bar in channel, and locate same. To what change in depth and position is entrance subject; if any, give rate and direction.

(*k*) Does bar break in ordinary or only heavy weather? Give direction and velocity of wind producing this effect. How far out do breakers extend? Can entrance be made while bar is breaking and, if so, for what draft?

Supplements to coast and inside route pilots are compiled in the office from information on hand and without field examination except in special cases.

Coast Pilot notes should be complete, clear, and accurate. It often is desirable to publish these notes before the field sheets are available for examination, and a supplement covering new work is frequently published several months before a new chart can be issued.

For this reason notes should be written, in so far as practicable, for use with the current editions of the charts covering the region described. For example, the description of a feature referred to by a name recommended by the field party but not yet named on the chart should include its distance and bearing from a near-by feature that is named on the current chart. If this is impracticable, its latitude and longitude should be given. Special care should be taken to verify sailing directions submitted for newly surveyed regions or for localities not covered by adequate charts.

Preparation of notes.—Coast Pilot notes should be forwarded as a separate report in duplicate, the original on medium and the carbon on thin paper. While such notes are used in the compilation of new editions, they are usually published first in supplements. Therefore, in order that they may be used in the preparation of manuscript without the delay and expense required for rearrangement and typing, the method of preparing manuscript outlined below should be followed whenever practicable in the preparation of Coast Pilot notes.

Preparation of manuscript for supplements.—Corrections and additions in supplements are usually made by—

(*a*) Correcting a paragraph by striking out or inserting a few words (when the greater part of the paragraph is correct).

(*b*) Striking out a paragraph and inserting a substitute paragraph (when the greater part of the paragraph requires correction).

(*c*) Inserting new sentences or paragraphs (when new information is available).

An inspection of any current supplement will furnish illustrations of the above method and its variations. The wording of new information should follow the general style of the Coast Pilot volume affected. Depths and heights should be followed by the metric equivalent in parentheses when this system is used in the Coast Pilot volume. Sailing directions should be prepared as previously described.

Typewritten manuscript is prepared in the following form:

Page 192.

Danvers River.—Paragraph 2, line 3, strike out " and unmarked." Add the following: " It is marked by spar buoys."

Long Cove.—Line 4, for " is a wharf " read " are the ruins of a wharf."

Page 206.

Strike out paragraph relating to White Cove and substitute the following:

White Cove is a deep bight in the shore line ——, etc.

Page 219.

After description of Long Beach add the following new paragraphs:

Long Beach Park is a summer resort near ——, etc.

Little Island, the small crescent-shaped island three-fourths mile southeast from Long Point, is low ——, etc.

The word "Page" should start flush with the margin with the beginning of each paragraph indented two spaces. When the name of the feature at the beginning of a paragraph is in the nature of a subhead and is not a part of the first sentence, it is followed by a period and two dashes. All notes should be single spaced with two spaces after conclusion of information relating to one page. Each page of the notes should start with a paragraph and preferably with a new volume page number. Page numbers need not be consecutive, as the notes are usually clipped and combined with other information in proper sequence. Names to be printed in italics should not be underscored with the typewriter but may be marked lightly with black pencil.

Illustrations.—Officers engaged in Coast Pilot revision and other field work should, whenever possible, secure photographs or sketches of prominent landfalls and objects of value to navigators for use as illustrations in the Coast Pilot volumes. Photographs preferably should be taken at about one-half the distance from the subject that it usually will be viewed by the navigator and should be on glossy paper. All illustrations should bear notation relative to the bearing and distance between the subject and the point from which the view was obtained; also identification of prominent features, especially those shown on the chart.

Illustrations published in the Coast Pilots should be inspected in the field to determine whether or not they still portray the features correctly.

APPENDIX

MISCELLANEOUS TABLES

TABLE 1.—*Bottom abbreviations*

Bottom material		Nature of materials		Colors	
Clay	Cl.	Broken	brk.	Black	bk.
Coral	Co.	Coarse	crs.	Blue	bu.
Gravel	G.	Fine	fne.	Brown	bn.
Mud	M.	Hard	hrd.	Dark	dk.
Ooze	Oz.	Large	lrg.	Gray	gy.
Pebbles	P.	Rocky	rky.	Green	gn.
Sand	S.	Soft	sft.	Light	lt.
Shells	Sh.	Small	sml.	Red	rd.
Specks	Sp.	Sticky	stk.	White	wh.
Stones	St.	Stiff	stf.	Yellow	yl.

TABLE 2.—*Equivalents for plotting soundings reduced to tenths of a foot*

Foot	Equivalent	
	Plotting in half feet	Plotting in quarter feet
	Foot	*Foot*
0.1	0	0
0.2	0	¼
0.3	0	¼
0.4	½	½
0.5	½	½
0.6	½	½
0.7	½	¾
0.8	1	¾
0.9	1	1

TABLE 3.—*Apparent specific gravity of sea water*

Salinity	Temperature (degrees)						
	32 F.	41 F.	50 F.	59 F.	68 F.	77 F.	86 F.
	0 C.	5 C.	10 C.	15 C.	20 C.	25 C.	30 C.
31	1.02453	1.02428	1.02374	1.02292	1.02188	1.02062	1.01914
32	1.02533	1.02506	1.02451	1.02368	1.02263	1.02136	1.01988
33	1.02614	1.02586	1.02529	1.02445	1.02340	1.02212	1.02063
34	1.02694	1.02664	1.02607	1.02522	1.02415	1.02287	1.02138
35	1.02774	1.02744	1.02685	1.02599	1.02492	1.02363	1.02213
36	1.02855	1.02824	1.02763	1.02676	1.02569	1.02439	1.02288
37	1.02935	1.02902	1.02841	1.02753	1.02644	1.02514	1.02363

NOTE.—Salinities are in parts per thousand (by weight) of total dissolved solids. Apparent specific gravities are as indicated by glass hydrometers correct at 15° C. (calibrated 15/4). Expansion or contraction of the hydrometer glass is considered in computing the above table. When the table is used to obtain salinity by hydrometer reading and temperature, the instrumental corrections must, of course, be applied to the instrument readings before entering the table.

Example.—For a given sample of sea water the hydrometer reading is 1.0243 and the temperature at the same time, 21.6° C. Hydrometer correction for the part of the scale in use is +0.00016; thermometer correction, −0.3° C. Required the salinity.

Applying the instrumental corrections gives an apparent specific gravity of 1.0245 and a temperature of 21.3° C.

It is convenient to reduce the apparent specific gravity to the nearest temperature listed in the table (in this case 20° C.) before interpolating. The apparent specific gravity is seen to decrease 2.6 in the fourth decimal place per degree centigrade in this part of the table, so that reduced to 20° C., it becomes 1.0248. Interpolating in the 20° C. column between 1.02415 and 1.02492, the salinity is found to be 34.8 0/00.

Table 4a.—*Correction factors for fathometer soundings in depths of 450 fathoms or less*

[Assumed velocity, 800 fathoms per second]

Salinity, parts per 1,000	Temperature (degrees)							
	32 F.	35.6 F.	39.2 F.	42.8 F.	46.4 F.	50.0 F.	53.6 F.	57.2 F.
	0 C.	2 C.	4 C.	6 C.	8 C.	10 C.	12 C.	14 C.
31	−0.010	−0.004	+0.001	+0.005	+0.011	+0.016	+0.021	+0.026
32	−0.009	−0.004	+0.002	+0.006	+0.011	+0.017	+0.023	+0.027
33	−0.008	−0.003	+0.003	+0.008	+0.013	+0.018	+0.024	+0.028
34	−0.008	−0.002	+0.004	+0.009	+0.014	+0.019	+0.025	+0.029
35	−0.006	−0.001	+0.005	+0.010	+0.015	+0.021	+0.025	+0.030
36	−0.006	0.000	+0.006	+0.011	+0.016	+0.022	+0.027	+0.031
37	−0.005	+0.001	+0.006	+0.011	+0.016	+0.022	+0.028	+0.033

Salinity, parts per 1,000	Temperature (degrees)							
	60.8 F.	64.4 F.	68.0 F.	71.6 F.	75.2 F.	78.8 F.	82.4 F.	86.0 F.
	16 C.	18 C.	20 C.	22 C.	24 C.	26 C.	28 C.	30 C.
31	+0.030	+0.035	+0.039	+0.042	+0.045	+0.049	+0.052	+0.055
32	+0.031	+0.036	+0.039	+0.043	+0.046	+0.050	+0.053	+0.056
33	+0.033	+0.037	+0.041	+0.044	+0.048	+0.051	+0.054	+0.057
34	+0.034	+0.038	+0.042	+0.045	+0.049	+0.052	+0.055	+0.058
35	+0.034	+0.039	+0.043	+0.047	+0.050	+0.053	+0.057	+0.060
36	+0.035	+0.040	+0.044	+0.048	+0.051	+0.054	+0.058	+0.061
37	+0.037	+0.041	+0.045	+0.049	+0.053	+0.056	+0.060	+0.063

Table 4b.—*Correction factors for fathometer soundings in depths of 450 fathoms or less*

[Assumed velocity, 820 fathoms per second]

Salinity, parts per 1,000	Temperature (degrees)							
	32 F.	35.6 F.	39.2 F.	42.8 F.	46.4 F.	50.0 F.	53.6 F.	57.2 F.
	0 C.	2 C.	4 C.	6 C.	8 C.	10 C.	12 C.	14 C.
31	−0.034	−0.028	−0.022	−0.017	−0.012	−0.007	−0.002	+0.002
32	−0.033	−0.027	−0.021	−0.016	−0.011	−0.006	−0.002	+0.002
33	−0.033	−0.027	−0.021	−0.016	−0.011	−0.006	−0.001	+0.003
34	−0.032	−0.026	−0.020	−0.015	−0.010	−0.004	0.000	+0.004
35	−0.031	−0.025	−0.019	−0.014	−0.009	−0.003	+0.001	+0.005
36	−0.030	−0.024	−0.018	−0.013	−0.008	−0.003	+0.002	+0.007
37	−0.029	−0.023	−0.017	−0.012	−0.007	−0.001	+0.004	+0.008

Salinity, parts per 1,000	Temperature (degrees)							
	60.8 F.	64.4 F.	68.0 F.	71.6 F.	75.2 F.	78.8 F.	82.4 F.	86.0 F.
	16 C.	18 C.	20 C.	22 C.	24 C.	26 C.	28 C.	30 C.
31	+0.006	+0.010	+0.014	+0.018	+0.021	+0.024	+0.027	+0.029
32	+0.006	+0.010	+0.014	+0.018	+0.021	+0.024	+0.027	+0.030
33	+0.007	+0.011	+0.015	+0.019	+0.023	+0.026	+0.029	+0.031
34	+0.009	+0.013	+0.016	+0.020	+0.024	+0.027	+0.030	+0.033
35	+0.010	+0.014	+0.018	+0.022	+0.026	+0.029	+0.032	+0.034
36	+0.011	+0.015	+0.019	+0.023	+0.027	+0.030	+0.033	+0.035
37	+0.012	+0.016	+0.020	+0.024	+0.028	+0.031	+0.034	+0.037

TABLE 5.—*Velocity of sound in sea water in fathoms per second*

Depth (fathoms)	Salinity 0/00	Temperature (degrees centigrade)															
		0	2	4	6	8	10	12	14	16	18	20	22	24	26	28	30
Surface and 100.	31	790	795	798	802	806	811	814	816	819	822	825	827	830	831	832	834
	32	791	795	799	803	807	811	814	817	820	823	825	828	830	831	832	834
	33	792	796	800	804	807	812	815	817	821	824	826	829	831	832	833	835
	34	792	796	800	804	808	813	816	818	821	825	827	830	832	833	834	836
	35	793	797	801	805	809	814	817	819	822	826	828	831	833	834	835	837
	36	793	798	802	806	809	814	818	820	823	826	829	832	834	835	837	839
	37	794	799	803	807	810	815	819	821	825	827	830	833	835	836	838	840
300	31	793	798	802	805	809	814	817	820	823	826	828	830	833	834	835	837
	32	794	799	803	806	810	815	818	821	824	827	829	831	833	834	836	838
	33	795	799	803	807	811	816	819	822	825	827	829	832	834	835	837	839
	34	796	801	804	808	812	817	820	823	826	828	830	833	835	836	838	840
	35	796	801	805	809	813	818	820	823	826	829	831	834	836	837	839	841
	36	797	802	806	809	814	819	822	824	827	830	832	835	838	839	840	842
	37	798	802	806	810	814	820	823	825	828	831	833	836	839	840	841	843
500	31	796	801	804	809	813	817	820	822	827	829	832	834	-----	-----	-----	-----
	32	797	802	805	809	814	818	821	823	827	830	832	835	-----	-----	-----	-----
	33	798	803	806	810	814	819	822	824	828	831	833	836	-----	-----	-----	-----
	34	798	803	807	810	815	819	822	825	829	832	834	837	-----	-----	-----	-----
	35	799	804	808	812	816	820	823	826	830	832	835	838	-----	-----	-----	-----
	36	800	804	809	813	817	821	824	827	831	833	836	838	-----	-----	-----	-----
	37	801	805	810	813	818	822	825	828	832	834	837	839	-----	-----	-----	-----
700	31	801	805	809	813	817	821	825	826	830	833	835	-----	-----	-----	-----	-----
	32	801	806	809	814	818	822	825	826	831	833	836	-----	-----	-----	-----	-----
	33	802	807	810	814	819	823	826	827	832	835	837	-----	-----	-----	-----	-----
	34	803	807	811	815	819	824	827	828	833	835	838	-----	-----	-----	-----	-----
	35	804	808	812	816	820	825	828	829	834	837	839	-----	-----	-----	-----	-----
	36	804	809	813	817	821	826	829	830	835	837	840	-----	-----	-----	-----	-----
	37	805	810	814	818	822	827	830	831	836	839	841	-----	-----	-----	-----	-----

Depth (fathoms)	Temperature							Salinity 0/00	Temperature				Depth (fathoms)
	0	2	4	6	8	10	12		0	1	2	3	
900	803	808	812	816	820	824	827	31	821	823	825	826	1,900
	804	809	813	817	821	825	828	32	822	825	827	827	
	805	809	814	818	822	825	829	33	823	825	827	828	
	805	810	815	819	823	826	830	34	824	826	828	829	
	806	811	815	820	824	827	831	35	825	827	829	830	
	807	812	816	820	825	828	832	36	825	827	829	831	
	809	813	818	821	826	829	833	37	826	828	830	831	
1,100	806	811	815	819	823	-----	-----	31	823	825	827	828	2,100
	807	812	816	820	824	-----	-----	32	824	826	828	829	
	808	813	817	821	825	-----	-----	33	825	827	829	830	
	809	814	818	822	826	-----	-----	34	825	827	830	831	
	809	814	819	823	827	-----	-----	35	826	828	831	832	
	810	815	820	824	828	-----	-----	36	827	829	831	833	
	811	816	820	825	828	-----	-----	37	827	829	832	833	
1,300	809	814	819	822	-----	-----	-----	31	828	830	832	833	2,300
	810	814	820	824	-----	-----	-----	32	829	831	833	834	
	811	815	820	825	-----	-----	-----	33	829	832	834	835	
	812	816	821	826	-----	-----	-----	34	830	832	835	836	
	813	817	822	827	-----	-----	-----	35	831	833	836	837	
	814	818	823	828	-----	-----	-----	36	832	834	837	838	
	814	818	823	828	-----	-----	-----	37	832	834	837	838	
1,500	813	817	822	-----	-----	-----	-----	31	830	833	835	836	2,500
	814	818	823	-----	-----	-----	-----	32	831	833	836	837	
	815	819	824	-----	-----	-----	-----	33	831	834	836	838	
	816	820	825	-----	-----	-----	-----	34	832	834	837	838	
	816	821	826	-----	-----	-----	-----	35	833	835	838	839	
	817	822	827	-----	-----	-----	-----	36	834	836	839	839	
	817	823	828	-----	-----	-----	-----	37	835	837	839	840	
1,700	816	820	826	-----	-----	-----	-----	31	833	836	838	839	2,700
	817	821	827	-----	-----	-----	-----	32	834	837	839	840	
	818	822	828	-----	-----	-----	-----	33	835	838	840	841	
	819	823	828	-----	-----	-----	-----	34	836	838	840	842	
	820	824	829	-----	-----	-----	-----	35	836	838	841	843	
	821	825	830	-----	-----	-----	-----	36	837	839	842	843	
	822	826	831	-----	-----	-----	-----	37	838	841	843	844	

TABLE 5.—*Velocity of sound in sea water in fathoms per second*—Continued

Salinity 0/00	Depth (fathoms)	Temperature 0	1	2	Depth (fathoms)	Temperature 0	1	2	Depth (fathoms)	Temperature 0	1	2
33		838	841	843		852	854	856		864	866	868
34		839	842	844		854	856	858		865	867	869
35	2,900	839	842	844	3,700	855	856	858	4,500	866	867	870
36		840	843	845		855	857	859		866	867	870
37		842	844	846		856	858	860		867	868	871
33		843	845	848		855	856	859		869	871	873
34		843	845	848		856	857	860		869	872	874
35	3,100	844	846	849	3,900	857	858	861	4,700	870	872	875
36		844	847	850		857	859	862		871	873	875
37		845	848	851		858	860	862		872	873	876
33		846	848	851		860	861	863				
34		847	850	852		860	861	864				
35	3,300	848	851	853	4,100	861	862	865				
36		849	851	854		861	863	866				
37		849	851	854		862	863	866				
33		849	851	853		862	863	866				
34		850	851	854		862	863	866				
35	3,500	850	852	854	4,300	863	864	867				
36		851	852	855		864	865	868				
37		852	854	856		864	866	868				

TABLE 6.—*Adiabatic corrections to velocity in fathoms per second*

Depth (fathoms)	Temperature (degrees centigrade) 0	5	10	15	20	25	30
Surface	0.2	0.8	1.6	3.2	4.4	6.7	8.8
300	.2	.8	2.0	3.2	4.6	6.7	8.8
1,100	.7	1.6	2.7				
2,100	1.6	2.8					
3,300	2.8						
4,300	4.0						

NOTE.—Corrections are to be added to the velocities from Table 5.

TABLE 7.—*Distance of visibility of objects at sea*

Height, feet	Nautical miles	Height, feet	Nautical miles	Height, feet	Nautical miles	Height, feet	Nautical miles
1	1. 1	43	7. 5	300	19. 9	940	35. 2
2	1. 7	44	7. 6	310	20. 1	960	35. 5
3	2. 0	45	7. 7	320	20. 5	980	35. 9
4	2. 3	46	7. 8	330	20. 8	1, 000	36. 2
5	2. 5	47	7. 9	340	21. 1	1, 100	38. 0
6	2. 8	48	7. 9	350	21. 5	1, 200	39. 6
7	2. 9	49	8. 0	360	21. 7	1, 300	41. 3
8	3. 1	50	8. 1	370	22. 1	1, 400	42. 9
9	3. 5	55	8. 5	380	22. 3	1, 500	44. 4
10	3. 6	60	8. 9	390	22. 7	1, 600	45. 8
11	3. 8	65	9. 2	400	22. 9	1, 700	47. 2
12	4. 0	70	9. 6	410	23. 2	1, 800	48. 6
13	4. 2	75	9. 9	420	23. 5	1, 900	49. 9
14	4. 3	80	10. 3	430	23. 8	2, 000	51. 2
15	4. 4	85	10. 6	440	24. 1	2, 100	52. 5
16	4. 6	90	10. 9	450	24. 3	2, 200	53. 8
17	4. 7	95	11. 2	460	24. 6	2, 300	55. 0
18	4. 9	100	11. 5	470	24. 8	2, 400	56. 2
19	5. 0	105	11. 7	480	25. 1	2, 500	57. 3
20	5. 1	110	12. 0	490	25. 4	2, 600	58. 5
21	5. 3	115	12. 3	500	25. 6	2, 700	59. 6
22	5. 4	120	12. 6	520	26. 1	2, 800	60. 6
23	5. 5	125	12. 9	540	26. 7	2, 900	61. 8
24	5. 6	130	13. 1	560	27. 1	3, 000	62. 8
25	5. 7	135	13. 3	580	27. 6	3, 100	63. 8
26	5. 8	140	13. 6	600	28. 0	3, 200	64. 9
27	6. 0	145	13. 8	620	28. 6	3, 300	65. 9
28	6. 1	150	14. 1	640	29. 0	3, 400	66. 9
29	6. 2	160	14. 5	660	29. 4	3, 500	67. 8
30	6. 3	170	14. 9	680	29. 9	3, 600	68. 8
31	6. 4	180	15. 4	700	30. 3	3, 700	69. 7
32	6. 5	190	15. 8	720	30. 7	3, 800	70. 7
33	6. 6	200	16. 2	740	31. 1	3, 900	71. 6
34	6. 7	210	16. 6	760	31. 6	4, 000	72. 5
35	6. 8	220	17. 0	780	32. 0	4, 100	73. 4
36	6. 9	230	17. 4	800	32. 4	4, 200	74. 3
37	6. 9	240	17. 7	820	32. 8	4, 300	75. 2
38	7. 0	250	18. 2	840	33. 2	4, 400	76. 1
39	7. 1	260	18. 5	860	33. 6	4, 500	76. 9
40	7. 2	270	18. 9	880	34. 0		
41	7. 3	280	19. 2	900	34. 4		
42	7. 4	290	19. 6	920	34. 7		

NOTE.—The above table is calculated by the formula $d=1.15\sqrt{x}$ in which d is the distance in nautical miles and x the height of the object or the eye in feet. To determine the maximum distance at which an object will be visible, find the distance corresponding to its height and the distance corresponding to the height of the eye and add the two.

PUBLICATIONS OF THE UNITED STATES COAST AND GEODETIC SURVEY

The following special publications of the United States Coast and Geodetic Survey, mentioned in this manual, are supplied by the bureau to officers requiring them. They may be purchased by those outside the bureau from the Superintendent of Documents, Government Printing Office, Washington, D. C., at the prices listed.

A complete list of publications of the Coast and Geodetic Survey is found in the List of Publications of the Department of Commerce, a copy of which may be obtained free of charge upon application to the Department of Commerce.

Special publications:

No. 5. Tables for Polyconic Projection of Maps; 20 cents.
No. 61. Physical Laws Underlying the Scale of a Sounding Tube; 5 cents.
No. 73. Precise Dead Reckoning in Offshore Soundings; 5 cents.
No. 93. Reconnaissance and Signal Building; 30 cents.
No. 96. Instructions for Compensation of Magnetic Compass; 15 cents.
No. 97. Deep-Sea Soundings, Atlantic and Pacific Oceans and Carribean Sea; 15 cents.
No. 107. Radio-Acoustic Method of Position Finding in Hydrographic Surveys; 10 cents.
No. 108. Velocity of Sound in Sea Water; 5 cents.
No. 118. Construction and Operation of the Wire Drag and Sweep; 10 cents.
No. 124. Instructions for Tidal Current Surveys; 15 cents.
No. 139. Instructions for Tide Observations; 20 cents.
No. 144. Topographic Manual.
No. 145. Manual of Third-Order Triangulation and Traverse.
No. 146. Radio-Acoustic Position Finding.

SUMMARY OF NECESSARY DETAILS ON COMPLETED HYDROGRAPHIC SHEETS

[Paragraphs referred to will be found in Part 1]

Maker's name and number of paper (par. 14).
Projection (pars. 20 to 22).
Control stations (par. 23).
Projection data (par. 25).
Shore line (pars. 26 to 28).
Sheet number (pars. 29 to 30).
Sounding lines (pars. 144 to 145).
Soundings (pars. 146 to 155).
Depth curves (par. 156).
Bottom characteristics and certain other data (par. 160).
Limits of adjacent sheets (par. 161).

SUMMARY OF DATA TO BE FORWARDED TO OFFICE

All hydrographic work:

Tide records.
Marigrams from automatic gauges.
All tidal tabulations and computations that are made in the field.
Current records.
Level records.
Sounding records.
Wire-drag records.
Record of cuts to hydrographic signals (if recorded separately).
Record of observations and computations of compass deviations.
Smooth sheets.
Boat sheets.
Title for each smooth sheet.
Tidal note for each sheet.
List of signals for each sheet.

All hydrographic work—Continued.

Landmarks for charts, each sheet.
Descriptive report for each sheet or group of adjoining sheets.
Statistics (included in descriptive report).
Approval sheet for each sheet or group of adjoining sheets.
Descriptions of hydrographic stations, for season.
Ranges for compass deviations, for season.
Coast-pilot notes, for season.

Additional for precise dead reckoning and control by floating signals:

Record of cuts to locate floating signals.
Logs of runs to locate floating signals.
Record of log tests.
Current records.
Current diagrams.
Precise dead-reckoning log.
Position by bearings log.
Observation and computation of astronomical positions.

Additional for radio-acoustic sound ranging:

Bomb record.
Record of tests to determine lags at shore stations.
Record of tests to determine velocity of sound in sea water.
Brief description of each shore station.

Additional for echo soundings:

Abstract of temperatures and salinities for season.
Factor tables (included in abstract of temperatures).

Additional for combined operations (see manuals covering operations mentioned):

Triangulation and traverse records and computations.
Base measurement records and computations.
Azimuth records and computations.
Topographic sheets, descriptive reports, etc.
Record of magnetic observations, computations, etc.

LIST OF RUBBER STAMPS FOR RECORDS

For all records:

No. 4. For initials of persons reducing records and plotting smooth sheets. Entered at end of each day.
No. 14. Organization of party. Entered at beginning of each day.
No. 16. Condition of sextants, clocks, etc. Entered at beginning and end of each day.
No. 17. Statistics. Entered at end of each day.
No. 18. Time of departure for working grounds. Entered at beginning of each day.
No. 19. Time of ending work. Entered at end of each day.
No. 20. Meteorological data. Entered at beginning of each day.

Additional for lead-line soundings:

No. 2. Lead-line correction. Entered at beginning and end of each day and whenever lead line is tested during the day.

Additional for wire and tube soundings:

No. 15. Data relative to sounding apparatus. Entered at beginning of day.

No. 21. For initials of person reading registering sheave or tubes. Entered at beginning of each day and whenever a change is made.

Additional for radio-acoustic position finding:

No. 22. For names or initials of persons computing and checking bomb records.

No. 23. For entry of bomb positions in sounding record.

No. 24. For entry of intermediate positions in sounding record.

NOTE.—Additional data not provided for by stamps, as initials of persons entering and checking fathometer corrections, etc., are entered in pencil just below the proper stamp.

INDEX

[Page numbers of part 1 of this manual, where the general requirements of the Coast and Geodetic Survey with respect to the various subjects will be found, are printed in italics]

December 7, 1928.

Coast and Geodetic Survey Circular No. 13 -- 1928.

Amendment to Hydrographic Manual.

To all officers and employees concerned:

The General Requirements for Hydrographic work as published in the Hydrographic Manual, Special Publication No. 143, are amended as follows:

Page 19.

Strike out paragraph 157 and substitute the following:

157. Plotting complicated areas. -- When it is difficult to plot sounding lines and soundings to show clearly the development of a complicated area on the scale of the hydrographic sheet, one of the two following methods should be used, either method permitting the Chief of Party to determine if the development is sufficient:

(a) Prepare a sub-plan on the hydrographic sheet covering the area, and plot the work on the sub-plan; the extent and scale of the plan to be large enough to show positions and soundings clearly and to include the signals used so that the work can be actually plotted on the larger scale.

(b) When the first method is impracticable, on account of lack of room on the sheet or for other reasons, plot on the hydrographic sheet only the system or systems of lines and soundings that can be shown clearly. Plot remaining systems on one or more overlay sections of tracing cloth; each overlay to be referenced to the sheet by showing on it the intersections of parallels and meridians. Each overlay need be large enough to cover only the developed area and with sufficient excess to permit its being secured over the sheet for plotting. On the overlays soundings should preferably be plotted in ink. All overlay sections should be forwarded with the sheet. Positions and soundings plotted on overlays will be transferred to the smooth sheet by the verifier in the office.

R. L. Faris

Acting Director.

HYDROGRAPHIC MANUAL

Coast and Geodetic Survey Special Publication No. 143.

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SUPPLEMENT - MAY 17, 1928.

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PAGE 1. -- Paragraph No. 4.-- At end of paragraph insert the following: "Objects located by previous surveys but subject to change in position, such as flagstaffs, beacons, signal masts, etc., shall not be used for control until they have been relocated or their original positions verified"

PAGE 2. -- Paragraph No. 5. -- Instead of a Manual of Third-Order Triangulation and Traverse, the Bureau has decided to issue a Manual of Second-Order Triangulation and Traverse which will also contain such instructions as are necessary for the execution of third-order work. Pending the issue of this publication (probably during the latter part of 1928), the instructions for triangulation published in Special Publication No. 26, General Instructions for Field Work, should be followed.

Paragraph No. 6. -- On the date of this supplement the Topographic Manual was in press. Pending its issue the instructions for topographic work in Special Publication No. 26, General Instructions for Field Work, and in Special Publication No. 85, Plane Table Manual, should be followed.

The corrections to this page also apply to the list of publications on page 163.

PAGE 5. -- Paragraph No. 41. - Line 10, change last part of sentence ending on this line to read "B at 30 fathoms, A at 40 fathoms, B at 50 fathoms, etc."

PAGE 55. -- Echo Sounding. - The more recent fathometers, several of which have been installed on ships of the Bureau, employ a new circuit in which no plate circuit relay is used. In such installations the wiring of the fathometer units, amplifier, and battery box is different from that illustrated in figure 19. Ships equipped with the new fathometer circuit are provided with suitable wiring diagrams and corresponding descriptions. The principles of operation and the result obtained are the same as described in this section of the manual.

On survey ships a switch is placed across the "automatic cut out" of figure 19. When it is closed a signal will be sent every revolution of the dial; when open, every other revolution. This is true for red light method and white light method. The switch may be opened when the depth is near 100 fathoms on red light method and when near 600 or 1800 fathoms on white light method. When near 1200 and 2400 fathoms, the procedure described in second paragraph, page 66 should be followed.

PAGE 57. -- Line 1, after "small" insert "governor-controlled".

PAGE 127. -- Line 3 (from bottom), for "vessels get" read "vessel gets."

PAGE 132. -- Figure 41, change second line of legend to read; "soundings obtained under various current conditions. Circles connected by solid lines."

PAGE 163. -- Special Publication No. 146 is being prepared but it is not yet available for issue.

ERRATA AND ADDENDA

REPRINT (1931) OF 1928 EDITION

PAGE 1.

Paragraph 4, **Recovery of stations.**—At the end of paragraph insert the following:

Objects located by previous surveys but subject to change in position, such as flagstaffs, beacons, signal masts, etc., shall not be used for control until they have been relocated or their original positions verified.

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Paragraph 5, **Establishment of control.**—In lieu of "Manual of Third-Order Triangulation and Traverse," in lines 3 and 4, substitute:

Manual of Second and Third Order Triangulation and Traverse.

PAGE 19.

Paragraph 153, fourth line, strike out entire sentence beginning "At important points," and substitute the following:

At critical places on navigable bars, in channels, or along inside routes, where in each case the controlling depth is 42 feet or less, the soundings that establish the controlling depth, and only such soundings, shall be plotted to the nearest half foot.

Paragraph 157, **Enlarged scales of complicated areas.**—Strike out entire paragraph and substitute the following:

Plotting complicated areas.—When it is difficult to plot sounding lines and soundings to show clearly the development of a complicated area on the scale of the hydrographic sheet, one of the two following methods should be used, either method permitting the chief of party to determine if the development is sufficient:

(*a*) Prepare a subplan on the hydrographic sheet covering the area, and plot the work on the subplan; the extent and scale of the plan to be large enough to show positions and soundings clearly and to include the signals used so that the work can be actually plotted on the larger scale.

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Echo sounding.—The more recent fathometers, several of which have been installed on ships of the bureau, employ a new circuit in which no plate circuit relay is used. In such installations the wiring of the fathometer units, amplifier, and battery box is different from that illustrated in Figure 19. Ships equipped with the new fathometer circuit are provided with suitable wiring diagrams and corresponding descriptions. The principles of operation and the result obtained are the same as described in this section of the manual.

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PAGE 57.

Line 1, after "small" insert "governor-controlled."

PAGE 85.

Inclined angles.—Strike out entire paragraph and substitute the following:

Inclined angles.—If it is necessary to observe a sextant angle between two objects, one of which is at sea level and the other at sufficient elevation to cause an appreciable difference between the inclined and horizontal angles, the inclined angle may be corrected by means of the graph given in Figure 24. This graph is constructed by using the formula $\text{Cos } Vc = \frac{\text{Cos } Vo}{\text{Cos } h}$

in which Vc = the horizontal or computed angle, Vo the inclined or observed angle, and h the angular elevation of the object not in the horizon.

To find the correction to an observed angle, enter the graph with the elevation angle as an ordinate and from the proper point of the scale on the left-hand margin extend a horizontal line to intersect the curve representing the observed inclined angle, obtained, if necessary, by interpolation between the curves provided on the graph. From the point of intersection drop down vertically to the scale at the bottom of the graph, which will give the correction to be applied.

If both objects are elevated the correct horizontal angle can be obtained from the following formula:

$$\text{Cos } Vc = \frac{\text{Cos } Vo - \text{Sin } h_1 \text{ Sin } h_2}{\text{Cos } h_1 \text{ Cos } h_2}$$

where h_1 and h_2 = the angles of elevation of the two objects.

Occasions often arise, in connection with the determination of sun or stellar azimuths, for using these formulas. In the case of the second formula, to facilitate computation by the use of logarithms, it can be converted into the following:

$$\text{Cos } \tfrac{1}{2} Vc = \sqrt{\text{Sec } h_1 \text{ Sec } h_2 \text{ Cos } S \text{ Cos } (S - Vo)}$$

in which $S = \frac{Vo + h_1 + h_2}{2}$

A convenient form for using the formula is as follows:

Vo	
h_1	Sec ....
h_2	Sec ....
________	
2) ________	
S	Cos ....
$S-Vo$	Cos ....
	________
	2) ________
$\tfrac{1}{2} Vc$	Cos ....
Vc	

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Line 3 (from bottom), for "vessels get" read "vessel gets."

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Fig. 41, change second line of legend to read:

soundings obtained under various current conditions. Circles connected by solid lines

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