U. S. DEPARTMENT OF COMMERCE
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COAST AND GEODETIC SURVEY
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HYDROGRAPHIC MANUAL

By

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U. S. Coast and Geodetic Survey

QB
275
.U35
no.143
Rev.ed.
1942

Chapter 7. THE SMOOTH SHEET

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Reprinted from
Special Publication No. 143
Revised (1942) Edition

U. S. COAST & GEODETIC SURVEY
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UNITED STATES
GOVERNMENT PRINTING OFFICE
WASHINGTON : 1944

National Oceanic and Atmospheric Administration

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12200 Kiln Court
Beltsville, MD 20704-1387
January 1, 2006

NOTE

This is a reprint of Chapter 7 of Special Publication No. 143, revised (1942) edition. The subject matter has been identified by a decimal numbering system and all referencing is by these numbers. There are nine sections in chapter 7, each section being subdivided into not more than nine numbered subjects, and each subject into not more than nine numbered headings. The first digit of a number identifies the chapter, the second digit identifies the section, the third digit the subject, and the fourth the heading. For example, **7326,** Verification of the projection, is the sixth heading under the second subject in the third section of chapter 7. Most of the references are intrachapter references, although a few will be found that refer to other chapters of the Hydrographic Manual.

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CHAPTER 7. THE SMOOTH SHEET

The *smooth sheet* is the name given to the hydrographic survey when reduced to plot form. It is essentially a record of the soundings taken during the field survey, but contains other data necessary for a proper interpretation of the survey, such as depth curves, bottom characteristics, names of geographic features, and control stations. The smooth sheet is plotted with the utmost care in the drafting room of the ship or a field office either as the survey progresses or after it is completed. After registry, verification, and review in the Washington Office (see **93**), the smooth sheet becomes the official permanent record of that particular survey. It is as complete for the water area as it is practicable to make it, and subsequent reference to the original Sounding Records is rarely necessary.

71. THE SHEET

711. SMOOTH-SHEET PAPER

It is obvious that surveys which cost thousands of dollars to execute should be plotted in their final permanent form on the best practicable medium available. Experience has shown this to be first-quality white drawing paper mounted on muslin. This paper is known as *smooth-sheet paper*, and is available in several makes and sizes. Smooth sheets shall be prepared only on paper furnished by the Washington Office for that purpose.

7111. Whatman's Paper

The standard paper for smooth sheets is Whatman's paper, available in only one size, 31 by 53 inches. In this paper the muslin backing extends approximately 1 inch beyond the paper on each edge, which feature tends to preserve the edges of the paper during extensive use and also prevents cracking. Whatman's paper shall be used for all smooth sheets where the size permits, and this requirement must be given full consideration in planning the sheet layout for any given area (see **1361**).

7112. Other Papers

Other mounted smooth-sheet paper is available in widths of 36 and 42 inches, in continuous rolls of 10 yards each. This should be used when the layout of sheets requires the use of larger sizes than the standard, as is frequently the case with offshore surveys. The quality of the different makes varies, "Paragon" being considered the finest drawing paper made. But this is foreign made and is difficult to get at the present time. In 1942 the best available paper is Keuffel & Esser No. 13320 *DM*.

When paper other than Whatman's standard is used, the smooth sheet shall have noted in the margin the maker's name and the trade name or number of the particular paper, if these are known. Some papers have this information imprinted at regular intervals along the margin but if this imprint does not contain all the desired data or if the entire imprint does not appear on the smooth sheet, it must be noted thereon in ink.

7113. Defective Paper

Drawing paper is purchased by the Federal Government in accordance with standard specifications. These require generally that paper be free of surface imperfections, that it be subject to a minimum dimensional change, that it permit inked lines to be drawn without spreading or *feathering*, and that it permit several successive erasures, with rubber or steel, in the same spot, on which lines can be subsequently inked with little or no spreading or feathering. In addition, the paper must not be so stiff and rigid that it will not withstand a reasonable amount of rolling and flexing without cracking.

Notwithstanding the specification requirements, considerable variation in the quality of smooth-sheet paper is found in practice. Paper which does not comply to a reasonable degree with the above general requirements shall not be used for smooth sheets and the Washington Office shall be notified of the specific fault in a letter stating the maker's name, the trade name of the paper, and the date of shipment to the party, if these are known.

7114. Paper Distortion

Drawing paper, not mounted on metal, does not exist which is free of distortion under varying conditions of temperature and humidity. This distortion is a decided nuisance to the surveyor in his field work and to the cartographer who subsequently uses the smooth sheet in the Office. The distortion is more troublesome in rainy climates and in localities where there are rapid and large changes in humidity. Because of this distortion, distances once laid off cannot be assumed to retain their correct length. If distances are plotted for use at some future date, it is necessary to verify them before use.

The best quality of smooth-sheet paper is manufactured so that the percentage of contraction or expansion is nearly equal in all directions. Such distortion can be compensated for, especially if it occurs after the survey has been completely plotted, because the effect is merely a change in scale. Where the percentage distortion is not uniform in all directions, as is the case with many grades of paper, its effect is *relatively* easy to compensate for, *provided* certain precautions are taken in laying out projections (see **1362**).

One test for distortion made in the field in Alaska in 1931 showed a maximum dimensional change in a standard Whatman sheet of 1.12 percent in length and 0.62 percent in width; the sheet assuming its greatest dimensions on a foggy day when the sheet was damp and its minimum on a clear day when the sheet was quite dry.

Recent tests in the Washington Office show that the following distortions may be expected for the various papers listed:

TABLE 23.—*Paper distortion*

Type of paper or material	Percentage of distortion caused by a change from 27 to 89 percent relative humidity	
	Across short dimension of sheet or roll	Along long dimension of sheet or roll
Cellulose acetate	0. 29	0. 19
Buff paper, K. & E. No. 13322–M	0. 51	0. 25
Chart paper (unmounted)	0. 65	0. 29
Buff paper, K. & E. Duplex No. 141 (in sheets)	0. 75	0. 35
White paper, Weil No. 72	0. 61	0. 39
Buff paper, K. & E. Duplex No. 141 (in rolls)	0. 65	0. 40
White paper, K. & E. Paragon	0. 97	0. 45
White paper, Whatman	0. 40	0. 56
Tracing paper, K. & E. Ionic No. 197 H	0. 54	0. 13
Tracing paper, Post No. 173	0. 82	0. 28
Tracing paper, K. & E. Doric	0. 99	0. 27
Tracing cloth, K. & E. No. 13303	1. 00	0. 28

7115. Seasoning Drawing Paper

Smooth-sheet paper should be well *seasoned* in the climate in which it is to be used and for as long a period as practicable before the projection is drawn. Paper in tight rolls, or in stacks or piles, will not season. Each sheet should be laid out or hung up separately where it will be completely exposed to the air on both sides for at least a few days, if not weeks, before use. For best results the period of seasoning should embrace a great variation of temperature and humidity.

If a sheet cannot be seasoned by laying it flat, it should be hung from successive edges and subsequently laid flat for several days before use.

The contraction and expansion seems to be greater during the seasoning period than subsequently. The paper *seasons* and *settles down* so that less distortion may be expected later.

7116. Drawing Paper in Rolls

Drawing paper in rolls is tightly rolled by the manufacturer and soon assumes a *set* in this position. It must be unrolled with extreme care or it will have a tendency to *buckle* or perhaps even crack. It is best to unroll it gradually over a period of several days before trying to put it in a flat position. This is done by first loosening the outer turns of the roll, until as much paper as is likely to be needed at the time has assumed a diameter perhaps twice as large as the roll had originally. The next day it is expanded again in diameter and so on, leaving it in the enlarged roll each time for a day, if possible, until it can be cut off the roll and laid flat for seasoning.

7117. Drawing Paper Requisitions

All smooth-sheet paper requirements should be requested from the Washington Office by ordinary letter, specifying the kind, grade, make, size, and quantity desired.

712. SMOOTH-SHEET SIZE

The standard size of smooth sheets is 31 by 53 inches and they shall ordinarily not exceed this size. It is sometimes impracticable to maintain this limit because of

the configuration of the shoreline, the availability of the signals, and the necessity for controlling offshore hydrography from shore signals. But the maximum size, which shall never be exceeded under any circumstances, is 42 by 72 inches.

For projections made in the Washington Office on the projection ruling machine the maximum size of the area on which lines can be ruled and the maximum size of the paper are given in **7327**.

7121. Dog-Ears

Dog-ears are small drawing paper extensions to the smooth sheet used for including control stations or portions of sounding lines that plot beyond the limits of the sheet unavoidably or through an error in the original layout.

Dog-ears must be avoided wherever possible. Eventually they almost always tear off or become so mutilated that they must be removed, and the smooth sheet itself is generally *buckled* in the process of adding the extension. Extreme care must be exercised in making the layout in order to ensure that all the needed control will fall within the limits of the sheet.

Where it is necessary to use a permanent dog-ear, the paper shall be neatly *stapled* to the smooth sheet with a wire stapler, using the minimum number that will ensure permanence, and avoiding interference with plotted information. Under no circumstances shall a permanent dog-ear extend more than 6 inches beyond the edge of the sheet.

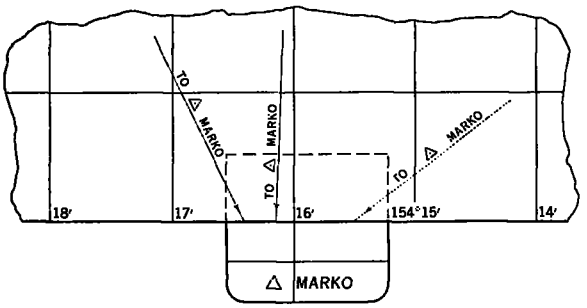

FIGURE 143.—Temporary dog-ear for smooth sheet.

If only a single station is to be included, the dog-ear shall be made of tracing paper, temporarily added to the smooth sheet by rubber cement or in any other way which will not damage the sheet. Three fine inked lines shall be drawn on the smooth sheet toward the station on the dog-ear, of such lengths and azimuths as will permit relocating the station in the future on another temporary dog-ear, should that become necessary. Each such line shall be marked thus: "to △ MARKO" (see fig. 143).

713. AUXILIARY PLOTTING SHEETS

Grained or painted aluminum sheets and drawing paper mounted on aluminum sheets are occasionally useful as accessories to the smooth sheet for—

(*a*) Plotting and adjusting the positions of survey buoys located by any of the methods described in section **25**, when plotting is preferable to computation. For example, where the computations are too involved, as in the case of cuts obtained from a vessel whose position is determined by a three-point fix (see **2514** and **2552**); where buoys are located by taut-wire distances; or where they are located by subaqueous sound ranging.

(*b*) Plotting and adjusting hydrographic positions located by; dead reckoning, astronomic sights, R.A.R., and combinations of these.

In all cases in which aluminum sheets are used as intermediaries the final results must be transferred to the smooth sheets; in the case of control, by *dms.* and *dps.* (see **7411**); and in the case of hydrographic positions, either by *dms.* and *dps.* or by a tracing-paper transfer similar to that described in **7413**. As finally plotted, the smooth

sheet must be complete without the necessity of reference to the aluminum sheet which is not a part of the permanent records. The smooth sheet itself, however, *must not* be plotted on aluminum.

7131. Grained Aluminum Sheets

The maximum size of aluminum sheets available at the Washington Office is 38 by 54 inches and they are all 0.02 inch thick. This size or smaller can be furnished either grained, painted, or mounted with drawing paper. A sheet of maximum size costs about $2.50 and the cost of graining is approximately 60 cents per sheet.

The grained surface of an aluminum plate will take either pencil or ink, but the abrasive nature of the surface wears a pencil point down so rapidly that it is difficult, if not impossible, to draw fine lines with a pencil sharpened to a chisel point. Soft pencil marks can be removed with art gum. A hard eraser should not be used since it removes the grain and once this has occurred neither ink nor pencil marks can be made on that portion, unless it is subsequently roughened with a snake slip. Ink can be removed from the grained surface by the use of water or a dilute solution of oxalic acid (1 ounce oxalic acid crystals to 15 ounces of water). A slight stain will remain which can be removed by the use of a snake slip.

Used aluminum plates need not be returned to the Washington Office.

7132. Painted Aluminum Sheets

Painted aluminum sheets are similar to the above, except that, instead of being grained, the drawing surface is provided by spraying the aluminum with enamel paint. The plates are generally given three or four coats of the enamel, applied in the same manner as is the finish on automobile bodies.

Both ink and pencil work can be done on painted aluminum sheets although with not the same facility as on a good grade of drawing paper.

7133. Mounted Aluminum Sheets

Drawing paper mounted on aluminum sheets is the most satisfactory solution of the distortion problem if the sheets are not unduly exposed to moisture. The paper must be mounted on both sides of the aluminum regardless of whether one or both sides are to be used; otherwise the paper will contract or expand and so warp the aluminum sheet that it will not lie flat. Mounted aluminum sheets are prepared in the Washington Office and any make of unmounted drawing paper can be used. The kinds ordinarily used are chart paper or two-ply Bristol board, depending on the purpose for which they are intended. (See also **233**.)

In mounting, the paper is applied to the two sides, one at a time, with a high quality lithographic paste, sparingly used and avoiding excessive moisture, as the latter has a tendency to make the paper surface porous or *mushy* which ruins the fine drawing quality of the paper. One of the requirements for successful mounting is that the paper must be bonded to the aluminum under considerable pressure, this pressure being more important than the quality of the paste.

Some difficulty has been encountered with the moisture in the paste oxidizing the aluminum and causing blisters to form at some future time. Of course this is no drawback if the sheet is being prepared for immediate temporary use. This difficulty can be overcome in various ways, one of the most successful of which is coating the aluminum with shellac before mounting.

714. TRACING MEDIUMS

7141. Tracing Cloth

Tracing cloth is a fine semitransparent linen or cotton cloth, sized on one side, and dull on the other. The best grade is free from pinholes. Because starch is used in its preparation, water will ruin and spot the surface, the spots showing on any reproductions. When working with tracing cloth, the portion not being used should be protected from perspiration by a sheet of paper.

The dull side of the tracing cloth should be used for all work because it takes ink better. Inking on tracing cloth is facilitated by dusting with talc or pounce, rubbing lightly with a cloth to remove traces of grease which prevent the flow of ink from the pen.

Tracing cloth distorts considerably more with age and climatic changes than tracing paper and therefore should not be used where a minimum of distortion is required. The best grade of cloth is not as transparent as a good grade of tracing paper.

The most satisfactory tracing cloth on the market in 1942 is "Micro-Weave," fabricated by Holliston Mills Company. It is made in 10- and 20-yard rolls in almost any width desired, and in rectangular sheets in a number of sizes from 19 by 24 inches to 41 by 59 inches. The sheet form is available on the General Schedule of Supplies, but the roll form is not. An inferior grade of cloth in 24-yard rolls can be furnished from the Schedule in widths of 30, 36, and 42 inches. This grade is suitable for use in protecting the smooth sheet during plotting (see **761**).

7142. Tracing Paper

Tracing paper (or vellum) is a thin tough semitransparent paper suitable for making tracings of drawings, or for miscellaneous use where permanence is not important or where pencil work is sufficient. The best quality is odorless, white, 100 percent rag, with a high degree of transparency and smooth surface, the texture permitting erasures without damage to the paper.

The best tracing paper, not available in 1942 because of the war, is foreign made under the trade name "Doric" and is marketed by Keuffel & Esser Company, New York. It is usually obtained in 20-yard rolls in widths of 30, 36, and 42 inches. Substitutes must be selected with care as there are many inferior grades on the market. Post's No. 173, fabricated by Frederick Post Company, Chicago, Illinois, is satisfactory for all except the most critical work.

7143. Cellulose Acetate

Transparent cellulose acetate sheeting (better known under the more familiar trade name "Celluloid") is useful either as a tracing medium or as a transparent cover for smooth sheets, maps, charts, etc. Cellulose nitrate sheeting must not be used since it is highly flammable and its presence creates a definite fire hazard. Cellulose acetate on the other hand burns at about the same rate that paper does.

The sheeting is used in two grades: (1) low shrinkage grade, for work requiring a minimum of distortion, and (2) ordinary grade, for purposes in which dimensional changes are not important.

The types of cellulose acetate ordinarily available are described below. All four kinds can usually be furnished by the Office although only the first three are on the General Schedule of Supplies.

(*a*) Cellulose acetate sheeting, special low shrinkage, one side frosted for drafting, 40 inches wide by 0.008 inch thick, in sheets 50 and 60 inches long and in rolls.

(*b*) Cellulose acetate sheeting, ordinary grade, one side frosted for drafting, in sheets 20 by 50 inches in size, and in thickness 0.005 inch, 0.0075 inch, and from 0.01 inch to 0.125 inch.

(*c*) Same as (*b*), except both sides are clear.

(*d*) Cellulose acetate sheeting, ordinary grade, clear, available in rolls up to 40 inches wide and from 0.00088 to 0.002 inch thick. Sold under the trade name of "Rigid Kodapak" by Eastman Kodak Company.

The frosted sheeting is preferable for either pencil or ink work. The clear sheeting cannot be used for pencil work and is not too satisfactory for ink work.

To ensure ease in drafting and the most permanent bond of the celluloid ink (see **7261**), the surface of both the frosted and clear sheeting should be cleaned thoroughly with either ammonia (U.S.P.) or magnesium carbonate, applied with a soft cheesecloth. Tracing cloth powder can also be used for this purpose, but magnesium carbonate seems to give better results.

72. DRAFTING AND LETTERING

721. CHARACTER OF THE DRAFTING

Artistic drafting and lettering are neither necessary nor desirable on a smooth sheet. A hydrographic survey is an engineering product and the resulting smooth sheet should give the appearance of such, rather than that of a work of art. The final result must be first, accurate; second, legible; and third, neat. While neither expert draftsmanship nor penmanship is required, the drawing should be of such quality that there will be no impression of carelessness, since a drawing apparently carelessly made is likely to reflect on the accuracy and the reliability of the field work. Care and patience combined with sufficient practice will produce the necessary accuracy and legibility.

It is particularly important that the smallest details appear on the smooth sheet accurately and clearly. In general, it should be possible to read, without difficulty, everything on the smooth sheet without the use of a magnifying glass. Those engaged in constructing, inking, and lettering smooth sheets should constantly keep in mind the fact that photographic copies of smooth sheets are frequently made for the use of agencies and persons, who have no access to the original documents, and that often these copies are at a one-half reduced scale.

It is only by following prescribed standards that an entirely satisfactory smooth sheet will be produced (see fig. 171). Particularly important is the use of standard symbols (see figs. 169 and 189), as great confusion often results where nonstandard symbols are used or where symbols are drawn so poorly as to make misinterpretation possible. Soundings, in particular, must always be clear and legible (see fig. 163).

722. ORIENTATION OF SMOOTH SHEET

North shall always be considered the top of the smooth sheet, whether or not the projection lines are parallel to the edges of the sheet. In plotting and inking smooth sheets all lettering and numerals of any kind shall be so lettered as to be read from the south (see **7733**). Where geographic names or legends cannot be lettered on an east-west line, but must be lettered at an angle or on a curve, they shall be so arranged as to be read when looking directly north (see **7872**).

723. LETTERING

The lettering on a smooth sheet should be bold rather than the reverse. Extremely small letters and numerals should be avoided unless lack of space renders a small size absolutely necessary. Thin ink should be avoided. Unless ink of sufficient body is used, the central part of the inked line frequently thins out, particularly where a mechanical lettering set is used. This results in a poor appearance and makes satisfactory photography of the smooth sheet impossible. Each inked line, whether in black or color, should present a solid uniform appearance throughout.

It should be noted that, in general, any number appearing in the water area of the smooth sheet should be in slanting numerals, except of course the soundings and position numbers, which are vertical (see **7825** and **7843**).

Periods shall not be used in the water area (see **781**).

7231. Mechanical Lettering Sets

Unless the draftsman is particularly skilled in lettering, it is preferable that a mechanical lettering set be used, where practicable. There are several types of these on the market (see **4834**). For most small lettering the pen sizes recommended by the manufacturer of the Leroy sets produce too heavy a letter. The preferable size for smaller lettering, such as station names, is "No. 00."

724. SELECTION OF PENCILS

Although individual preferences vary somewhat, the experienced draftsman knows with which make and grade of pencil he can obtain the best results for any given requirements. All makes of drawing pencils listed in the General Schedule of Supplies, the standard list of materials contracted for by the Government, can be considered of high grade and of comparable quality, although tests have shown that a variation of approximately one grade may be found in the hardness of one make as compared with another. Gradations of any one make, however, can be depended upon to be consistent. Before being listed in the General Schedule of Supplies, drawing pencils are rigidly tested to determine whether they comply with the specifications. The leads in most pencils are made by the same process. Of those listed in the General Schedule in 1942 the Van Dyke Microtomic Graphite is believed to smudge the least and the Koh-i-noor and Turquoise pencil leads are thought to average slightly harder for the same grade than other makes. It is also the belief of some draftsmen that the Koh-i-noor leads are, on the average, of a more uniform quality.

For most pencil work on a smooth sheet, pencils of a grade no harder than 3H or 4H should be used, except for the construction of projections and the plotting of control stations by *dms.* and *dps.* (see **7411**). For these a much harder pencil should be used, extreme care being required to prevent damage to the surface of the paper. On a humid day when the paper is likely to be damp and easily indented, a pencil one grade softer should be used than is customary for the same purpose on a dry day.

Under no circumstances should a hard chisel-edged pencil be used to draw the connecting lines between positions on the smooth sheet, because this may result in rupturing the paper at the most critical place, that is, along the line of soundings. Furthermore, the indentation formed makes inking the soundings extremely difficult, because the pen catches in the indentation. A pencil no harder than 4H, sharpened to a point, not a chisel edge, should be used for this purpose.

725. SELECTION OF PEN POINTS

The drafting pens on the General Schedule of Supplies are not uniform in quality nor are they tested as thoroughly as the pencils are. As in the case with pencils, an experienced draftsman will know with which make and type of pen he can obtain the best results for a particular style of drafting.

The Gillott crow-quill pen (No. 659) is believed to be the best all-purpose pen for fine work, especially after the point has been dressed slightly. For a draftsman who prefers a fine limber point, Gillott No. 290 or No. 291 is perhaps the best. For average work Gillott No. 170, and for heavy work such as shoreline Gillott No. 303 or No. 404, are recommended. For the very fine lines required in inking day letters and position numbers on sounding lines, a Hunt No. 104 may be preferred to the Gillott No. 290 or the crow-quill.

In 1943, because of the war, Gillott pens were not obtainable. Esterbrook pens are the best available on the General Schedule of Supplies. The numbers of comparable grades of Esterbrook pens are 62, 354, 355, 356, 357, and 358, for Gillott pen numbers 659, 291, 290, 170, 303, and 404, respectively.

726. INKS

Waterproof drawing inks, particularly colored inks, vary considerably in quality from year to year and no recommendations can be made at any particular time with the expectation that they will be found correct in the future. The inks listed in the General Schedule of Supplies are satisfactorily tested before listing, and it is believed that at any given date the General Schedule is, perhaps, the best guide. It does not follow, however, that if ink of one make is satisfactory in one or two colors, other colors of the same make will necessarily be satisfactory. Experience is, after all, the best guide.

Black waterproof drawing ink is the only ink which is entirely waterproof. Other colored waterproof inks are not fully waterproof and this fact should be carefully considered in connection with their use.

In the past, Higgins waterproof drawing ink has, perhaps, been found consistently better than other makes. At the present time both Higgins and Keuffel & Esser black waterproof ink comply with the federal specifications.

7261. Celluloid Ink

While ordinary drawing ink can be used on celluloid sheeting, it is preferable to use celluloid ink because it makes a more permanent bond and does not rub off or chip so easily. It can be removed with a steel eraser; light ink work can be removed with an ink eraser or an erasing machine, the latter leaving a better surface for redrafting.

Celluloid ink will be furnished by the Office on request. It is available in light, medium, and heavy grades. The medium is more generally used. The solvent in celluloid ink evaporates rapidly making it necessary to thin the ink from time to time. This is done with a special thinner, which is also available on request. A small quantity at a time should be thinned, suitable for the individual draftsman.

727. ERASING AND CLEANING

During the construction and plotting of the smooth sheet every effort should be made to keep the sheet clean and to avoid placing unnecessary marks thereon (see **731**). Even with considerable care, a smooth sheet will eventually become slightly soiled.

Errors are occasionally made which must be corrected, and temporary notes or lines are placed on the sheet which must be removed. These erasures as well as the cleaning of the sheet require extreme care in order to avoid damaging the surface of the paper.

Most temporary pencil lines and notes, if made lightly with a 3H or 4H pencil, can be removed with an art gum eraser without damage to the paper. Penciled errors and the badly smudged places generally require the careful use of a soft red eraser of the "Ruby" or "Venus" type now on the General Schedule. Ink erasures cannot be made without some damage to the surface, but less damage is generally caused with the skillful use of an electric eraser (see **4852**) than by any other method. Hard abrasive erasers should never be used, even for the removal of ink work. Colored erasers should always be tested before use to determine whether the color rubs off, and if so, they must not be used on the smooth sheet.

The sheet in general may be cleaned by crumbling a small piece of art gum over it and gently rubbing the crumbs across the surface with a piece of clean white paper placed flat under the hand. Bread crumbs may be used for the same purpose.

73. PREPARATION OF THE SMOOTH SHEET

The completed smooth sheet is a valuable original document. It is preserved indefinitely in the archives at the Washington Office. The amount of care taken to protect the sheet during its construction will be directly reflected in its future longevity.

731. PROTECTION OF SMOOTH SHEET

Prior to and during the construction and plotting of the smooth sheet, the paper should be kept in as dry a place as possible, especially if the climate is at all humid. All drafting work is done much easier on dry paper.

It is inevitable that the sheet will become slightly soiled while being worked on, but there is no reason why it should be soiled excessively if a reasonable amount of care is taken to keep all parts of the sheet covered, except the small area on which work is actually being done.

Smooth-sheet paper has a specially prepared surface and every care should be taken to avoid damage to this surface. Lines should never be scratched on the paper, except short arcs necessary in constructing a projection. This damages the surface and ink *runs* in the scratches. It is equally important to avoid the indentations made by using too hard a pencil or by pressing too heavily when drawing lines, particularly the connecting lines between positions (see **724**). Smooth sheets have been received in the Washington Office with the surface cut so badly by sharp pencils that in a short time the paper cracked at these places. When this occurs, deterioration of the sheet soon follows.

Temporary construction marks and temporary notes should be kept at a minimum, and these, particularly the notes, should be made with as soft a pencil as practicable so that they may be erased without damage to the paper.

7311. Rolling the Smooth Sheet

The mounted paper used for smooth sheets is of the best possible grade and if it receives careful treatment during the making of the smooth sheet and subsequently, it should suffer comparatively little distortion. If practicable, the smooth sheet should be kept flat during the entire period of its construction. Rolling during this period is

not only harmful to the paper, but results in a curve set in the paper, which makes plotting and inking unnecessarily difficult. If the smooth sheet must be rolled at any time, it should be rolled loosely to a diameter of not less than 6 inches with the cloth-backed side of the paper on the outside.

Under no circumstances should the smooth sheet be allowed to extend over the edge of the table during plotting. This subjects the sheet to permanent creasing or bending which may result in weakening the paper to such an extent that it eventually cracks or breaks.

732. THE PROJECTION

The graphic record of a hydrographic survey is a smooth sheet, which in effect is a map of the area surveyed. A map is a flat-surface representation, at a given scale, of some part of the curved surface of the earth. On a map the features of the earth's surface are represented with reference to each other according to some system which will simulate their relation in nature. In order to accomplish this best, a projection is used—that is, an orderly arrangement of the terrestrial meridians and parallels on a plane surface.

No matter how small a part of the earth's surface is under consideration it is still curved, and theoretically cannot be represented on a plane with perfect accuracy. As the area increases, the distortion or the departure from nature becomes greater when an attempt is made to show it on a plane surface. It follows consequently that the meridians and parallels cannot be shown on a plane exactly as they are on the earth. Projections can be constructed in which some one or more desirable properties are mathematically exact but only at the expense of other properties. Therefore, every form of projection is at best a compromise. For practical purposes, however, it is found that as the area considered is reduced it eventually reaches a size so small that it can be represented at a given scale on a plane surface without any plottable error.

The subject of projections is treated extensively in Special Publication No. 68, Elements of Map Projection.

7321. The Polyconic Projection

Various projections have been adopted by different countries and different surveying agencies within each country on which to plot the results of their surveys. The Coast and Geodetic Survey has adopted for all surveys a projection, known as the Coast and Geodetic Survey polyconic projection. All surveys must be plotted on this projection.

This polyconic projection was devised by Ferdinand Hassler, the first Superintendent of the Coast and Geodetic Survey. It is extensively used for surveys of comparatively small areas, such as those covered by the hydrographic and topographic surveys of the Bureau, because it effects a satisfactory compromise with all of the most desirable properties of map projections, because of its ease of construction, and because a general table for its use has been calculated for the entire spheroid. The projection data are based on Clarke's reference spheroid of 1866 and are contained in Special Publication No. 5, Tables for a Polyconic Projection of Maps and Lengths of Terrestrial Arcs of Meridian and Parallels. This publication is familiarly known by its short title, "The Polyconic Projection Tables."

The polyconic projection is the development of an area by means of successive cones tangent to the surface at successive parallels. The central meridian of any

polyconic projection is a straight line, all other meridians and all the parallels being curved lines, except for the special case of the Equator which is a straight line. The parallels are arcs of nonconcentric circles with radii of decreasing length as the latitude increases, but whose centers lie in the extension of the central meridian. The curved meridians are concave toward the central meridian in increasing amounts as the distance from the central meridian increases. Practically, in the larger scales usual in hydrographic surveying the meridians may be considered straight lines within the limits imposed by graphic methods of construction. The longitude scale is everywhere correct, but the latitude scale is strictly correct only on the central meridian.

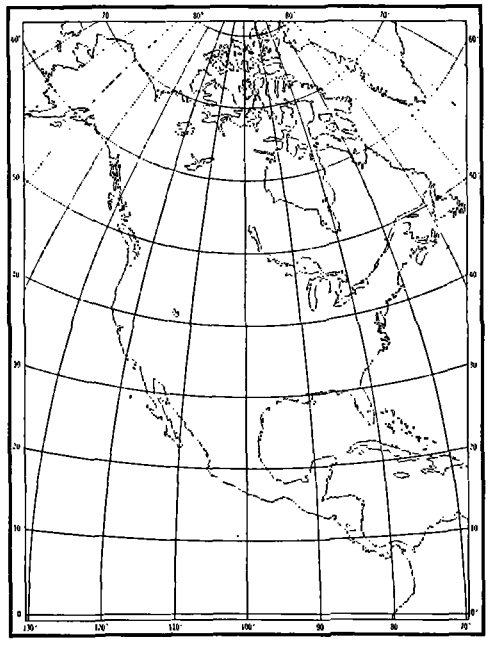

FIGURE 144.—Polyconic projection of North America.

The accuracy inherent in the polyconic projection is a matter of some interest. Some idea of the departure from true representation is given by the following two examples. On a 1:40,000 scale projection on a sheet 31 by 53 inches in size the scale distortion in the worst part does not exceed 9 parts in 1,000,000 and the angular error does not exceed 1″ of arc. On a 1:120,000 scale projection on a sheet 42 by 72 inches in size the scale distortion in the worst part does not exceed 3 parts in 20,000 and the maximum angular error is 15″.3 of arc. It is apparent, then, that the errors of azimuth and distance on sheets usually used in plotting hydrographic surveys are of such small proportions as not to be graphically measurable.

Since the meridians of the polyconic projection are curved lines concave toward the central meridian two adjacent maps or surveys cannot be joined together in an east-west direction, because the curvatures of the marginal meridians on the two maps are in different directions.

7322. Verification of Scales and Straightedges

Before beginning the construction of the projection, the meter bar and meter scales and the straightedges should be verified unless definite information of their correctness is at hand. It cannot be assumed that the scales are correct since in the past several have been discovered with appreciable errors in the divisions. Perhaps the best test that can be applied in the field is by comparison with a meter bar known to be correct. In lieu of this a comparison of the various scales and meter bars against one another will suffice (see **4821**).

Straightedges can also be tested by comparison with one another but a better test is described in **4831**.

7323. The Projection Lines

The projection intervals between the meridians and parallels to be shown on a survey sheet depend on the scale and shall be according to the following table:

TABLE 24.—*Projection line intervals for various scales*

Scale of survey	Projection line interval
1:2,000 and larger	Every 5 seconds.
1:2,001 to 1:3,000	Every 10 seconds.
1:3,001 to 1:6,000	Every 15 seconds.
1:6,001 to 1:12,500	Every 30 seconds.
1:12,501 to 1:25,000	Every minute.
1:25,001 to 1:60,000	Every even minute.
1:60,001 to 1:125,000	Every fifth minute.
1:125,001 to 1:250,000	Every tenth minute.

The projection is constructed in pencil. It must be verified and all of the control stations plotted by *dms.* and *dps.* (see **7411**) and checked while the lines are in pencil. Only then are the projection lines to be inked as fine solid black lines 0.15 mm in width. The lines should extend entirely across the sheet. No borders are to be placed on smooth sheets.

The numbers representing the latitude and longitude shall be drawn in black ink at the ends of each parallel and meridian. They should be 3 mm in height and should be made in accordance with figure 145, preferably with a mechanical lettering set. Those representing degrees shall be repeated every fifth minute on scales of 1:20,000 and larger; every tenth minute on a scale of 1:40,000; and every thirtieth minute on smaller scales. For scales larger than 1:8,000, where the entire area falls within a 1-degree interval, the degree number must be shown at least once on the sheet, preferably near the center, the other lines being identified by the minutes and seconds only. The numbers must be followed by the respective degree, minute, and second symbols. Degree symbols should be 1.0 mm in diameter, and minute and second symbols 1.0 mm long, all centered on line with the top of the numbers. The numbers and symbols must be checked.

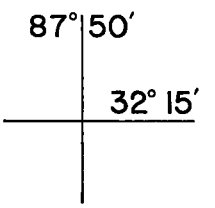

FIGURE 145.—Referencing projection lines.

7324. Construction of a Polyconic Projection

The construction of a polyconic projection is a comparatively simple problem, but extreme accuracy and care are necessary. The following instruments are needed: meter bar, beam compass, straightedge, dividers, and a quarter-meter scale (see **4821**). All of the elements are found in Special Publication No. 5, "The Polyconic Projection Tables." The area to be embraced and the orientation of the sheet and the scale are found in the layout of the project (see **136**); the interval between projection lines to be drawn depends on the scale (see **7323**).

From the layout locate the intersection of the most central meridian and parallel which are to be shown, and the direction of the central meridian. The accuracy with which this needs to be done depends on how near the edge of the sheet the work will extend. If extreme accuracy is required it is generally necessary to lay off carefully the limits of the sheet on a published chart of the area, thereby locating the central intersection and orientation. In some cases even preliminary mathematical computa-

tions are necessary to ensure the inclusion of the required control points as, for example, where they fall dangerously close to opposite edges of the sheet.

Although the projection can be made by continued reference to the projection tables, it is most desirable to make a rough sketch of the projection on a sheet of paper (see **322**), noting on it all of the distances to be plotted with the meter bar and beam compass. Depending on the scale of the projection being made and the scale of the meter bar being used, these distances will of course be reduced for use directly on the meter bar. For instance, if the projection is to be 1:40,000 and the scale of the meter bar is 1:20,000 all distances taken from the tables must be halved. All data from the tables must be taken out for the latitude in which they are to be used.

Referring to figure 146, the distances mm_1, mm_2, mm_3, and mm_4, are taken from the table headed "Meridional arcs," under "Continuous sums of minutes." The distances mx, mx_1, mx_2, mx_3, mx_4, and mx_5, for each parallel are taken from the table headed "Arcs of the parallel in meters" for scales of

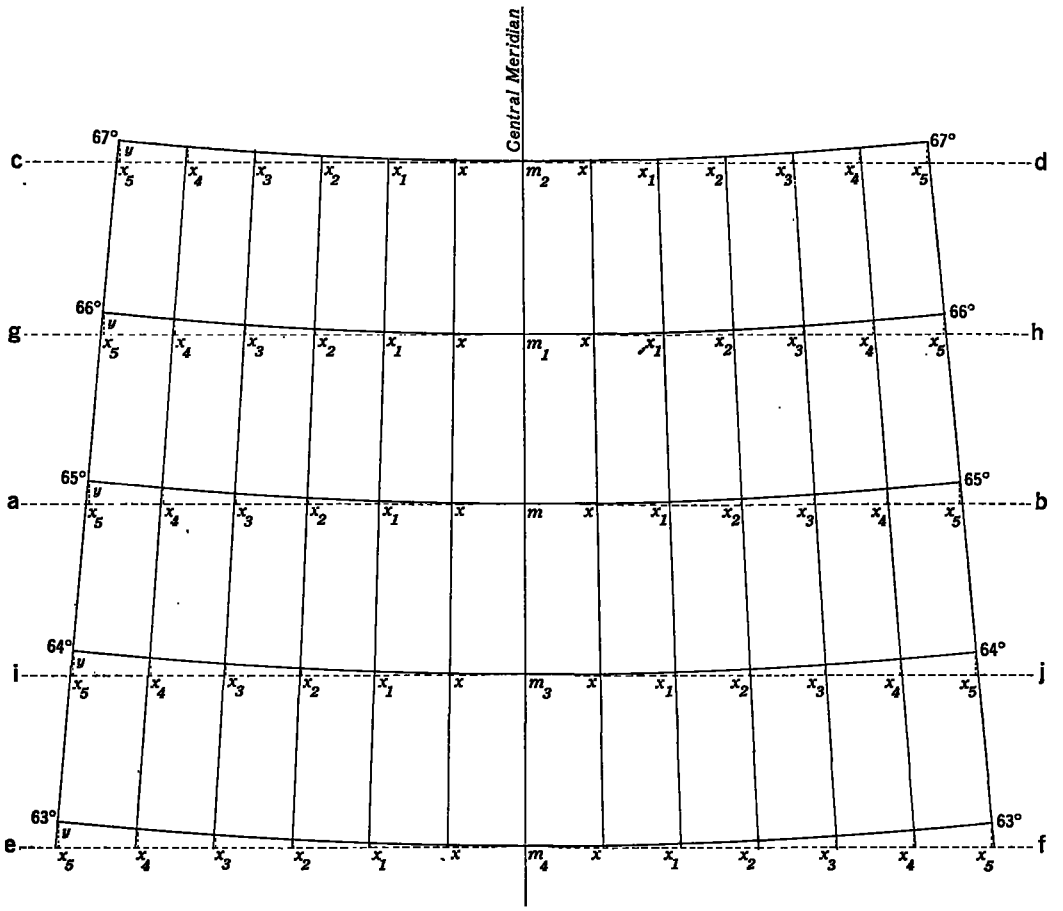

FIGURE 146.—Construction of a polyconic projection

1:40,000 or larger. For scales smaller than 1:40,000 they must be taken from the values of "X" under the table headed "Coordinates of curvature," interpolating for latitudes and longitudes intermediate between those given in the tables.

The construction is carried out by drawing the central meridian and the straight construction line ab perpendicular to it. The distances mm_1, mm_2, etc., are laid off along the central meridian using the beam compass and meter bar. The straight construction lines cd, ef, gh, and ij are drawn parallel

to ab through the points m_2, m_4, m_1, and m_3, respectively, and the distances mx, mx_1, mx_2, mx_3, mx_4, and mx_5 are laid off along these construction lines from the central meridian. It is especially important that these distances be laid off from the central parallel and the central meridian. The successive points m_1, m_2, etc., and x, x_1, x_2, etc., must never be laid off from one another.

The projection tables are now entered and "Y" values under the table headed "Coordinates of curvature" are found corresponding to the respective x-points. These values are laid off parallel to the central meridian, north of the construction lines if the projection is north of the Equator. These are usually short distances and difficult to plot. Best results can be attained by plotting an arbitrary distance, such as 100 or 200 meters on a 1:20,000 scale, south of the x-points and then plotting the arbitrary distance plus the "Y" values north from the arbitrary points.

"Y" values for latitudes intermediate between those given in the tables can be obtained by linear interpolation, but for longitudes intermediate between the tabular values, the following relationship should be used:

The ratio of any two successive ordinates of curvature expressed in meters, equals the ratio of the squares of the corresponding abscissas expressed in minutes or degrees.

This approximation is close enough under most conditions.

Each of the points plotted north of its respective x-point represents the intersection of a meridian and a parallel. Curved lines drawn through these points represent the meridians and parallels. Because it is difficult, in practice, to draw a curve of very large radius, the intersection points must be frequent enough so that the curved meridians and parallels can be drawn as a series of chords which will approximate the true curves. The projection must be left in pencil until verified and the control has been plotted. Finally the projection should be checked by measuring the intercepted distances between the adjacent meridians and parallels.

On projections of scales 1:10,000 or larger, it is generally sufficient to apply the Y-coordinates at the extreme meridians only, joining these points and the corresponding points on the central meridian with straight lines. The parallels so drawn are then subdivided equally for determining the intermediate meridians.

The construction of a polyconic projection is fully explained in Special Publication No. 5, "The Polyconic Projection Tables," and on pages 60–62 of Special Publication No. 68, Elements of Map Projection. The latter publication also gives the formula from which the errors of scale and area of any polyconic projection may be determined.

7325. Continuous Construction

The construction of a projection must be continuous, that is, it must not be begun and then laid aside to be resumed at a later date. It should be completed and checked on the same day, if possible. Construction on days of excessive humidity or excessive dryness should be avoided. When possible the projection should be made at a time of day and during a period of weather when the atmospheric conditions are stable and nearly average for the conditions under which the smooth sheet is to be used. It is important during construction that the projection be not exposed to the direct rays of the sun.

7326. Verification of the Projection

All details of the construction of the projection must be checked. This must be done while the projection is still in pencil, and must consist of a verification of the values taken from the polyconic projection tables and a complete check by measurement of the construction of the projection. Finally, corresponding diagonal distances should be compared with one another. It is to be noted that the polyconic projection is symmetrical with respect to the central meridian. Therefore, the diagonal distance between any two intersections on one side of the central meridian is equal to the diagonal distance between two corresponding intersections on the opposite side of the central meridian. A good construction check is a comparison of the long diagonal distance from

the northeast to the southwest corner through the construction center with the corresponding distance from the northwest to the southeast corner.

The verification must be made the same day that the projection is constructed and, if practicable, immediately following the construction.

7327. Ruling Machine Projections

Hand-ruled projections, carefully constructed, are usually of as great accuracy as is warranted when drawn on cloth-mounted paper. The Coast and Geodetic Survey has a projection ruling machine designed especially for ruling precise projections on mediums subject to little or no dimensional change, such as aluminum-mounted paper, aluminum plates, copper, and glass negatives. If practicable, all projections on such mediums should be made on the machine. It is not necessary to describe the details of the machine, except to say that projections of any type can be ruled on it, limited in size to 38½ by 56½ inches and limited approximately by the curvature required in a 1:500,000 scale conic projection.

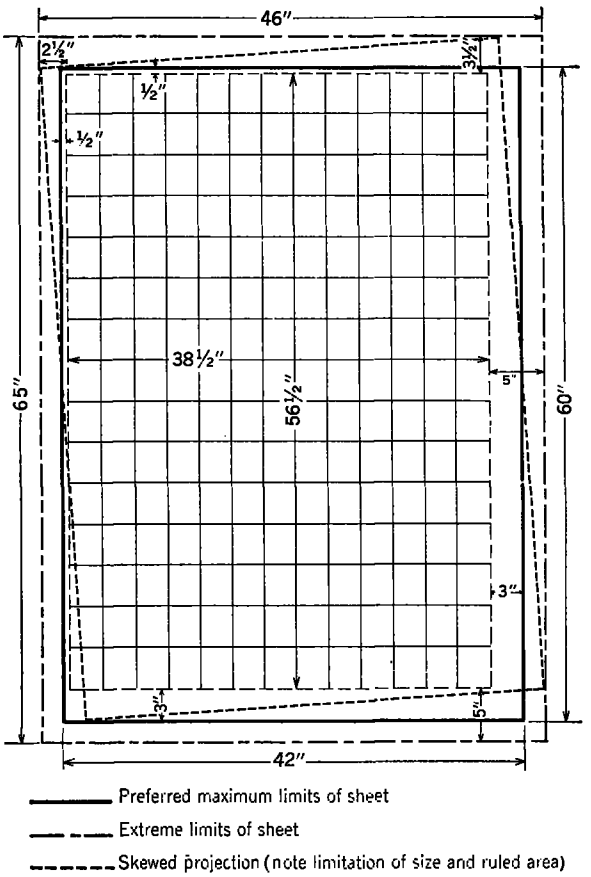

FIGURE 147.—Sheet limits for ruling-machine projections.

Chiefs of Party who wish machine-ruled projections should forward their requests sufficiently in advance to reach the Washington Office at least 3 weeks prior to the date they wish them shipped to the party. Such requests must always be accompanied by rough layout sketches showing the sheet limits by latitude and longitude, the scale, and the orientation of the projection if it is not parallel with the sheet edges. The polyconic projection will be assumed unless otherwise specified.

The size of a projection that can be drawn on the ruling machine is limited by a rectangle 38½ by 56½ inches whose sides are parallel to the projection lines. The sheet itself, however, can extend somewhat beyond these limits, but ordinarily should not exceed 42 by 60 inches (see fig. 147). In special cases a sheet 46 by 65 inches can be used. When projections larger than 38½ by 56½ inches are required, the lines must be extended by hand from the part ruled on the machine, which cannot be centered.

Where a skewed projection is to be ruled, the size of paper is also limited by the above dimensions, i. e., measured parallel to the projection lines, diagonally opposite corners of the sheet cannot be separated more than 46 inches in one direction nor 65 inches in the other direction (see fig. 147).

7328. Plane Coordinates

Plane coordinates are not used by the Coast and Geodetic Survey for plotting the results of hydrographic surveys, although they are used for this purpose in many foreign countries and are used in this country by various agencies for plotting all types of surveys.

There are various types of plane and rectangular coordinates. Three principal types are now in use in the United States:

(*a*) A rectangular system in which the plane of projection is a tangent plane, and the curvature of the earth is neglected; that is, the distances and angles measured in the survey are considered to have been measured on a plane surface.

(*b*) A system of rectangular coordinates in which the plane of projection is a tangent plane, but correction or adjustment is made for the curvature of the earth.

(*c*) The official systems of State coordinates on the Lambert conformal and the transverse Mercator projections devised and computed by the Coast and Geodetic Survey in 1933 and 1934.

In each of the above systems the coordinates are referred to two reference axes at right angles to one another, one of which almost invariably coincides with the true meridian. By convention the X-coordinate of a position is its distance east or west of one reference axis, positive where east and negative where west, and the Y-coordinate is its distance north or south of the other axis, positive where north and negative where south.

In coordinate systems of type (*a*) it is usual to select some point on the earth's surface as a point of origin. This may be a well-known landmark, the geographic position of which may or may not be known, but it is usually a geodetic station the latitude and longitude of which have been determined by the geodetic control surveys of the country. In such a system the area covered must be small and the part included is considered to be a true plane, and the results of the survey are plotted on the system without correction or adjustment for the curvature of the earth.

To coordinate such a survey with the nautical charts or the surveys of this Bureau, it is necessary that the latitude and longitude of the point of origin and the azimuth of one of the reference lines be known; or these data may be derived from the known latitudes and longitudes of other points and azimuths in the system, whether or not one of them is taken as the point of origin. For coordination it is preferable that the latitude and longitude of several widely separated points on the survey be known so that not only can the survey be coordinated, but its scale may be determined independently. (See **2361**.)

For systems of rectangular coordinates of type (*b*) the points on the earth's surface are corrected for curvature so that the plane coordinates resulting therefrom have an accuracy of 1 part in 50,000 at a distance of 25 miles from the origin of the system. In this method of computation the plane coordinates are derived directly from the differences in latitude and longitude between some chosen origin and the given station. These differences are transformed directly into X- and Y-coordinates by the use of tables given in Special Publication No. 71, Relation Between Plane Rectangular Coordinates and Geographic Positions. This system approximates an equidistant azimuthal projection on a tangent plane and it is sufficiently accurate to cover a considerably larger area than can be covered in type (*a*). In no case, however, should it extend more than 20 or 25 miles from the origin.

The official State coordinate systems of type (*c*) were devised and computed by the Coast and Geodetic Survey in 1933 and 1934. One system with one point of origin

is used for each State, where practicable, although in the larger States two or more systems were necessary. These have been computed on two different types of projection: the Lambert conformal conic for those States of an east-west extent proportionately great as compared to their north-south extent; and the transverse Mercator projection for those States with a proportionately great north-south extent. The coordinates on the State systems have been computed for all geographic positions adjusted since 1935 and these are published in the official publications of the triangulation of the country.

Details of these systems, the methods of making the computations and the methods of plotting various types of surveys thereon, are given in several publications. They are given in brief in Serial No. 624, Computation of Traverse by Plane Coordinates, and in fuller detail in Special Publication No. 193, Manual of Plane Coordinate Computation; Special Publication No. 194, Manual of Traverse Computation on the Lambert Grid; and Special Publication No. 195, Manual of Traverse Computation on the Transverse Mercator Grid.

For the coordination of surveys on the systems in type (*c*) with hydrographic surveys of this Bureau, no information is needed except the knowledge that the survey is on one of the official State systems and which system.

733. Hydrographic Sheets From Air Photographic Surveys

Where the shoreline and hydrographic control originate with air photographic surveys (see **239**) the information for the boat and smooth sheets will be furnished by the Washington Office in the form of reversed tracing-paper prints, ozalid prints, printed sheets, or map projector transfers. The form used will depend upon the conditions peculiar to the project and will be stated in the project instructions.

The short descriptions of stations, for the information of the hydrographer, will be furnished on ozalid prints to be used by the hydrographic party when recovering the stations and building the signals (see **2392**).

7331. Reversed Tracing Paper Prints

Ordinarily the air photographic survey drawings are forwarded to the Washington Office as soon as the location of the shoreline and the hydrographic control is completed. These are reproduced in the Office to the same scale as the hydrographic surveys and reversed copies are printed in black on tracing paper and furnished the hydrographic parties. The ink used is slow drying and usually the print used in preparing a boat sheet can also be used for preparing the smooth sheet some months later.

The transfer of the shoreline and control is effected by superimposing the tracing (inked side down) on the boat sheet or smooth sheet, so that corresponding projection intersections are in coincidence, and burnishing down the details. Adjustments for differences in the projections can be made by small shiftings of the tracing (see **7413**).

If the ink has dried before the smooth sheets are prepared, additional tracing-paper prints will be furnished on request.

7332. Ozalid Prints

In some cases where the air photographic surveys are made at exactly the same scale as the hydrographic survey and when sufficient time is not available to prepare reversed tracing-paper prints, ozalid prints will be furnished the hydrographic party for transfer of the shoreline and control.

Ozalid prints are photographic contact prints prepared in much the same manner as blueprints. The developed print shows a colored line on a white background. These prints are developed by a dry process and have a low percentage distortion. They are satisfactory copies from which to transfer shoreline and control points, but it is necessary that the hydrographic party make a pencil tracing for such transfer (see **7413** and **7561**).

7333. Printed Hydrographic Sheets

Where the hydrographic sheet layout can be made to conform approximately to the air photographic sheet layout, and where there are numerous stations and intricate shoreline details, printed smooth sheets and boat sheets are practicable and economic, and will be furnished to hydrographic parties. The copies are printed at the scale of the hydrographic surveys and on the same cloth-backed paper ordinarily used for boat sheets and smooth sheets. All details are reproduced in black, including triangulation and topographic station symbols, in addition to the projection and topography.

The positions of the stations need not be checked by the field party. The symbols for the topographic stations shall be left in black on the smooth sheets, but may be encircled with additional 3 mm red circles on the boat sheets, if this is found desirable. The triangulation symbols shall be left in black. Topographic station names shall be assigned by the hydrographic party, and shall be shown in red on both the boat and smooth sheets. (See also **744**.)

7334. Map Projector Transfers

In some cases, although the boat sheets and smooth sheets are prepared in the Washington Office, photolithographic reproductions are not made because of insufficient time, or because the air photographic surveys are on an odd scale and a printing plate is not yet available, or when their limits differ greatly from the hydrographic survey. In such cases the projections are made on the projection ruling machine, and the shoreline and control points are transferred (and checked) from the air photographic surveys by means of the map projector (see **4854**). The transfer is usually made in pencil and shall be inked by the field party. A data record showing how the projection was made, and how and by whom the shoreline and stations were transferred and checked is forwarded to the field party with each smooth sheet. This record shall be included in the Descriptive Report for the sheet (see **842***E*).

734. PROJECTIONS FOR R.A.R. SHEETS

The best grade of well-seasoned paper shall be used for an R.A.R. smooth sheet. The projection is constructed just as any other projection is, but immediately after its completion and verification and the plotting and verification of the R.A.R. stations, and before any inking is done, the *distance circles* must be drawn (see **7341**), in order to avoid complications due to distortion of the paper. Obviously, such projections should not be requested from the Washington Office.

7341. R.A.R. Distance Circles

In contrast to other methods of hydrographic control, positions determined by Radio Acoustic Ranging (described in chapter 6) are based on distances from the R.A.R. stations and these are sometimes quite long. To facilitate plotting these distances and to take into account any distortion which occurs in the smooth sheet after the projec-

tion is made, segments of concentric circles are drawn on the sheet from each R.A.R. station as a center, covering the area in which bomb returns were received from the respective stations. These circles are termed *distance circles* to distinguish them from the short *distance arcs*, which are drawn only in the immediate vicinity of each R.A.R. position (see **763**).

All distance circles are plotted in units of time intervals from a given station based on an assumed velocity of sound of 1,460 meters per second. The spacing of the circles on the sheet should be according to table 25.

TABLE 25.—*Distance circle intervals for various scales*

Scale of survey	Distance circle interval
1:40,000	Every 3 seconds.
1:50,000 to 1:80,000	Every 5 seconds.
1:100,000 to 1:160,000	Every 10 seconds.
1:200,000	Every 15 seconds.

The unit of measurement *second* is used here to mean a second (time) of sound travel through sea water. Thus, a circle representing 5 seconds of sound travel would be plotted a distance of 1,460 x 5=7,300 meters from the station at the scale of the survey.

Preparatory to placing the circles on the sheet, and preferably even before the projection is begun, the boat sheet should be studied to determine the area in which bomb returns were received from each R.A.R. station. This will be the area through which the distance circles should be drawn. It is important that this instruction be carefully followed in order to avoid unnecessary confusion where many stations are used on a sheet. A table should also be prepared in advance giving the lengths in meters of the various radii, computed at the plotting velocity of 1,460 meters per second and converted to the scale of the meter bar being used. This table is then used for setting the distances on a beam compass.

To plot the circles the successive radii lengths are pricked lightly on the smooth sheet. This should be done at two or more radial directions from the R.A.R. stations, so that each distance circle when drawn may be checked as it passes through the pricked points. To avoid a repetition of measurements, each distance, as set on the beam compass, should be plotted from every R.A.R. station where it will be needed.

After the plotting of the radii has been checked, the distance circles are drawn in blue ink through the pricked points, using a fine light line. The distances in seconds may be placed on the circles in pencil for temporary convenience.

It is essential that the smooth sheet be kept absolutely flat while the radii are being plotted and the circles are being drawn. This can be accomplished, in the first case, by laying a straightedge on the sheet from the station to the pricked points, and in the second case, by having an assistant slide a straightedge along the sheet paralleling the beam compass, immediately in advance of or behind it. A clean stainless steel straightedge, or one whose underside is covered with a clean piece of paper, must be used in order to prevent soiling the smooth sheet.

The continued use of the beam compass at the R.A.R. stations tends to enlarge the station holes. To avoid this a small circular piece of thin celluloid is temporarily placed over each station with Scotch tape, so that the compass point rests on the celluloid instead of on the paper. Where this is done the pricked point in the celluloid must be precisely over the plotted position on the smooth sheet. Pencil lines should be drawn at right angles through the plotted position on the smooth sheet, by which the celluloid, on which similar lines at right angles have been drawn or finely etched, may be correctly superposed. If only a few distance circles are to be drawn from any one station the celluloid may be dispensed with, if caution is taken to avoid an excessive downward pressure on the beam compass.

Two R.A.R. control stations are frequently used at locations very close to one another. Confusion would result if concentric distance circles were drawn from both of these as origins. Instead, the distance circles are drawn from that station from which the larger percentage of R.A.R. distances was obtained during the survey. The method of plotting in such cases is explained in **7631**.

There will be occasional cases where an R.A.R. station used for control is beyond the limits of the sheet. If such a station is within reach of a beam compass, it may be plotted by using a computed distance and direction from a latitude and longitude intersection on the projection. A specially long beam compass may be required for drawing the distance circles (see **3741***c*1).

Distance circles involving radii too long to be drawn with a beam compass may be constructed by computing the rectangular coordinates of points on the circles and drawing the circles by using standard curves. The formulas for computation are the same as for constructing "circle" sheets by the computation method except that the origin of coordinates is taken as the intersection of two distance circles on the sheet, the Y-axis being the azimuth from the intersection to an R.A.R. station and the X-axis being normal thereto at the same point. (See **3741***c*2.)

After the distance circles have been drawn on the smooth sheet and the other control stations plotted and checked, the projection lines are inked (see **7323**). Control station names in the water area must be left in pencil for subsequent inking (see **7443**).

735. PLOTTING LARGE-SCALE OFFSHORE SURVEYS

Large-scale offshore surveys using three-point fix control cannot usually be made or plotted with the degree of accuracy required, if conventional methods of plotting are used—that is, with a three-arm protractor. Instead, the "circle" sheet method is used in which the observed angles are plotted by means of their loci, systems of which have been drawn in advance on the boat sheet or smooth sheet. A full discussion of this method of surveying and of the method to be used in preparing such sheets is given in section **37**. The smooth plotter should familiarize himself thoroughly with the method before beginning work on such a smooth sheet.

After the arcs have been plotted and verified, they should be inked in blue using a fine light line similar to that used for R.A.R. distance circles (see **7341**). The arcs should be identified by inking the degrees and minutes in the same color near the ends of the arcs. It is unnecessary and undesirable to ink all the arcs used in protracting

the positions. The purpose of inking is to give permanence to selected arcs, so as to facilitate future identification of the positions. The smooth-sheet plotter should bear this in mind when selecting the arcs to be inked. In general, a spacing of about 3 inches between inked arcs will be satisfactory. Only those portions of the arcs in the sounded area should be inked.

736. CHANGING DATUM OF SURVEY SHEET

To correlate the results of two surveys, it is first necessary to bring the two to the same geographic datum (see **2171**). This makes it possible to compare corresponding areas by means of the projection lines on the sheets.

Practically all of the recent surveys of the Bureau in continental United States are based on the North American datum of 1927, but many prior surveys are still on the North American datum or some independent datum. To change the datum of a survey sheet the usual practice is to apply corrections to the projection on the sheet. When copies of old surveys are furnished to field parties, the latest datum is usually shown on the sheet. The procedure given below describes how this may be accomplished under various conditions. Where the datum on a survey sheet has to be corrected in the field, the data available will generally determine the method to be used.

There are two methods of applying a datum correction to a survey sheet, a numerical one (**7362**) and a graphic one (**7363**).

7361. Distortion Factor

Before datum corrections can be applied, the distortion factor of the sheet must be determined in both a north-south and an east-west direction. This is done by comparing the scaled distances between projection lines on the sheet with the corresponding values given in Special Publication No. 5, "Polyconic Projection Tables" (see **7324**). The distortion factor is determined from the relation:

$$\frac{\text{Tabular value} - \text{Scaled value}}{\text{Tabular value}} = \pm \text{Distortion factor}$$

Several distances in each direction should be measured in order to obtain a mean factor and to ensure against errors in the original projection. The distortion factor should be applied to every distance that is to be plotted on the sheet. To reduce measurements on the distorted sheet to true values the following relation should be used:

$$\frac{\text{Tabular value} - \text{Scaled value}}{\text{Scaled value}} = \pm \text{Correction factor}$$

7362. Numerical Method

In the numerical method three widely distributed triangulation stations on the sheet are selected, whose geographic positions on the N.A. 1927 datum are available. Identify these stations on the datum of the projection in the old registers in the Surveys Branch of the Chart Division, or in any of the publications of the Bureau, and check their geographic positions with the positions plotted on the sheet. The mean of the differences between the values on the two datums is the correction to be applied to the projection on the sheet. The differences for the three stations should nearly equal each other. If a wide variance is found, an investigation should be made for possible errors in the computations or for failure to identify common stations on the two datums.

Great care must be taken to see that the correction is applied in the proper direction. The following rule will be found helpful in determining the direction:

If the latitude (N.) and longitude (W.) on the old datum are greater than the corresponding values on the new datum, then the new projection will be to the north and west, respectively, of the old projection. If the old values are smaller than the new ones, it will be to the south and east.

From this the direction of the correction for other relationships can be readily determined. To avoid errors of application in plotting, a sketch should be made, showing the relationship of the two datums to one of the selected triangulation stations, with the corresponding latitudes and longitudes indicated.

The new datum should be marked by short intersections at not less than two projection intersections on the sheet and should be shown in colored ink, preferably red. At one of the intersections the name of the datum, the latitude and longitude, the initials of the cartographer making the correction and of the verifier, and the date the correction was made, should be noted in colored ink. (See fig. 148.)

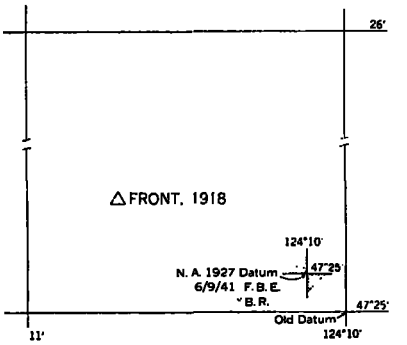

FIGURE 148.—Change of datum of survey sheet—by numerical method.

Example: In figure 148, the latitudes and longitudes of △ FRONT, 1918 on the old and new datums are as follows:

North Latitude	*West Longitude*
47° 25′ 450 meters (old datum)	124° 10′ 900 meters (old datum)
47° 25′ 300 meters (N.A. 1927 datum)	124° 10′ 750 meters (N.A. 1927 datum)
150 meters difference	150 meters difference

Applying the above rule, the new projection (N.A. 1927 datum) is found to be to the north and west of the old projection. Therefore, the intersection of latitude 47° 25′ N. and longitude 124° 10′ W. on the new datum is obtained by laying off the distances 150 meters (corrected for distortion) in a north and in a west direction from the old datum.

Reference station on the sheet.—If the latitude and longitude of one of the plotted stations is recorded on the sheet (see **746**), the correction may be obtained by subtracting from them the corresponding values on the N.A. 1927 datum. For field application, where photographic copies of old surveys are used, the single correction thus obtained is sufficiently accurate for use on the entire sheet, but in the Office where the original sheet is available, additional stations should be used and a mean correction obtained in accordance with the procedure outlined above.

The numerical value shown on the sheet should always be checked against the plotted position of the station before using it for determining a datum correction.

7363. Graphic Method

This method of correcting the datum on a survey sheet is applicable under three conditions: (1) as an alternative to the numerical method, (2) where geographic positions of the stations on the datum of the sheet can be found neither in the old registers (see **7362**) nor in any of the publications of the Bureau, and (3) where the old registers are not available, as is usually the case in the field.

Select three well-distributed stations on the sheet, the geographic positions of which are available on the N.A. 1927 datum. Determine the *dm.* and *dp.* of each station (see **7411**) from the projection lines nearest to it (this will mean using the

back *dms.* and *dps.* in some cases), and with these values as radii from the plotted position of the station as a center, swing short pencil arcs in the proper directions. Draw pencil lines tangent to these arcs and parallel to the latitude and longitude lines on the sheet. The intersection of these lines will give the position of the new datum. Carefully scale the offsets $\Delta\phi$ and $\Delta\lambda$ from the old datum on the sheet. (Fig. 149 illustrates the application of this method to the example given in **7362**.)

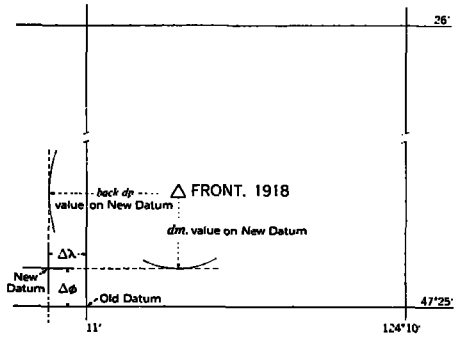

FIGURE 149.—Change of datum of survey sheet—by graphic method.

Follow the same procedure with the other selected stations and compare the offset values obtained in each case. If they do not differ by a plottable amount, accept the intersections as determined, otherwise use a mean of the values. Any appreciable differences should be investigated. The method of designating the new datum on the sheet is the same as for the numerical method.

7364. Lost or Unrecoverable Stations

Stations are sometimes lost or have become unrecoverable and cannot therefore be included in the triangulation to connect them with the new datum. Where a survey sheet contains such stations only, then the relationship between the old and new datums must be obtained from stations on adjoining sheets for which the new datum values are available. A mean of the corrections derived from the adjoining sheets should be used.

The present plan of the Bureau is to include, in the published triangulation data for the coastal states, a list of lost stations with their geographic positions (unadjusted) on the North American datum of 1927. While such values are not to be used for extending triangulation, they are adequate for coordinating old and new surveys. These volumes should be consulted before applying datum corrections to a sheet.

737. PROJECTION CONSTRUCTED AFTER SURVEY

It becomes necessary occasionally to execute a survey and complete the smooth plotting prior to the determination of the geographic positions of the control points, as where the local triangulation has not been connected to the main net of triangulation or where astronomic observations have not been made. In such cases the control points are plotted on the boat sheet and the smooth sheet either by angles or distances. Many of the early surveys of the Bureau were made in this manner. (See **392** and **393**.)

In constructing a projection on a survey sheet that has no projection, the distortion of the sheet is one of the important elements to consider and upon the accuracy of its determination will depend the accuracy of the projection. Paper does not always distort uniformly and the shrinkage or expansion should be determined in both a north-south and an east-west direction and a factor applied to all measurements to be laid down on the sheet (see **7114**). It should be remembered, however, that the smaller the distance to be plotted the less will be the error of distortion so that in laying down projection lines from plotted triangulation stations, corrections may be avoided by selecting stations close to the lines to be constructed.

Whenever a smooth sheet is prepared in advance of the position computations, two distances not less than one-half meter in length should be plotted on the sheet at right angles to each other, along the bottom and along the right-hand edge. The ends of these distances should be marked with small inked circles and the distances at the scale of the survey indicated. This will permit checking the distortion at any time and simplify the future application of a projection.

There are two methods of reconstructing a projection on a survey sheet. One is a rigid method applicable to small-scale surveys and the other is a graphic method applicable to large-scale surveys. In both methods the essential problem is the determination of the cardinal lines of the projection, namely, the central meridian and the central construction line.

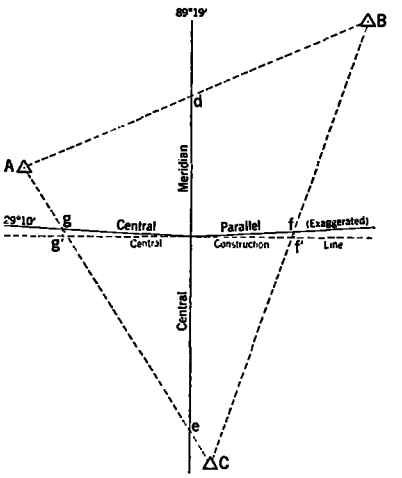

FIGURE 150.—Construction of a polyconic projection on a completed survey sheet—for small-scale surveys.

7371. *On Small-Scale Surveys*

For surveys on scales smaller than 1:10,000 the following method is used:

(1) Select three triangulation stations, *A*, *B*, and *C* (fig. 150) so situated with respect to the central meridian that the distance *de* will cover more than half the latitude extent of the sheet. Two of the stations should be selected, if possible, in about the same latitude (see (6) below). From the scaled lengths of *BA* and *CA* and the corresponding computed lengths (make inverse computations for these if they are not in the triangulation data), determine the distortion factor along each line (see **7361**).

(2) Select the central meridian (as near to the middle of the sheet as possible) and compute the distances *Bd* and *Ce* and the latitudes of the points *d* and *e*.

This is accomplished on Form 27, Position Computation, Third-Order Triangulation. Since both the distance and latitude are involved in the position computation formulas, a trial-and-error method is used. A value is assumed for the required latitude (ϕ') and from the known longitudes (λ) and (λ') of station *C* and the central meridian, respectively, and the known azimuth (α) of the line *Ce* (obtained either directly from the triangulation data or from the inverse computation), the distance (s) is computed from the longitude formula. This distance is then used in the latitude formula and the latitude increment or decrement ($\Delta\phi$) is obtained. This computed $\Delta\phi$ may not agree with that derived from the assumed latitude (ϕ'), but by repeated assumptions a value for $\Delta\phi$ will be obtained that is in absolute agreement with the assumed latitude.

To obtain a close first approximation, a sketch should be drawn at about one-fifth the scale of the sheet, using a rectangular grid and using as units of measurement the values of a minute of latitude and longitude at the center of the sheet. From this sketch the latitude where a given line crosses the central meridian can be scaled and this value used as the first assumed value in the computation.

(3) Plot points *d* and *e* along lines *BA* and *CA* correcting each computed distance for the distortion determined along the respective lines. Through *d* and *e* draw a straight line for the full length of the sheet. This is the *central meridian* of the projection.

(4) Scale the distance *de* on the sheet and from the computed latitudes obtain from the polyconic projection tables the true distance. From these two values the distortion in a north-south direction is determined.

(5) On the central meridian lay off the tabular distance (corrected for distortion) from point *d* or *e* to the central parallel and at this point construct a perpendicular to the central meridian extending the full east-west length of the sheet. This is the *central construction line.*

(6) From here the problem is the ordinary one of constructing a polyconic projection as given in **7324**. The distortion factor to be applied to east-west measurements may sometimes be obtained from the disposition of the selected triangulation stations (see (1) above).

The projection should be checked against every triangulation station on the sheet. Small differences in latitude or longitude may be due to unequal distortion of the sheet. In such case the projection should be made consistent with the triangulation even though this results in a slightly skewed projection.

Determining east-west distortion.—If the east-west distortion of the sheet is not available from the disposition of the triangulation stations on the sheet, it can be determined in the following manner:

(1) Compute the longitude crossings of the lines *CB* and *CA* (fig. 150) on the central parallel or any other parallel that will give a distance long enough to determine a good distortion factor.

This is accomplished on Form 27 in a manner similar to that described in (2) above for determining the latitude intersection. With the azimuth of the line *CB* as previously determined and the known latitude increment or decrement ($\Delta\phi$), a value for (s) is found by trial and error that will make the sum of the latitude terms in the computation formula equal to ($\Delta\phi$). From this value of (s) the required longitude (λ') is computed.

A close first approximation for the distance (s) can be obtained by making $\Delta\phi$ equal to the 1st term in the latitude formula (neglecting the 2nd term) and with the (s) value thus found, the 2nd term is computed. A new value for the 1st term is then found that will make the sum of the two terms equal to $\Delta\phi$. The resulting value of (s) is then used in the longitude formula to obtain (λ').

Because of the distances usually involved, it will seldom be necessary to carry the computation beyond the 2nd term in the latitude formula.

(2) Plot the computed distances *Cf* and *Cg* (corrected for distortion) along lines *CB* and *CA* and at points *f* and *g* draw short lines parallel to the central meridian. Lay off to the south (in north latitude) on these lines the *Y*-coordinates from the polyconic projection tables for the appropriate longitude distance and obtain points *f'* and *g'*. The scaled distance between these points compared with the tabular distance as determined from their *X*-coordinates will give the distortion factor in an east-west direction (see **7361**).

If a linear interpolation of the *X*-coordinate values given in the table is not close enough for any latitude ϕ and difference of longitude $\Delta\lambda$, then the interpolation should be made by second differences or the values computed from the formula:

$$X \text{ (in meters)} = \frac{6{,}378{,}206}{(1-0.00676866 \sin^2 \phi)^{1/2}} \cot \phi \sin (\Delta\lambda \sin \phi)$$

The error due to neglecting second differences is no greater than one-eighth their value.

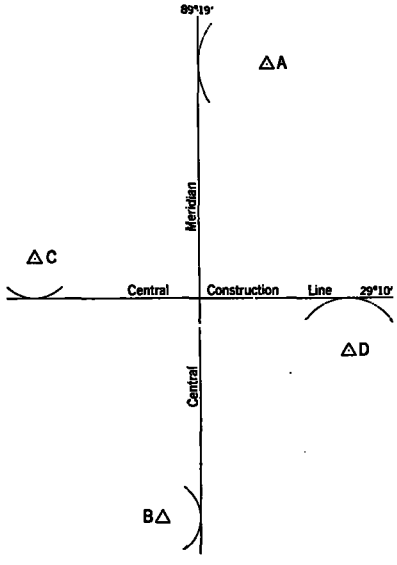

FIGURE 151.—Construction of a polyconic projection on a completed survey sheet—for large-scale surveys.

Wherever possible, advantage should be taken of the location of some of the triangulation stations to reduce the amount of computation for determining the east-west distortion. For example, in figure 150, the parallel through station *A* can be used instead of the parallel through *g*, thereby making it unnecessary to compute the longitude of *A*.

7372. *On Large-Scale Surveys*

For small areas such as those covered by the large-scale topographic and hydrographic surveys of the Bureau, the polyconic projection is practically identical with the rectangular projection or a modification thereof (projection with converging meridians); therefore in reconstructing a projection on surveys of scale 1 : 10,000 or larger, the following graphic method can be substituted for the more rigid method described above.

(1) After the distortion of the sheet has been determined, from comparisons between scaled and computed distances, select two triangulation stations, *A* and *B* (fig. 151), near the north and south extremities of the sheet and as close to the center of the sheet as possible. From the "Arcs of the parallel" in the polyconic projection tables, obtain the distance from each station to the central meridian and with these distances (corrected for distortion, see **7361**) as radii and the stations as centers swing arcs. Draw a line tangent to these arcs for the entire length of the sheet. This line is the *central meridian* of the projection.

(2) Select two other triangulation stations *C* and *D* near the east and west extremities of the sheet and as close to the central parallel as possible. From the "Meridional arcs" in the polyconic projection tables obtain the distance in meters from each station to the central parallel. To these distances add or subtract the *Y*-coordinates from the tables corresponding to the difference in longi-

tude between the central meridian and each station. (For north latitude, add if the station is above the central parallel and subtract if below. For south latitude the reverse is true.)

(3) With the distances thus obtained (corrected for distortion) as radii, swing arcs from stations *C* and *D* in a direction toward the central parallel. Draw a line tangent to these arcs for the entire width of the sheet. This line will be perpendicular to the central meridian and will be the *central construction line* of the projection.

(4) The remainder of the projection is constructed according to the method given in Special Publications No. 5 and 68 for large-scale projections.

7373. Modified Methods

The above two methods illustrate the general principles involved in the problem of constructing a projection on a smooth sheet subsequent to its completion. It may sometimes be necessary to modify the methods described because of special conditions encountered. For example, where all the triangulation stations are on one side of the central meridian, the rigid method is not applicable in its entirety and a combination of the two methods must be used. In such cases the central meridian is determined graphically and the intersection of the central parallel with a line between two of the triangulation stations is computed. The *Y*-coordinate of the intersection is plotted and a perpendicular erected to the central meridian, the intersection of the two being the center of the projection.

Even in a small-scale survey, if the longitude extent is small enough, the curvature of the parallels may be neglected and the graphic method will give the required accuracy.

There are also cases where the survey is a planetable traverse (**392**) or a running ship survey (**3941**) in which the azimuths and distances at one end are comparatively accurate but which decrease progressively in accuracy toward the other end. Where such a survey is plotted without a projection and selected stations are subsequently located by triangulation and an attempt is made to place a projection on the sheet adjusted to the triangulation stations, a single harmonious projection could not be constructed. If the work is not to be replotted, then the only way to bring the entire survey into harmony geographically is to place a discontinuous projection on it, each portion being based on the triangulation in its vicinity.

In adapting any of the methods to a particular problem in hand, the two considerations to be kept in mind are the theory of the polyconic projection and the means available for determining the distortion of the sheet.

74. PLOTTING THE CONTROL

After the projection has been made and checked, the next step in the preparation of a smooth sheet is the plotting of the control (see section **21**). There are two general classifications of control insofar as a hydrographic survey is concerned. First, the fixed control, also commonly known as shore control (see sections **22**, **23**, and **24**); and second, the floating control (see section **25**). Before plotting is begun, a selection should be made from the control falling within the limits of the smooth sheet and only those stations plotted that were actually used to control the hydrography. The boat sheet may be used as a guide (see **3245**).

The control stations must be plotted with the utmost care and accuracy, since inaccuracies in their positions may result in errors in the positions of the soundings, the errors increasing with the distance from the control stations. Stations whose geographic positions are known should be plotted with an accuracy that will ensure no plottable error at the scale of the survey sheet.

741. PLOTTING THE SHORE CONTROL

Shore control may be divided into three classes according to the method and accuracy of determination (see **211**). First, is the control located by triangulation; second, that located by topography; and third, the remainder, which is located by the hydrographic party, usually by sextant angles. Of these three types of control the latter, the hydrographic stations, are invariably located for the purpose of controlling the hydrographic survey. The topographic stations are almost always located for this purpose, especially if the topographic survey immediately precedes the hydrographic survey. The triangulation stations, however, have often been located for the purpose of controlling the topography or as part of an arc of triangulation, and may or may not be valuable in controlling the hydrography.

There are several methods in use for plotting the shore control on the smooth sheet, depending upon the form in which the data are available. These methods are described in the following items.

Cuts, angles, and distances may often be combined in various ways to furnish positions of control stations. These are described in chapter 2. Such determinations are usually best plotted with the three-arm protractor in the manner described in **4534**, if computations are impracticable.

7411. Plotting by Dms. and Dps.

The data for plotting triangulation stations are usually furnished on Form 28*B*, Geographic Positions. The latitude and longitude in degrees, minutes, and seconds are given for each station, as well as the distances and azimuths between stations. The equivalents in meters of the seconds of latitude and longitude are also given for stations along the coast and these are known as the *dms.* (meridional differences) and *dps.* (parallel differences), respectively, of the stations. Thus, if the position of a station is given as latitude 54°44′34″.189 N. (1,057.2 meters), longitude 130°56′42″.362 W. (756.5 meters), its *dm.* is 1,057.2 meters north of the 44-minute parallel, and its *dp.* is 756.5 meters west of the 56-minute meridian.

To plot a triangulation station, the quadrilateral on the projection within which the station falls is first identified. With a pair of dividers and a metric scale (see **4821**), plot its *dm.* near each meridian line and mark with a fine prick point. Connect the two points thus plotted with a fine pencil line, using a chisel-edged 6H pencil. Plot the *dp.* of the station along this line and mark with a fine prick point. This will be the position of the station provided there is no distortion in the paper.

As a check of the plotting, and to compensate for any possible distortion, the station must also be plotted from the north parallel and the west meridian of the quadrilateral. These distances are the *back dm.* and *back dp.* for the station, and if not already available, they may be obtained by subtracting the *dm.* and *dp.* values from the value of 1 minute of latitude and longitude, respectively, as given in the polyconic projection tables for the latitude of the station. If the sheet contains an appreciable amount of distortion the plotted distances will result in two pairs of points, each pair closely adjacent. The true position of the station will be at a distance from the points proportional to their respective distances from the projection lines. (See fig. 152.)

The position of the station should be marked with a fine prick point and identified temporarily by a small circle and the name of the station, both in pencil.

In plotting by *dms.* and *dps.* do not use the intersections of meridians and parallels to plot from, but use points on the parallels or meridians slightly offset from the intersections. A magnifying glass should always be used for setting the dividers on line and for selecting the final position of the station. The beam compass should be used if the distances are too long to plot accurately with dividers.

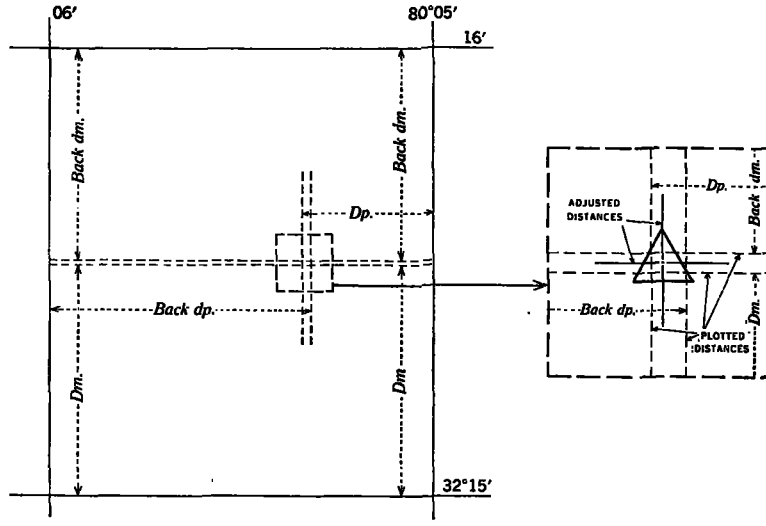

FIGURE 152—Control stations plotted by *dms.* and *dps.* on a distorted sheet.

On recently constructed smooth sheets in which there is no distortion, triangulation stations should always be plotted by the *dm.* and *dp.* method. The plottings may be checked with the "latitude and longitude scales" (see **7412**).

Other types of control are often plotted by *dms.* and *dps.*, especially when their positions are available only in this form.

7412. With Latitude and Longitude Scales

Geographic positions may also be plotted with latitude and longitude scales (*C* in fig. 91). These are similar in appearance to a triangular engineer scale, each containing one scale for the plotting of latitude and five scales for the plotting of longitude at various latitudes. With these scales a geographic position is plotted by minutes and seconds directly, without recourse to the *dms.* and *dps.*

Each scale covers a distance slightly longer than 1 minute of arc at a scale of 1:10,000 and is divided into 60 main divisions, each division being further subdivided into 5 divisions. It is thus possible to plot 0.2 second of arc directly from the divisions and to interpolate to 0.05 second. By placing the scale slightly at an angle to the meridians or parallels, the two ends of the scale may be made to coincide with the two adjacent meridians or parallels, thus dividing the intervening space into 60 equal parts. When a station is to be plotted, the correct latitude should be marked at a slight distance each side of the station, the two points being connected by a fine straight line. The longitude may be similarly plotted, the correct position being at the intersection of the two lines; or the longitude may be plotted directly on the line of correct latitude. (For further description see **4822**.)

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These scales may be used satisfactorily for plotting stations on scales of 1:10,000 and 1:20,000. They are not particularly useful for other scales. Their chief advantage is in plotting on sheets that contain some distortion, and in checking previously plotted positions. Tests in the Washington Office indicate that geographic positions can be plotted with these scales with approximately the same accuracy as is attained by the use of a beam compass or dividers, and can be scaled or checked with considerably greater speed by one accustomed to their use.

7413. Plotting by Transfer

The stations located by topography are usually placed on the smooth sheet by transfer from the topographic sheet. Ordinarily the topographic survey has immediately preceded a hydrographic survey and its scale has been determined by the desired scale of the hydrographic survey. In such cases, the scales are identical and, if there is no distortion in either sheet, the most expeditious method of transferring the positions of the signals to the smooth sheet is by tracing paper. Tracing cloth should not be used for this purpose since it is subject to larger dimensional changes than the paper.

The tracing paper is securely fastened over the topographic sheet and a needle, or other fine point, is used to prick the exact positions of the topographic stations and the adjacent projection intersections through the paper; the shoreline and topography are usually transferred at the same time (see **7561**). The stations and the intersections are temporarily identified by symbols or otherwise in pencil. The tracing paper is then superposed on the smooth sheet with the corresponding projection-line intersections in coincidence, and the positions of the topographic stations are pricked through the holes in the tracing paper into the smooth sheet, and temporarily marked in pencil.

If there is distortion in one or both of the sheets, the projection intersections will not all coincide. In such a case the tracing paper must be adjusted for each quadrilateral so that the difference between the two projections is proportioned for each station plotted. Sometimes the tracing has to be shifted several times, as where stations are located in different parts of the quadrilateral. Even if there is no apparent difference between the two projections the coincidence of the adjacent intersections should be verified before the stations are pricked through.

Where shoreline and other topographic detail are also to be transferred, it may be found more expeditious to prick on blank tracing paper the projection intersections of the sheet *to* which the transfer is to be made. These pricked intersections are then adjusted, quadrilateral by quadrilateral, to the topographic survey *from* which the detail is traced. This eliminates the awkwardness of having to shift constantly both the tracing and the transfer paper when making the final transfer to the smooth sheet (see **7561**).

7414. With Proportional Dividers

Control stations may be transferred from one sheet to another by proportional dividers, but this method should be used only where the transfer is from a comparatively large-scale survey to a comparatively small-scale one. The principle of the proportional dividers is explained in **4812**. In using them for the transfer of stations, the scale setting of the dividers must be used only for a preliminary adjustment. Before actual use, a final setting must be made by trial and error on the two projections. In most cases, one setting will suffice for both latitude and longitude measurements; but this should be verified and if necessary a different setting used. Control stations transferred by this method should be plotted as explained in the second and third paragraphs of **7411**.

7415. Plotting by Cuts

Cuts are sextant angles, usually taken from a survey vessel, between an object whose position is known and an object whose position is to be determined. The position of the observer is located by two sextant angles. Two or more such cuts taken from different positions determine the position of the unknown object. Cuts may also be taken from previously located shore stations. Cuts are recorded in the various Sounding Records and indexed on page 2 of volume No. 1 (see **248**).

To plot a control station from sextant cuts, the position of the observer is first carefully plotted, if not at a previously determined station, using a metal protractor whose adjustment has been previously checked (see **762**). The third angle or cut is then set on the protractor and with the center placed directly over the observer's position and one arm passing through the known station, the angle to the new station is plotted by a short line drawn along the edge of the protractor arm with a hard chisel-edged pencil (see **724**). This must be temporarily identified by the name of the new station in pencil. All other cuts to this same station are plotted in a similar manner from the respective locations from which they were taken. If the observing has been carefully done and based on control precisely located, and the sheet is free from distortion, all of the cuts should intersect at one point, which is the location of the station. It rarely happens that this is the case, and a position must be adopted which will most nearly fall on all of the plotted cuts, taking into consideration their respective probable accuracies. The penciled cuts must not be erased from the smooth sheet until after the verification of the survey in the Washington Office.

7416. Stations Located by Three-Point Fixes

Control stations are sometimes located by three-point fixes at the station. In such cases their positions may be plotted on the smooth sheet with the three-arm protractor (see **4534**) verifying the plotting with the check angle, if taken. If there is distortion in the sheet or if stations observed are considerable distances away, the position should be computed on Form 655 (see **2431**) and plotted on the smooth sheet by the *dm.* and *dp.* method.

742. PLOTTING THE FLOATING CONTROL

The floating control which may be used to control a hydrographic survey usually consists of survey buoys or sono-radio buoys, and occasionally small marker buoys. There are various methods of determining the positions of such buoys depending upon the availability of shore signals, the distance offshore, the character of the area surveyed, etc. These methods can be grouped generally as follows: (*a*) sextant locations either by three-point fixes at the buoys or by cuts from the vessel; (*b*) directions from shore stations; (*c*) sun azimuths from the vessel to shore stations; (*d*) sun azimuths and distances; (*e*) astronomic observations; (*f*) by reference to submarine relief; and (*g*) various combinations of these.

A complete discussion of these methods as well as the methods to be used in determining the geographic positions of the buoys is contained in section **25**. In determining the geographic positions for smooth-sheet plotting, the plotter should follow the method recommended for the particular case involved. The following item deals only with certain general aspects of the problem.

7421. Determining Positions of Floating Control

The positions of the floating control are ordinarily known prior to the construction of the smooth sheet, since they must be known in order to execute the field work. There are two general methods of obtaining these positions, (*a*) by computation and

(*b*) by graphic plotting on an aluminum sheet. In both methods the geographic positions of the buoys, and consequently their *dms.* and *dps.* are obtained; hence positions of the buoys are plotted on the smooth sheet in the same manner that shore stations are plotted by *dms.* and *dps.* (see **7411**). Graphic methods usually furnish the required accuracy of position for buoy-control surveys, provided accurate methods are used and care is exercised in the plotting; but it is frequently desirable and easier to compute the positions.

a. By computation.—Positions of buoys are determined by computation generally when it is not practicable to plot the observed data on the smooth sheet, as when the sheet is distorted or the scale is too small or the stations observed on are too far distant.

b. By graphic plotting.—Graphic plotting should generally be resorted to when the data can be plotted on an aluminum sheet, or where the computations are too involved as in the case of cuts obtained from a vessel whose position is determined by a three-point fix. (See **2552** for detailed description of latter method.) Graphic plotting should also be used where buoys are located by taut-wire distances or by subaqueous sound ranging or by reference to submarine relief.

Where a number of buoys have been located and plotted by three-point fixes, it may be desirable to compute the positions of selected ones to verify the accuracy of the graphic plotting.

In graphic plotting, an accurately adjusted metal protractor should always be used and the work should be done with the utmost care and precision. Usually the buoys are in such locations that the angles of the three-point fix are relatively small, which tends to magnify plotting inaccuracies.

743. STATION SYMBOLS

Each station used for the control of the hydrography shall be identified on the smooth sheet by its appropriate symbol and name, both inked in the color specified (see fig. 169). The actual station point is a fine needle hole, the edges of which are blackened by rotating a sharp hard pencil point in the hole to facilitate its use in plotting the hydrography. Ink should never be used for this purpose (disregard fig. 169 in this respect). The symbols and colors shall be according to the following scheme:

(*a*) Triangulation and traverse stations shall be identified by red equilateral triangles, 4.5 mm on a side (fig. 153), symmetrically placed around the station point with the base of the triangle normal to the meridian and the apex north.

(*b*) Topographic stations shall be identified by red circles 3 mm in diameter, symmetrically located around the station point. Stations on air photographic surveys which have been located by the radial plot for the use of the hydrographic party, are classed as topographic stations. Stations to supplement those located by the radial plot, and which are located by the hydrographic party by approved methods, shall also be classified as topographic stations (see **2393**).

(*c*) Hydrographic stations (stations located by sextant or other means, see section **24**) shall be identified by blue circles 3 mm in diameter symmetrically located around the station point. The positions of ordinary survey buoys are to be identified by the symbol for hydrographic stations.

(*d*) Stations which have been spotted by the hydrographic party from the details of the photographs or the air photographic survey (see **2394**), shall be identified by green circles 3 mm in diameter, symmetrically placed around the station point.

(*e*) R.A.R. stations shall be identified by a double concentric circle, the inner 3 mm in diameter in blue ink, and the outer 5 mm in diameter in a distinctive color corresponding to the distance arcs drawn from it (see **7637**).

The symbols for topographic and hydrographic stations are easily made and centered by the use of the drop-bow pen (see **4841**). There is some difficulty, however,

in making the triangulation station symbol neatly and symmetrically around the station point. There are several methods of doing this. One method is to draw a faint pencil circle 2.6 mm in diameter, and with a straightedge and an equilateral triangle draw the sides of the symbol tangent to the circumference of the penciled circle.

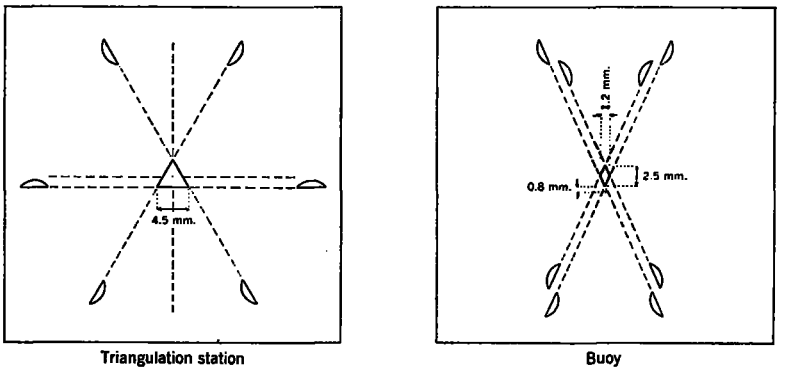

FIGURE 153.—Templates for triangulation station and buoy symbols.

Another method is by means of a celluloid template cut to the correct size (see fig. 153). The perpendicular etched lines are used in centering the symbol and in orienting it with reference to the projection lines. The small holes on the extensions of the triangle sides are used to draw pencil lines as guides for drawing the symbol in ink after removal of the template. Inking inside the template cannot be neatly done and should not be attempted. (See also **4834** and fig. 96.)

744. STATION NAMES

All of the station names shall be inked on the smooth sheet in vertical letters with an over-all height of the upper case letters not to exceed 3 mm, and a thickness of ink line not to exceed 0.5 mm. Slanting letters shall not be used for any station names. Under this heading instructions are given only for station names (see **215** and **3245**). Instructions for geographic names are given in **787**. Instructions for names of aids to navigation are given in **7843**, and instructions relative to miscellaneous notes are given in **781** and **7825**. The names of triangulation and topographic stations shall be in red ink, names of hydrographic stations in blue ink, and names of stations spotted from the air photographic detail shall be in green ink. (See figs. 169 and 171.)

Where only a part of the triangulation station name is used in the hydrographic survey, this part shall be emphasized by underlining it in red ink. Where an entirely different name, arbitrarily selected, is given to a triangulation station, for use in the hydrographic survey, the arbitrary name shall be inked in blue, followed by the triangulation name in red and in parentheses.

7441. Agreement of Names

The station names on the smooth sheet must agree with those used on the boat sheet, the topographic sheet, and in the Sounding Records. If there is any disagreement between these three sources it must be investigated and corrected, and the name actually used in the Sounding Records placed on the smooth sheet with an appropriate notation in the various records to clarify the original discrepancy.

Where identical stations are used in the overlapping area of two hydrographic surveys, the station names must be identical. If, inadvertently, a different name is used than appears on the prior survey, both names shall be placed on the smooth sheet, the one actually used in the Sounding Records being followed by the older name in parentheses with an appropriate explanatory note.

7442. Size of Lettering

Unless the draftsman is particularly skilled in lettering, it is preferable that a mechanical lettering set (see **4834**) be used in inking station names on the smooth sheet. The 3 mm maximum height of upper case letters may be obtained by the use of Leroy lettering set template No. 120 with No. 00 pen. Although letters 3 mm in height are to be considered the standard, in congested areas this size is sometimes impracticable and a smaller size must be used.

The most important station names shall be in capital letters; included in this designation are all triangulation station names and the station names of the most prominent signals (i. e., those most frequently used). Station names of all minor signals on a hydrographic sheet (i. e., those used only for sextant fixes in the immediate vicinity) shall be in capitals and lower-case letters.

7443. Placement of Station Names

North shall be considered the top of the smooth sheet and all station names shall be lettered on lines normal to the central meridian. Wherever practicable, names shall be on line with the bottom of the station symbol, and east of and separated from it by a space of one letter (see fig. 169). There should never be any doubt as to the name of a station. Where it is necessary to place the name so far away that doubt may arise as to its reference, a fine inked arrow or leader, in the same color as the name, should be drawn from the name to the symbol. The leader should be broken where it crosses soundings.

Names should never be placed in the water area where it is practicable to avoid it. Where this cannot be avoided, as in some cases of hydrographic stations (particularly survey buoys) or stations on detached rocks, the names must be placed where they will interfere least with the plotted hydrography. The inking of such names must be deferred until after the soundings have been penciled.

The name of a triangulation station must always be followed on the same line (not below) by the year of establishment and the year of recovery, a comma separating the name and the date, and a hyphen separating successive dates.

7444. Stations in Water Areas

Unless it is clear from the topographic information, names of stations offshore from the high-water line must be accompanied by a brief note, or legend, explaining whether the stations are located on permanent features (natural or artificial), or on temporary ones. If the station is on a rock or shoal, the desired information is usually apparent. If it is on a pile or other structure built in the water, or is on a pole placed in the water by the hydrographic party, the note must explain fully the circumstances, so that the cartographer will know whether to chart an obstruction, pile, or other feature at the location. Such notes should be in black ink, as closely adjacent to the station name as practicable, but indubitably referring to it. (See **781**.)

745. VERIFICATION OF THE CONTROL

The plotting of the control must be verified by a person other than the one who did the plotting. The verification must consist of the actual replotting of the stations, their placement in the correct quadrilaterals of the projection, and their identification by the correct names.

Only after this has been done, are the symbols and names to be inked.

746. PROJECTION AND CONTROL DATA

The projection and control data shall be given in the lower right-hand corner of the smooth sheet, and rubber Stamp No. 42, Hydrographic Survey, shall be used for this purpose. The center of the stamp should be about 7 inches from the right edge.

Entries should be made in all of the applicable spaces of the stamp. The initials of the persons plotting and verifying each of the items listed should be entered, together with the dates. It is important that the verification information be given, otherwise unnecessary duplication results, since the Office cannot assume a field verification unless evidence of this appears on the survey sheet. If an item in the stamp is not applicable to a particular survey, as where no hydrographic stations are on the sheet, an explanatory entry should be made, such as "none" opposite "Hydro. Sta."

The registry number of the survey shall be given if known, as well as the field number (see **154**). Opposite the item "Ref. Sta." on the stamp, the name and date of establishment of some one triangulation station on the sheet, should be given. The latitude and longitude with seconds in meters shall be given immediately below. Whether the position has been adjusted or not shall be indicated by ruling out the inapplicable abbreviation following the data, if this is known.

No. 42 HYDROGRAPHIC SURVEY

Field No. Oc-8341 **Reg. No.** H-6671
Scale 1: 80,000 **Plotted.: Verified**
Projection : H.J.C. : F.C.M.
Tri. Sta. : H.J.C. : F.C.M.
Topo. Sta. : H.J.C. : F.C.M.
Hydro. Sta. : H.J.C. : F.C.M.
Datum NORTH AMERICAN 1927
Ref. Sta. BALD HEAD, 1854
Lat. 43° 42' 685.8 m. {**Adj.**
Long. 69° 51' 375.7 m. {~~**Unadj.**~~

FIGURE 154.—Projection and control data for smooth sheet.

All of the projection and control data shall be shown in black ink. A facsimile of Stamp No. 42 with the necessary data entered is shown in figure 154.

75. TRANSFER OF THE TOPOGRAPHY

The hydrographic smooth sheet, as finally registered, is not the authority for the topography, which is surveyed on a separate sheet. Where the topography is surveyed by planetable, it is usually done in the same season, immediately preceding the hydrographic survey and under the direction of the same Chief of Party. In the case of air photographic surveys, however, the photographs may have been taken several years earlier and the planimetric maps may have been completed some time before the hydrographic survey. Infrequently there is no contemporary topographic survey; that is, no survey accomplished during the same season or in a season immediately preceding the hydrographic survey, which is considered to be a part of the same project.

The Chief of Party shall have the hydrographic party verify, and revise if necessary, the high-water line and all topographic details offshore therefrom, which are

derived from the topographic survey, so that they are correct and in agreement with data originating with the hydrographic survey (see **381**).

In order that the hydrographic survey may present a complete graphic record of the area, all topographic details within the limits of the hydrography and adjacent to it, including the high-water line, must be shown on the smooth sheet except as noted in **751**.

The transfer of the topography must be made with the utmost care so that there is no appreciable inaccuracy in position. Photographic copies of the hydrographic surveys are frequently furnished to the public and to governmental agencies, and it is

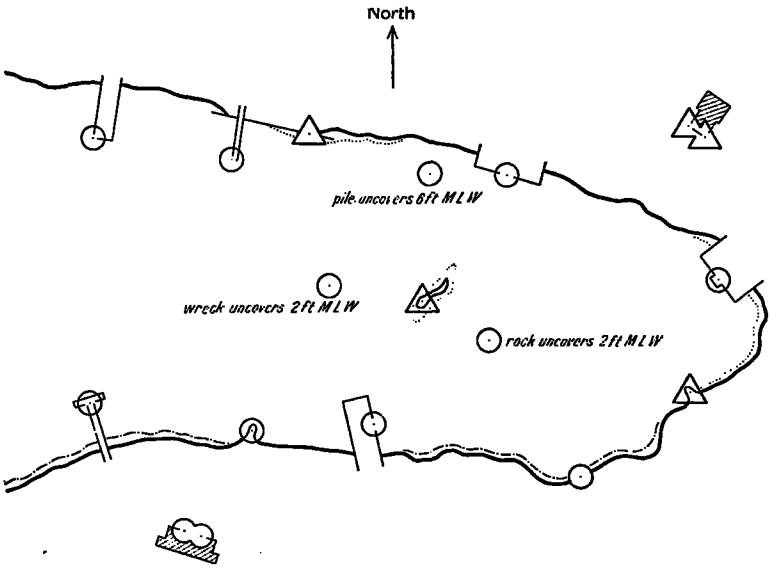

FIGURE 155.—Shoreline shown on smooth sheet without obscuring positions of control stations.

naturally assumed by many of these that the topographic details shown thereon are correct.

When the topography is transferred, the high-water line and all offshore details are transferred at the same time *in pencil*, but are inked only as specified in **752** to **755** inclusive (see also table 28). Topographic detail must never obscure the centers of control stations. Only important detail should be shown inside the station symbol, but in no case shall the shoreline be drawn through the station point. Examples to be followed are illustrated in figure 155.

Topographic details inshore from the high-water line shall be omitted from the smooth sheet, except where stations are on or near buildings (see **7844**).

751. OMISSION OF TOPOGRAPHY

The field plotter may omit all or part of the topography from the smooth sheet in the following cases:

(*a*) Where there is no contemporary topographic survey. After the hydrographic survey has been reviewed in the Washington Office, a decision will be made as to whether any topography is to be shown thereon.

(*b*) Where the topographic and hydrographic surveys are on different scales and the transfer presents difficulties. In such cases the topography will be added to the sheet at a later date in the Washington Office.

(*c*) From an offshore survey (one where another survey exists or is contemplated between it and the shore). If the survey is on the same scale as the topographic survey, the high-water line only should be transferred but not the topographic detail adjacent to the shore.

(*d*) From wire-drag smooth sheets where the drag limits are not very close to the shoreline. Where the shoreline is shown, it is not necessary to transfer all the rocky detail adjacent thereto. It is usually sufficient to show only such off-lying rocks and reefs as were factors in delimiting the inshore extent of the dragged area.

752. THE SHORELINE

The shoreline which is shown on the topographic survey and likewise on the smooth sheet, and on the charts published by the Coast and Geodetic Survey, is a *mean high-water line*, except in marsh and mangrove areas. In the latter cases the shoreline is the visible edge of the marsh or mangrove, because this is the line which appears to the mariner as the shoreline.

After transfer of the topography, the mean high-water line should be inked at once, except in those areas where the boat sheet discloses a possible conflict between the shoreline as located by the topographic survey, and the hydrography. In such cases the shoreline shall be left in pencil until the soundings have been plotted and a study made of the results. All details offshore from the high-water line must also be left in pencil pending the plotting of the hydrography.

The mean high-water line on fast solid land shall be shown on the smooth sheet by a firm continuous solid black line about 0.4 mm thick. The shoreline of marsh, swamp, and mangrove areas shall be shown by a fine solid black line about 0.2 mm thick. (See **962**.) The outlines of small details of waterfront areas, such as small piers and bulkheads, shall be shown by moderately fine lines, somewhat finer than those used for the mean high-water line on fast land, in order that the small details of pier lines and pier corners may not be obliterated. (See fig. 169.)

753. REVISIONS BY HYDROGRAPHIC PARTY

The hydrographic party is responsible for the correctness of the topographic detail falling within the limits of the hydrographic survey, including the high-water line and waterfront details if the survey is carried close thereto. Where the topographic survey was not made in the same season as the hydrographic survey and under the direction of the same Chief of Party (see **381**), revisions or corrections thereto shall be shown on the smooth sheet, according to the following instructions:

(*a*) Where the revised shoreline or topography has been determined by standard topographic methods or methods resulting in an equal accuracy, it shall be inked in a solid red line.

(*b*) Where the revised data are only sketched by careful estimation or are based on sextant fixes, or sextant cuts, they shall be inked in broken red lines. Where the shoreline has been sketched by the method described in **3812**, it shall be left in a broken pencil line by the field party, to be inked in the Washington Office in a broken black line when, at the time of review, no accurate survey is known to be contemplated.

(*c*) The thickness of the inked lines shall be equal to those prescribed in **752** (i. e., 0.4 mm for the shoreline of solid ground and 0.2 mm for the visible edge of marsh or mangrove areas).

(*d*) Appropriate notes shall be made both on the smooth sheet and in the Descriptive Report explaining the discrepancies and the methods used in determining the positions of the revised data.

The red color will distinguish immediately between shoreline and topography which have originated with other sheets, and the revised data for which the smooth sheet and the hydrographic party are the authority (see fig. 169).

754. THE LOW-WATER LINE

The low-water line shown on the planetable survey is usually not a surveyed line. It has ordinarily been sketched by the topographer and is furnished as a guide to the hydrographer during his hydrographic survey. Occasionally, however, where the topographer is in a locality at low tide, he may actually delineate the low-water line by rod readings.

The low-water line is the curve of zero depth and its best delineation for hydrographic purposes results from soundings obtained in its vicinity. Since such soundings are subject to possible modification in the Washington Office, caused by changes in the tide reducers or for other reasons, the low-water line shall be left in pencil on the smooth sheet by the field party, to be subsequently inked in the Office when the survey is verified. Where minus soundings are plotted, care must be taken to see that the curve is correctly shown relative to them (see **7715**).

After the soundings have been penciled on the smooth sheet, the complete low-water line shall be shown thereon *in pencil* in accordance with the following preferences, using the same symbols as are prescribed for its inking (see fig. 169):

(*a*) The zero depth curve as determined by the reduced soundings in areas where the hydrographic survey has extended over the low-water line during periods of high water—to be eventually inked as a continuous yellow line.

(*b*) Those parts of the low-water line that were rodded in by the topographer at low tide—to be eventually inked as a black line of alternate dashes and dots.

(*c*) Those parts of the low-water line which can be reasonably well determined from notes in the Sounding Records and sketches on the boat sheet made by the hydrographer at the time of the hydrographic survey—to be eventually inked as a yellow dash line.

(*d*) In cases not covered by any of the preceding three classes the low-water line shall be taken from the best available source, usually that sketched on the topographic survey—to be eventually inked as a black dotted line.

Occasionally it may be desirable to delineate the low-water line by symbols, such as for rocky ledges or coral reefs. In such cases the offshore edge of the symbols shall be considered the low-water line.

The low-water line derived from an air photographic survey shall be considered to be in class (*d*), unless there is a positive statement in the Descriptive Report that parts of it were rodded in by planetable, when of course those parts shall be considered in class (*b*). The latter, however, is rarely the case.

755. OFFSHORE DETAIL

Topographic details offshore from the low-water line, such as rocks, reefs, ledges, rocky areas, and shoal areas, except islands or islets of some extent, shall be left in pencil on the smooth sheet until the soundings have been penciled. The hydrographic survey frequently contains data which supplement, and in some cases modify, the topographic survey. Before such details are inked on the sheet, all of the data must be considered and disposition made as to character, location, and elevation in accordance with the rules prescribed in **782**. (See also **7862**.)

It is unnecessary to transfer the elevations of bare rocks that do not fall within the limits of the hydrography, such as the numerous rocks that are often found close to the high-water line in certain areas.

756. METHODS OF TRANSFER

There are five methods of transferring topographic detail from one sheet to another depending on the respective scales of the two sheets, the degree of accuracy sought, and the instrument equipment available. These are: (*a*) by tracing paper; (*b*) by projector; (*c*) by pantograph; (*d*) by the method of squares; and (*e*) by the radial-line method. The projector and pantograph are generally not available to field parties nor to Processing Offices and these methods are, therefore, not described in this section. A description of the projector is given in **4854** and of the pantograph in **4853**.

7561. Tracing-Paper Method

Where the topographic and hydrographic surveys are on the same scale, the simplest method of transfer is by means of tracing paper. Tracing cloth must not be used. As explained in **7413** the topographic details are traced at the same time that the topographic control is pricked through, making the adjustments for distortion by small shiftings of the tracing on the topographic sheet. The transfer to the smooth sheet can be accomplished in several ways. The preferred method is to use a letter-size sheet of thin transfer paper, which is prepared in advance by dusting with red offset chalk powder (Kiel), or dry powdered graphite, rubbing it lightly over the surface with a small rag until an even coating is produced. Red is preferable because of its contrast with penciled or inked detail that may be on the smooth sheet. These materials are needed in very small quantities and will be furnished by the Office on request. Vermilion dry pigment should not be used because it is slightly greasy. In an emergency black or red carbon paper can be used.

The actual transfer is made by superposing the tracing on the smooth sheet so that corresponding projection intersections are in exact coincidence. The transfer paper is then placed, coated side down, between the tracing and the smooth sheet and with a stylus or sharp hard pencil the detail on the tracing is gone over. This leaves a sharp outline on the smooth sheet. The transfer paper is moved to an adjoining portion of the sheet and the procedure repeated. It is of the utmost importance that the tracing does not slip during the transfer process. This should be checked as each portion is transferred. The transferred detail is subsequently inked or penciled as explained in **752** to **755** inclusive.

Where a small amount of transfer is involved, the reverse side of the tracing itself may be coated, applying the powdered chalk only in the vicinity of the topographic details. Another method is to smear the underside of the tracing paper with the lead of a soft pencil, using the side of the lead for the purpose. Special care must be taken with the latter method because of the danger of distorting the tracing paper during the rubbing.

In transferring detail by the tracing-paper method excessive pressure must not be used on the tracing, as this will engrave the lines in the smooth sheet. A slight pressure is generally sufficient to ensure a satisfactory impression.

The tracing or tracings used in the transfer shall be forwarded to the Washington Office with the boat sheet (see **8351**).

7562. Method of Squares

This method is not sufficiently accurate for the transfer of topographic detail to the smooth sheet, but may be used to transfer the shoreline to the boat sheet or in other cases.

In the method of squares (fig. 156), common points on the two surveys are selected—usually intersections of meridians and parallels. Referred to these common points, sets of corresponding squares or rectangles are constructed lightly in pencil, which are identical when referred to the actual

ground detail, but differ in size on the two sheets. Every fifth line should be accentuated to facilitate identification. The detail may then be transferred from one sheet to the other by reference to the positions within these small squares.

In order to obtain any reasonable accuracy, the squares on the smaller scale should be formed by lines not more than one-eighth inch apart. When these squares are correctly drawn, they may be termed *corresponding squares* because each square corresponds to its respective square in terms of the ground area.

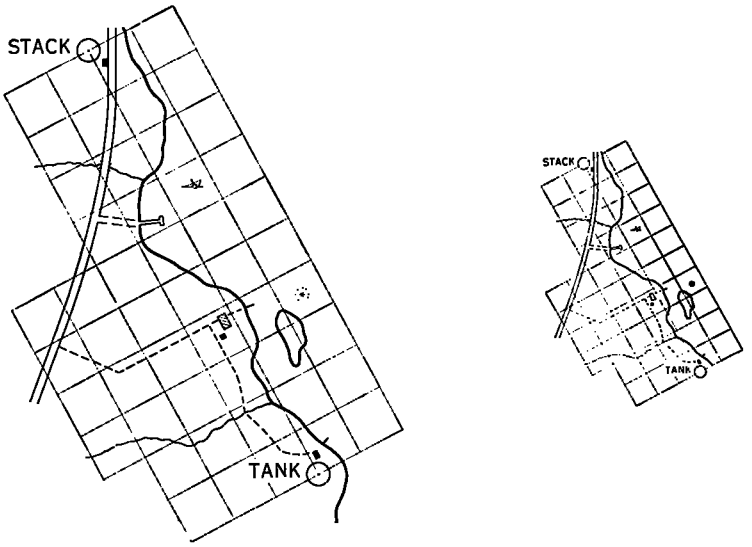

FIGURE 156.—Reduction of topography by method of squares.

If it is desired to avoid marking up the source sheet, the squares may be drawn on tracing paper and laid over the detail to be transferred. The procedure is then the same as above.

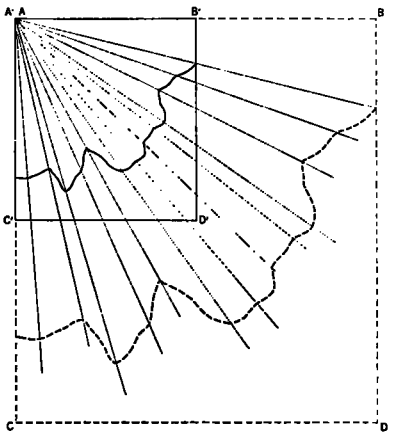

FIGURE 157.—Reduction of topography by radial-line method.

7563. *Radial-Line Method*

Like the method of squares, this method (fig. 157) should not be used for transferring topographic detail to the smooth sheet. It is of most value where only an approximate accuracy is needed and the detail consists only of the high-water line. It is faster than the method of squares. To use the method, a point common to the two surveys is selected from which radial lines can be drawn to intersect the general trend of the shoreline at not too acute an angle.

In practice, tracing paper is placed over the sheet with the source material, and from the selected point radial lines are drawn to intersect the shoreline at all salient points and at enough intermediate points to permit fairly accurate sketching of the detail. In the simplest case, where it is desired to transfer to a scale twice as large or half as large as the original, it is merely necessary to use dividers to double or halve the radial distances from the common point to the intersections with the shoreline and plot the new distances along the same lines. Subsequently the intervening

shoreline is sketched in pencil by eye through the new points so that it corresponds to the original. The shoreline at the new scale may then be transferred by one of the methods described in **7561**. This same method can, of course, be used to increase or decrease the scale in any proportion by the use of proportional dividers.

757. VERIFICATION OF TRANSFER

The transfer of all the topographic details must be verified by a person other than the one doing the original work. A statement that this has been done shall be included in the Descriptive Report, accompanying the statement giving the source of the topographic detail (see **842***G*). If the detail is to be inked in the field (see **792**), the verification should be made after the inking.

76. PLOTTING THE POSITIONS

As explained in **332**, there are at present various methods or combinations of methods by which the hydrography is controlled, depending on the conditions under which the operations are carried on. The most common of these are: (*a*) The three-point fix method in which the position of the vessel is determined by measuring simultaneously the two angles between three control stations (see **333**); and (*b*) the Radio Acoustic Ranging method in which distances from the vessel to two or more hydrophone stations, whose positions are known, are obtained by subaqueous means (see **612** and **681**).

In this section is given the general procedure for plotting all positions as well as the detailed procedure for the above two methods. In addition the methods for plotting astronomic positions and dead reckoning are described. The procedure for plotting positions determined by special methods will be apparent from the description of those methods (see **3323**).

Prior to plotting the positions, and at least once a month during the progress of the plotting, the protractor must be tested and the metal protractor adjusted, if necessary (see **4533**).

The positions on sounding lines are usually plotted in the order in which they were taken; that is, the smooth plotter begins with position 1 of "*A*" day and plots all of the positions on the smooth sheet in the order in which the work was actually executed in the field. This is not obligatory, of course, and in fact it may be preferable to plot the positions in critical areas first, especially if plotting is done while field work is still in progress, in order to give immediate evidence whether additional work is required in the area.

In plotting the positions, use should be made of the entries in the Sounding Records at the beginning of each day's work, giving the approximate latitude and longitude of the first position. This is given to facilitate the plotter in locating quickly that portion of the smooth sheet on which the position falls. Similar information is given at the beginning of any line starting in a new area.

In plotting the smooth sheet, a certain systematic procedure is necessary to permit the smooth plotter to attain speed and still retain accuracy in his work. As the plotting proceeds, he soon learns to sense where there is some deficiency in the recorded data. It is imperative for best results that the person plotting the smooth sheet be familiar with the methods by which the field work was done. If the plotter has not actually been engaged in similar work, he should study the Hydrographic Manual so thoroughly that all phases of the work will be clear to him, and as the plotting proceeds he will be able to visualize the progress of the vessel during the work.

During the plotting of the positions on the smooth sheet, continued reference should be made to the notes in the "Remarks" column of the Sounding Record (see **815**) and to the notes that are kept during the progress of the field work from which the Descriptive Report is subsequently written (see **385**). Quite frequently valuable information will be found in these sources which will guide or influence the plotter during his work. When the plotting of each day's hydrography has been completed, the smooth plotter enters his initials with a colored pencil at the end of the day's entries in the appropriate space in Stamp No. 38, Processing (fig. 183), to indicate his responsibility for the plotting of that day's work.

FIGURE 158.—Protracting three-point fixes with three-arm protractor.

761. SMOOTH-SHEET COVERS

To protect the surface of the smooth sheet while the protractor is being used, the entire sheet should be covered with a piece of tracing cloth or heavy tracing paper, otherwise the continual sliding of the protractor over the sheet will soil it excessively. A small round hole, about three-eighths inch in diameter, is cut in the cover over each station, exposing the center to permit accurate plotting. The holes should be cut cleanly so that their edges will not fray out and catch the protractor arms. One method of cutting the holes, after they have been marked in pencil, is by the use of a grommet hole cutter. If the cover is difficult to see through, it is desirable to letter each station name on the cover alongside its respective hole. Positions plotted by protractor are pricked through the cover into the smooth sheet.

Thin celluloid may also be used as a protective cover. This material is so transparent that small circular holes at the locations of the signals are unnecessary. The principal objection to celluloid as a protective medium is the difficulty in making temporary notes on it and in identifying the successive positions as they are plotted.

After being correctly placed in position, the cover should be secured by weights or thumbtacks. Since it is necessary to lift the cover frequently, it will be found convenient to secure it along the edge of the sheet farthest from the plotter with a sufficient number of tacks to hold it in position, using only one or two tacks elsewhere.

It is not necessary to lift the protective cover every time a position is plotted. Occasional positions, say every fifth one, may be numbered temporarily on the cover itself. It is customary to plot at least all of the positions on one page of the Sounding Record, or all of the positions on a line, before raising the cover to number the positions on the smooth sheet and to connect them (see **7682**). The smooth sheet should always be covered when not in use.

R.A.R. smooth sheets are difficult to keep clean since the plotting of positions must be done directly on the surface of the sheet. A convenient method of protection is to use two obsolete charts or pieces of wrapping paper folded in the form of envelopes to fit loosely over each end of the smooth sheet, each envelope being held together by Scotch tape. These are supplemented by two pieces of paper folded lengthwise over the sides of the smooth sheet, but with the ends open. The paper should completely cover the smooth sheet when each pair is in its innermost position. The envelopes should fit loosely enough so that they may be slid away from the smooth sheet as desired in order to expose the area being worked on. Several loose sheets of paper or a hand towel should be laid on top of the exposed surface to prevent its being touched by the hands or arms any more than is absolutely necessary.

762. PROTRACTING THREE-POINT FIX POSITIONS

Three-point fix positions are plotted graphically in hydrographic surveying by the use of a protractor. This is usually a three-arm protractor made of either metal or celluloid having a fixed center arm and two movable arms with which the two observed angles can be set. The left angle of the fix is set with the left movable arm and the right angle with the right movable arm. The protractor is then manipulated into a position on the smooth sheet so that the three arms pass precisely through the respective centers of the plotted positions of the stations between which the angles were measured. The intersection of the three arms, which is the center of the graduated circle, then marks the position of the vessel or sounding. (See **4534**.)

7621. With Metal Protractor

Most three-point fix positions are plotted on the smooth sheet with the metal three-arm protractor described in **4531**. The construction of the metal protractor is such that it is inconvenient or impossible to use it in plotting positions which are at short distances from the stations. Neither can it be used with the rapidity or ease with which a celluloid protractor can be used.

Extensions to the arms of a metal protractor are provided for use where the stations observed on are so distant that the regular arms do not reach them. When these extensions are used, extra precaution should be taken in the plotting.

7622. With Celluloid Protractor

The use of the celluloid protractor (**4536**) shall be limited to areas of the smooth sheet where the stations are never more than 10 inches from the positions, the sum of the two angles is not less than 60°, and the smaller of the two angles is not less than 20°. Positions based on stations farther away than 10 inches or based on angles smaller than the above prescribed limits, must be plotted with a metal protractor. Critical positions shall be plotted with a metal protractor, if practicable.

7623. Positions Close to Control Stations

Celluloid protractors of the present model permit plotting three-point fixes which are quite close to the control stations, but because of the opaqueness of the protractor near its center, it sometimes happens that even this cannot be used satisfactorily. In such cases the angles of the three-point fix are plotted on a piece of tracing paper, or on a transparent paper protractor (**4539**), which is then manipulated the same as a three-arm protractor to plot the position.

7624. Procedure for Protracting Positions

The Sounding Record is the official record of the sounding and position data, and the plotter should follow the recorded data strictly, unless it is apparent that an error has been made. Since the system of field work requires that the sounding vessel proceed at as nearly a constant speed as practicable (see **3461**), and since the hydrographer, almost invariably, attempts to run straight lines, the dead-reckoning position of the vessel provides a reasonable check on the recorded position data. The boat sheet provides the best check since the positions thereon were plotted by the officer-in-charge at the time the work was executed, and he was in a position to know where his vessel was at the time a particular position was taken (see **7671**).

Lines of soundings are run systematically, and it is usual for a number of positions to occur on a comparatively straight line (see **314**). The smooth plotter, therefore, usually protracts all of the positions recorded on one page of the Sounding Record, or on one straight sounding line, before comparing them with the boat sheet and connecting them with penciled lines. When the plotter has assured himself that the positions of the series have been correctly protracted, a checkmark in colored pencil must be placed in the Sounding Record alongside each position number. A pencil of identical color should be used by the smooth plotter throughout his work, in making entries and corrections in the Sounding Records.

As the protracting progresses, the notations in the "Remarks" column should be noted in order that due attention may be paid to any remark which may affect the smooth plotting, and for information regarding features to which cuts were taken or which were otherwise located during the progress of the survey. As each such item is applied to the smooth sheet, this should be indicated by placing a checkmark after it in the Sounding Record.

It is usual to protract all of the positions on the smooth sheet before the soundings are penciled, including the detached positions and all the cuts and other data that need to be located on the smooth sheet. When the protracting has been completed, the smooth sheet should contain all position information and, in general, it should not be necessary to use the protractor during the subsequent plotting of the soundings, except for occasional verification of a position.

A. ERRORS IN RECORDED DATA

Although every effort is made to have all data recorded with the strictest accuracy, the smooth plotter must keep constantly in mind the fact that in many cases the hydrography is performed under circumstances conducive to errors in recording. The recorder is frequently working under continuous pressure, and since the hydrography proceeds at a constant rate and it is his duty to record all phases of it, he may fail to correct known errors, or question suspected data. Launch hydrography is particularly susceptible to recorded errors. Hydrographic launches are often propelled by gasoline engines in which the noise level is quite high. Angles and station names are being called by the observers, soundings are being called by the leadsman, and orders are being given, all in a loud voice, and the recorder is supposed to make an accurate record of all of these at the time they occur.

As the smooth plotter becomes experienced, he will learn the kinds of errors which are most likely to occur in the recorded position data. The following list is not intended to be complete, but will serve as a guide to an inexperienced smooth plotter:

(1) One or more station names may be incorrect—such errors are likely to occur where station names have similar sounds.

(2) The station names are correct, but two or more of them have been transposed.

(3) The right angle and left angle may be reversed.

(4) The degrees and minutes of an angle may be reversed.

(5) The observer may have read his sextant wrong, the most frequent errors being 10°, 30′, 1°, and 20°, in that order.

(6) The recorder may have misunderstood the angle, when called out, as for example, when 15 is mistaken for 50, 7 for 11, and vice versa.

(7) The recorded data appear complete, but actually the right and left angles were not observed to a common center object.

Corrections to recorded data should be made according to **7741** and figure 164.

7625. Protracting Inadequate Fixes

It frequently happens in three-point fix hydrography that the position data obtained are inadequate for plotting the positions by the conventional three-point method. It is then necessary to use special methods of plotting, or the data must be supplemented by other information before the position can be plotted. Such cases occur, (*a*) where only one angle has been observed, (*b*) where the two angles are not observed on a common center object, (*c*) where the three-point fix is weak, and (*d*) where the position is located by estimation.

In (*a*), the procedure is first to plot the locus of the single angle. This is accomplished by setting the angle on the protractor and placing the center near where the position is likely to be. The two arms are then made to pass through the two stations involved. The center of the protractor will then be a point on the locus of the angle. Several such points are plotted in the vicinity of the position sought and a short pencil arc is drawn through them. The exact position of the vessel is then determined by the use of the dead reckoning in conjunction with the plotted locus. If the locus is nearly perpendicular to the course, the next following position on the line should be protracted and connected with the previous position by the dead reckoning. The intersection of the dead-reckoning track and the locus will then give the position. Where the locus is nearly parallel to the course, a strong determination of the direction of the sounding line is obtained, but the position must be determined on a basis of proportional time between the preceding and following positions, assuming there has been no change in speed. Thus, if positions 5*A*, 6*A*, and 7*A* were taken at 9:04, 9:07, and 9:11 respectively, then position 6*A* would be plotted at three-sevenths the distance between 5*A* and 7*A*, on the locus of the observed angle.

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Wherever the locus of an angle is to be plotted, this can be done directly on the smooth sheet, using the protractor centerpiece with a hole in it. Only the final position will then be pricked on the sheet. Care must be taken, of course, to see that the underside of the protractor is clean.

In (*b*), which usually occurs through a misunderstanding or error, the position is determined by plotting separately the locus of each angle, the correct position being at the intersection of the two arcs, assuming that they do not intersect at too acute an angle.

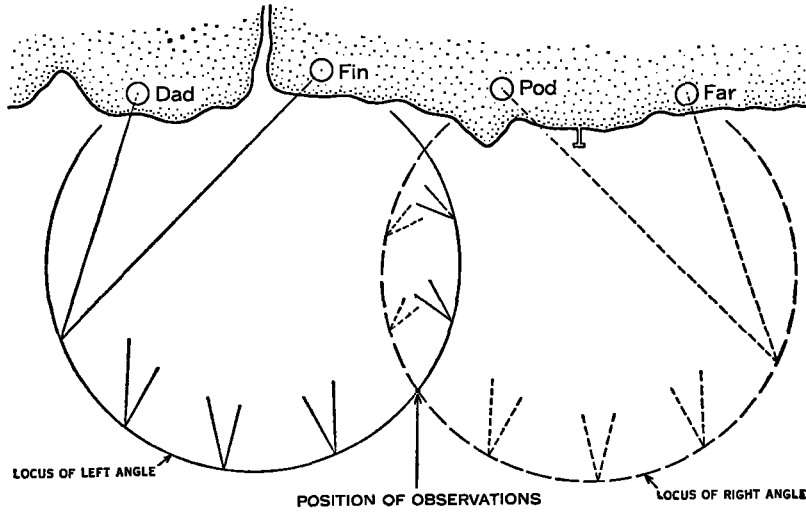


FIGURE 159.—Sextant fix plotted by intersection of loci. No common center object.

In (*c*), the recorded data may be complete, but the fix is weak, giving an inadequate determination of the position (see **3332**). There are two types of such fixes. In one type, the fix can be plotted in one position but the result is erroneous because of the weakness of the fix in conjunction with other factors. In the other type, known as a *swinger* or *revolver*, the fix can be plotted in any one of several positions. In either type, the recorded data must be supplemented by the dead reckoning in order to determine the most probable position. In the first case it is usually necessary to disregard that part of the recorded data which has resulted in the erroneous position, while in the second case all of the recorded data may usually be used to plot a locus of the position.

In (*d*), it is generally not possible to obtain a three-point fix, and other data are usually recorded by the hydrographer for plotting the position, such as an estimated distance from the high-water line, or an estimated distance and direction from a control station. All such data should be plotted and used in conjunction with the dead reckoning in order to arrive at the most probable positions, bearing in mind that the distances are not measured distances, and that the general tendency is to underestimate distances over the water from a stationary position. (See also **335**.)

763. PLOTTING R.A.R. POSITIONS

Radio Acoustic Ranging (R.A.R.) is a comparatively new method of control for hydrographic surveys. Notable changes have been made in recent years in the design of the equipment and in the field methods. These are described in detail in chapter 6. Likewise, improvements have been made in the methods and procedure of plotting the smooth sheet. It is expected that these will continue, but at the present time the methods described herein are considered the most satisfactory and shall be used until other methods are proved preferable.

R.A.R. positions are determined by the intersection of distance arcs whose centers are the R.A.R. stations from which the bomb returns were received. Like the distance circles described in **7341** these arcs are plotted in units of time. Because of uncertainties inherent in the R.A.R. method, due principally to the lack of complete knowledge of

the path of the transmitted sound wave, other data obtained during the progressfe such a survey must be appraised with the acoustic distances, and the most probabd positions adopted. Such supplemental data are sextant angles, bearings, and dea reckoning.

To avoid confusion, too many positions should not be plotted at any one time before they have been analyzed and accepted (see **7637**). In areas of systematic sounding lines not complicated by crosslines, or development, three or four lines may usually be plotted at one time, but in areas where previous lines have been plotted only a comparatively few positions should be plotted before analysis.

Numerous pencil notes are necessary to keep track of position numbers and other data. These must be placed directly on the smooth sheet, since this type of plotting is done without a sheet cover (see **761**). A soft pencil should be used so that the marks may be easily and completely erased.

7631. Plotting the Distance Arcs

Before plotting is begun a small circular piece of heavy celluloid should be fastened over each R.A.R. station to protect the center from wear due to repeated use of the beam compass. The best adhesive is nonvulcanizing rubber cement, thinned by an approximately equal amount of benzol or, as a substitute, benzine. The underside of the celluloid and the respective area on the smooth sheet are covered with a thin coat of cement and allowed to dry until sticky, after which the celluloid is pressed into place. Care should be taken to prick the point in the celluloid directly over the station hole. These protective celluloid pieces should not be confused with those described in **7341** for plotting the distance circles, which are fastened temporarily to the sheet.

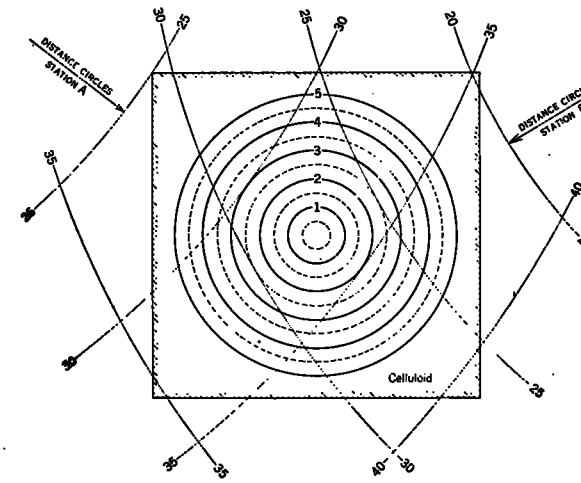


FIGURE 160.—Plotting R.A.R. positions with Odessey protractor. (Position illustrated is 33 seconds distant from station *A* and 27.5 seconds distant from station *B*.)

All R. A. R. positions must be plotted by means of their distance arcs so that a study can be made of all the factors influencing the final positions. The distance arcs are plotted directly from the data in the Bomb Record (**8311**), in which the measured time intervals have been reduced to the plotting velocity of 1,460 meters per second (see **7341**). The radii of the arcs are found on the smooth sheet by applying short increments or decrements of time to the plotted distance circles. Thus, the plotting radius for a 16.83-second time interval would be obtained by plotting the increment 1.83 seconds from the 15-second distance circle. To plot these increments or decrements on the sheet, three methods are available:

a. With Odessey R.A.R. protractor.—This device, the construction of which is described in **4537**, consists of closely spaced concentric circles on a piece of transparent celluloid, the circles being spaced according to the plotting velocity, 1,460 meters per second, at the scale of the survey. When the device is placed on the sheet so that the circle corresponding to the time increment or decrement is tangent to

the proper distance circle, the center of the device will be a point on the distance arc required. The intersection of the two distance arcs can be plotted in the same manner by making the appropriate concentric circles tangent to the two distance circles involved. The center is then a point on both distance arcs. There is no limit to the number of distance arcs that can be drawn with this device at any one position, although only two distance arcs can be used simultaneously. It is especially well suited for verification work.

b. With dividers and scale.—In this method a special scale is used, similar to a metric scale, constructed for the plotting velocity of 1,460 meters per second at the scale of the survey. The increments or decrements are measured with dividers. One point of the dividers is set on the distance circle and, with the aid of a large celluloid triangle alined toward the station, the desired point is pricked along the alined edge. This method is slow because the increments or decrements must be plotted in an exact radial direction from the respective stations.

c. With R.A.R. plotting scale.—A long rule similar to an engineer scale is used, with scales graduated in seconds for the plotting velocity of 1,460 meters per second at various survey scales (see **4828**). The rule is long enough to be alined with the station by eye, the desired point being pricked directly along the edge of the graduated scale. If such a scale is not available a substitute can be made on a long narrow piece of celluloid graduated in seconds, with 1 or 2 seconds at one end divided into tenths of seconds, the hundredths being estimated.

After the points for the distance arcs have been pricked on the smooth sheet, short pencil arcs are drawn through them with a beam compass set at the approximate plotted positions of the respective stations. These pencil lines should be short, just long enough to ensure their intersection with the sounding line. For drawing distance arcs of various radii, it is convenient to use two sets of beam compasses, one with a long beam and the other with a short beam, to avoid having to shift the fixtures an excessive amount.

Where two R.A.R. stations comparatively close to each other have been used, distance circles are drawn from only one (see **7341**). To plot an arc from the station for which no circles have been drawn, the increment or decrement is measured from the distance circle plotted on the sheet. The total distance from this pricked point to the true center of the distance circles is set on the beam compass, but the distance arc must be drawn from the R.A.R. station from which the bomb return was received. In this case the point of the beam compass must be centered exactly at each station.

7632. Plotting the Sextant Angles

After the distance arcs have been plotted the sextant angles are plotted. Sextant positions can generally be plotted with a celluloid protractor since they are usually not far from the buoy stations. Single angles are often obtained at R.A.R. positions and the loci of these angles should be plotted, since the locus of each angle so obtained is in effect another distance arc which must be considered in the determination of the final position (see **7635**).

7633. Plotting the Bearings

Bearings may be plotted by several methods. Parallel rulers may be used, but their undersurface should be covered with paper so that the metal will not soil the sheet. An inconvenience in their use is that the pieces of celluloid over the stations are frequently detached by the rulers. The best method of plotting bearings, which is sufficiently accurate, is by using the circular no-arm protractor (**4539**). When this instrument is used it is centered at the station and oriented by means of a short north-south line drawn through the station, the bearings being plotted directly without shifting the protractor.

7634. Adjustment of the Dead-Reckoning Plot

After the distance arcs and the other position data have been plotted in pencil and the dead reckoning for that part of the hydrography has been plotted on tracing paper (see **765**), a study is made of the dead reckoning to fit it best to the distance arcs and the other position data. In areas comparatively close to the R.A.R. stations where most of the bomb distances are reliable, this study is a comparatively simple matter. But where the control is inadequate or unreliable, as is often the case in areas distant from the control stations, the adjustment may be difficult even for one with extensive experience in R.A.R. methods. Continued and determined study in such cases frequently yields results seemingly impossible of attainment when the first attempt at adjustment is made.

The two positions which were used to determine the speed or log factor must not be given too much weight since it is always possible that one of these may be in error in spite of the fact that they were originally selected as being probably correct. It is to be noted that because these were used in determining the speed or log factor the dead-reckoning plot will fit them regardless of their actual accuracy of position.

Occasionally a series of three R.A.R. distances is obtained from one station which is relatively close to the sounding line. If the true azimuth of the sounding line is accurately known, the dead reckoning may be fitted to these three arcs in the same manner it would be fitted to bow, beam, and quarter bearings.

Where the dead-reckoning plot cannot be fitted satisfactorily to the position data, this is occasionally due to the use of an erroneous speed or log factor, in which case the dead reckoning must be replotted.

The outer ends of long offshore sounding lines are perhaps the most difficult to adjust. These are generally far distant from the control stations where the intersections of the distance arcs are weak at best and where, because of the extreme distances, many of the bomb returns are unreliable. Where the line is in extremely deep water, as it generally is, there is an added uncertainty due to the incomplete knowledge of the path of the sound wave in such areas, and consequently the apparent velocity needed for plotting. Some of these dead-reckoning runs are 6 to 8 hours or more long, during which period a considerable change in the leeway may be caused by wind or weather, and a change in the direction of the current, if tidal, may be expected. There is never sufficient knowledge of the current on such an offshore line.

Such offshore sounding loops must be adjusted to the last two or three positions on the offshore run that are believed to be reliable and the first two or three similarly reliable positions on the inshore run. The dead-reckoning plot is adjusted approximately for azimuth to the reliable positions at the beginning of the line. The closing error at the end of the line is adjusted graphically, proportional to time, in the manner that a closed traverse is adjusted. This first adjustment is made on tracing paper. An additional adjustment is usually required to fit it to the R.A.R. data in order to give the distance arcs their appropriate weights. (See **3376** and **3378.**)

If there are crosslines in such an area as has been discussed in the preceding paragraph, a study of the boat sheet should be made to determine how well the respective lines have been controlled. The best-controlled line should be plotted first and the successive lines plotted in the order of the strength of their control. On each line the soundings at the crossings should be tentatively plotted and used as additional control data, the positions of the more poorly controlled lines being influenced by those that are better controlled.

7635. Analysis of Data

For analyzing the various data, it is not possible to prepare a table of relative weights to apply to the different situations that might arise. Experience is the best guide and much depends on the conditions prevailing at the time of the survey. All three-point sextant fixes should be considered precise locations until proved otherwise. The locus of one sextant angle should likewise be considered a fixed line of position unless proved erroneous. Bearings to near objects will generally be accurate. The acoustic returns from the nearest station will generally be found more reliable than those from more distant stations, except that consistently good returns may be received from certain stations while those from other stations may be just as consistently unreliable. A position determined by a good intersection of three distance arcs may generally be accepted as a reliable position, but it must be remembered that an inaccurate velocity or other factors may cause the arcs to intersect at a position which is not the correct one.

7636. Sources of Error in R.A.R. Positions

Before the final positions are accepted, all conflicting data should be resolved, if possible. Such conflicts may be due to determinable errors, such as those arising in the plotting or in the reduction of the records, or they may be due to certain indeterminable errors inherent in the method itself. The various sources of error may be grouped as follows:

a. Scaling the chronograph tape.—A large error is sometimes made in identifying the signal offset on the tape. If this occurs at one position only of a series of positions, and for one distance arc, the error is generally recognizable, but where made at all of the positions of the series it is harder to detect. A large error in all of the time distances at one position is usually easily detected since the resultant arcs plot with a large triangle of error and not in accord with the dead reckoning. An error of 1 second in reading the tape has been found in this manner. (See also **6853**.)

Errors are also sometimes made in scaling the initials on the chronograph tapes. Such an error is more difficult to detect for it may result in a comparatively small triangle of error that may appear to be caused by the use of an erroneous velocity of sound. Errors are occasionally made in marking the bomb return on the tape at the time it is received, especially if this occurs during excessive static conditions or other radio interference, when it is difficult to distinguish the bomb returns from the *strays* or false indications. In such cases a re-examination of the tape will sometimes disclose the correct return, but changes should not be made in the distances in the Bomb Record unless the correct bomb return can be identified on the tape with reasonable certainty. The above are a few of the reasons why the chronograph tapes must be available to the smooth-sheet plotter (see **6854**).

b. Plotting and reduction of records.—Errors in drawing the distance arcs on the smooth sheet are not common. An error is occasionally made by plotting the time increment as a decrement from the next larger distance circle or vice versa, where the position falls approximately midway between them. A distance arc may be plotted occasionally from the wrong station. Mathematical errors are sometimes made in converting actual elapsed times to those used in plotting. For this reason, where certain distance arcs appear doubtful, the mathematical conversions should be rechecked in th Bomb Record. (See **8311**.)

c. The use of an erroneous velocity of sound.—These cases are not uncommon and they are particularly difficult to detect since an incorrect velocity will proportionally enlarge or reduce the distances from all stations, and the distance arcs will still plot with a very small triangle of error. In analyzing such cases it should be remembered that the correct position will be inside the triangle of error only where the stations are arranged in a triangle around it. A change in velocity will probably alter the distances to all stations proportionally. Therefore, in case of an error in velocity the correct position will be distant from each plotted arc an amount proportional to the distance of each arc from its respective station.

d. Errors inherent in the R.A.R. method.—There are certain inherent errors in the R.A.R. method of control of which little is known at present. One of these is that the time interval for an R.A.R. distance from a nearby control station is apparently shorter than it should be. The cause of this and the distance at which the effect ceases to exist are not definitely established, but it has been detected in distances up to 7 or 8 seconds from a station.

Another error, the cause of which is unknown, occurs on lines far distant from the control stations where, with the same sized bomb, the time intervals apparently lengthen slightly more than they should as the survey ship proceeds away from the stations. In such cases, if a change is made to a larger bomb, the excess time distance is apparently reduced. And just the opposite effect is noted when the ship is heading toward the control stations from far offshore.

Since neither the cause nor the magnitude of these errors is known, there is no way of compensating for them. Further experiments in the field may disclose a solution to these and other problems.

e. Errors in bearings.—Bearings are only accurate where they are observed to comparatively close objects. In general, those observed to an object not more than 4 miles away may be considered reliable, but some of these and all of those taken at greater distances should be used with caution.

7637. Accepting and Inking Positions

After the analysis has disclosed which distance arcs and position data are reliable and to be used, the exact fitting of the dead reckoning to them and the pricking of the finally accepted positions should be accomplished. The dead-reckoning plot will seldom fit all of the accepted position data exactly. As one position after another is finally decided upon and pricked, it is necessary to shift the dead-reckoning plot small amounts to adjust it to the successively accepted positions.

As the positions are accepted on a given sounding line, the distance arcs shall be inked or left in pencil according to the following rules:

(1) All arcs that are 3 mm or more distant from the accepted position are temporarily questioned and the reduction and plotting are rechecked. If no errors are found and the *arcs are not used* in determining the R.A.R. position, they are left in *pencil* on the smooth sheet and the values are marked "R" in the Bomb Record to indicate that they have been rejected.

(2) All arcs within 3 mm of the accepted position that did not influence the location of the position are *inked* on the sheet but are marked with a question mark (?) in the Bomb Record.

(3) All arcs, regardless of their distances from the accepted position, *which have influenced* the location of the position are *inked* on the smooth sheet.

After the accepted positions have been pricked on the smooth sheet they should be inked and numbered (see **7681**) and the distance arcs inked.

For purposes of identification the distance arcs from each R.A.R. station should be inked in a distinctive color. The preferable colors in the order listed are carmine, brown, green, purple, and blue. Where there are more than five R.A.R. stations on one sheet a repetition of colors is necessary. Confusion will be avoided from such duplication if a study is first made of the returns received from the various stations. The assignment of colors should be made by one familiar with the actual field operations of that particular survey. Distance arcs should be inked with an over-all length of 6 or 7 mm, interrupted at the position dot and leaving a space in which to pencil the sounding. Arcs that do not pass through or too near the position may be inked as short continuous lines.

Bearings should be inked as fine black lines, as above, but slightly longer.

After the positions on a sounding line have been inked, the area covered by the line should be cleaned with a soft art gum eraser before connecting the positions. In this the dead reckoning must be used as a guide for changes in course which occurred between positions.

764. PLOTTING ASTRONOMIC POSITIONS

Beyond the limit of the usual control, sounding lines are controlled by dead reckoning and astronomic sights. The only data for location of the sounding lines and the positions are the astronomic sights and the carefully recorded dead reckoning. It is usual, when practicable, to observe a series of star sights at dawn and dusk to give positions at these two times. At other times, single astronomic sights, usually sun sights, are taken and these must be used in conjunction with the dead reckoning. (See also **337** and **338**.)

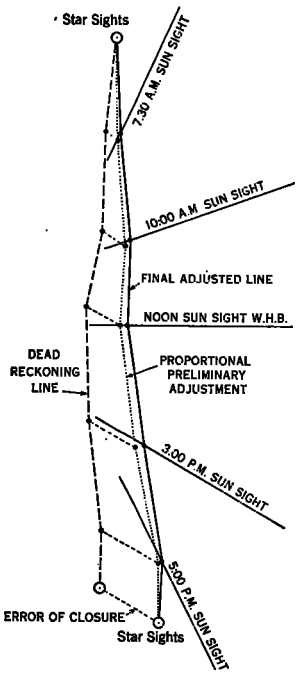


FIGURE 161.—Dead reckoning adjusted to astronomic sights.

In plotting a smooth sheet controlled by astronomic sights, the positions are usually computed and determined on separate records and it is only necessary to plot the most probable positions as determined by the hydrographer. These positions may be considered as fixed positions, a note being placed on the smooth sheet explaining their determination, such as "star sights" (see **3387**). Each intermediate single sight must be plotted as a line of position, accompanied by a legend indicating the astronomic body observed and the initials of the observer (see **3383**). Where all of the astronomic sights between two positions fixed by star sights, have been plotted on the smooth sheet, the dead reckoning between the star sights must be carefully plotted, either on the smooth sheet itself or on a piece of tracing paper, and adjusted to the two end positions and the intermediate sights, taking all circumstances into consideration in order to arrive at the most probable location of the entire line. This type of work can be plotted only by one thoroughly familiar with ship hydrography, navigation, and the probable errors that enter into dead reckoning and astronomic sights. (See **3384**.)

765. PLOTTING THE DEAD RECKONING

Dead reckoning may be plotted in various ways depending on the accuracy of the hydrographic survey and the purpose for which the dead-reckoning plot is to be used. (See also **337**.)

Where dead reckoning is used alone or in conjunction with astronomic control, since comparatively few changes in course are made, it is generally satisfactory to plot it lightly in pencil directly on the smooth sheet and make an adjustment similar to a traverse adjustment. Where dead reckoning is used in conjunction with R.A.R. control it is almost always preferable to plot it on tracing paper so that it can be adjusted to the other control data. For such purpose a good grade of comparatively thick tracing paper should be used; Keuffel and Esser Ionic No. 197-*H* is recommended. This might at first appear too thick and opaque but actually it is sufficiently transparent and otherwise very satisfactory.

Several steps in the plotting are similar, regardless of the purpose for which it is to be used. Where the dead-reckoning line is long and it is plotted directly on the smooth sheet, the direction of each course should be determined by reference to the

nearest meridian. Where the line is short, changes in course may be plotted by their angular differences, disregarding their true azimuths.

7651. Determination of the Speed or the Log Factor

For the plot of a section of dead reckoning the first step is the determination of the speed of the ship or the log factor, if log distances are used. For this it is necessary to select two well-fixed positions between which only minor changes in course have been made. The actual distance over the ground between these two positions is compared with either the log distance or the time run, in order to obtain a log factor or a speed with which the dead reckoning is plotted. In hydrography controlled by R.A.R. methods it is sometimes difficult to select accurately fixed positions. A good intersection of three distance arcs may usually be depended on as an accurate position, if it is verified by the course and distance between it and an adjacent good position. The speed or log factor should be determined from a comparatively long distance but it must be remembered that speed and log factors differ with different directions of the sounding line. A different speed or log factor must be determined after each major change in direction. (See also **4826** and **4827**.)

7652. Dead Reckoning in Conjunction With R.A.R.

Since there are still numerous uncertainties in the R.A.R. method of control, it is frequently necessary to use a dead-reckoning plot in conjunction with the other data to determine the most probable positions. There are two general cases where this is necessary; first, in areas very close to the control, where for some reason or other the R.A.R. data are inadequate; and second, on the outer ends of long lines distant from the R.A.R. stations where few, if any, R.A.R. returns are obtained. The dead-reckoning plot is made from the data in the Sounding Record supplemented and checked by the R.A.R. abstracts. Where the dead reckoning is plotted by log distances, the use of the R.A.R. abstracts is necessary because only on this form are the log intervals determined. (See also **7634**.)

Dead-reckoning plots are not necessary in connection with all R.A.R. surveys. In areas where the positions are controlled by three R.A.R. distances which plot consistently with good intersections the dead-reckoning plots are unnecessary. On the other hand, where the R.A.R. returns are not consistently and accurately received for any reason whatsoever, the control data should always be supplemented by the dead-reckoning plot; for example, dead-reckoning plots should always be used in plotting the outer ends of offshore sounding lines. It is good training for an inexperienced person to plot the dead reckoning of all of the lines controlled by R.A.R. The dead-reckoning plots may also be advantageously used by the supervising officer in verifying the work of a new employee.

7653. Plotting a Dead-Reckoning Line

There are several methods by which dead reckoning may be plotted, the choice between which depends on the amount which is to be done. Parallel rulers may be used. With them the successive courses may be plotted with reference to a meridian line or by the small angular differences between the courses. A circular no-arm protractor may be used. This is considered a better method than the use of the parallel rulers. In this method each successive course is plotted in azimuth relative to the previous course.

A special compass rose has been found advantageous for making R.A.R. dead-reckoning plots. This is a partial rose about 16 inches in diameter on heavy paper. Each single degree is drawn for about 15° or 20° on each side of a central line extending the length of the paper, and numbered according to its angular distance from the central line. To use this rose a mean course or an approximate direction of the line is assumed with respect to which the successive courses are plotted by differences in degrees. The tracing paper on which the dead-reckoning plot is to be made is placed over the compass rose and weighted down. The successive courses are then plotted on the tracing with reference to the compass rose by the use of two triangles to transfer each direction to the position from which it is to be plotted. In using this special rose it is best to assume an average course of an even 5°.

Dead reckoning may be plotted by log distances or by time. Each method may be preferred under different conditions. If the r.p.m.'s of the engine are reasonably constant and if a careful record of the time has been kept in the Sounding Record, the use of time alone is believed preferable since this eliminates the necessity of computing and checking the log intervals and generally simplifies the work. Log distances are probably slightly more accurate and should be used for all comparatively long dead-reckoning plots. This is only true, however, if the log is an accurate one and the survey is made in waters where there is no floating debris to become attached to the log rotator or log line.

Except on the outer ends of offshore dead-reckoning lines, U-turns (where the direction of the line changes 90° and soon thereafter another 90° in order to put the ship on an adjacent parallel line) are not plotted unless they are necessary to fill a *holiday* in the surveyed area. The recorded data are rarely adequate to plot such turns satisfactorily, unless a fixed position has been obtained between the two 90° turns. Where it is necessary to plot a 90° turn and other evidence is lacking, approximately two-thirds of the distance around the turn should be added to the previous course and one-third of the distance to the new course. (See **3454**.)

During the survey the ship occasionally gets so far off line that an S-turn is required to get back on the original line. It is particularly difficult to plot the dead reckoning of these turns because sufficient data relative to them are rarely recorded. The data needed are the times the vessel begins to turn after each order to change course, the time the vessel is steadied on the new course, and the course and time steered on the intermediate course. (See **3464**.)

Each completed dead-reckoning plot should be the best possible graphic representation of relative courses and distances between fixed positions. Several dead-reckoning plots may be included on one sheet of tracing paper but each one should be properly identified. In order to avoid confusion not more than one day's hydrography should be included on one sheet. The plot should be made neatly and accurately and marked for subsequent easy identification.

All sheets of tracing paper containing dead-reckoning plots shall be transmitted to the Washington Office for use in connection with the verification of the survey, after which they are destroyed.

766. Detached Positions

The detached positions in the Sounding Record are of the utmost importance, since they are usually taken to locate rocks, floating aids to navigation, least depths on

shoals, or other dangers or features of importance. They must, therefore, be plotted with extreme care. The plotting of positions on a continuous line of soundings is automatically checked to a certain degree by the dead reckoning. There is no such check on detached positions. The survey requirement for important detached positions is that a third, or check, angle shall be taken at such positions. In plotting the smooth sheet this check angle must always be used by the plotter to verify the correctness of his protracting. The fact that this has been done must be indicated in the Sounding Record by a colored pencil checkmark placed after the third or check angle.

767. USE OF BOAT SHEET IN SMOOTH PLOTTING

7671. Comparison With Boat Sheet

During the protracting of the smooth sheet, constant reference should be made to the boat sheet, as a check on the smooth plotting. Generally, a visual comparison is sufficient, but where difficulty in plotting is encountered or where numerous errors are found in the recorded data, it is sometimes advisable to trace from the boat sheet the positions of an entire line for comparison with the smooth plotting. Where a discrepancy between the two is noted, it must be investigated. Such discrepancies may arise from errors in the smooth plotting; from errors in the boat-sheet plotting; or from errors in the recorded data. In determining the position most probably correct, several facts must be kept constantly in mind, the most important of which is that the boat-sheet position is usually plotted independently of the recorded data. The plotter, himself, has usually observed one of the angles and knows which signals he used. The other angle he obtains orally from the other angleman. Furthermore, the officer-in-charge knows what he is trying to do and where the most probable position of the vessel should be, irrespective of where the recorded data place the position. It frequently happens, either intentionally or unintentionally, that an angle is measured to a different signal from that previously used, but in the haste to plot the position, the change of signal is not reported or is not entered in the Record when it is reported. (See also **3211**.)

Frequently when some error has been made in the observed data, such as an angle observed on a wrong signal or an error in reading the sextant, the boat-sheet plotter may not have sufficient time to determine what this error is. He plots the position as best he can, and may instruct the recorder to question either the entire fix or a part of it. The smooth plotter should study such cases. With a little patience he can often determine what the most probable error is, and can make the necessary correction to the recorded data. Such corrections must be made with a colored pencil (see **7741**).

7672. Positions From Boat Sheet

There are cases in hydrographic surveys where it is impossible to obtain a three-point fix or other position data. This frequently happens in narrow winding channels and sloughs. The hydrographer, in such cases, spots his position on the boat sheet from the adjacent features of the shoreline and from his sense of dead reckoning. The smooth plotter should transfer such positions to the smooth sheet and note that fact in the Sounding Record with his colored pencil. In addition, he should transfer the curved connecting lines between positions, which in narrow channels usually conform to the bends in the shoreline, it being impossible to run a straight course between positions. (See **3252** and **3352**.)

There are occasional cases where position data, although recorded, are so erroneous that they obviously cannot be used. In such cases the smooth plotter's last recourse is the boat sheet. Often by placing the center of the protractor on the boat-sheet position and trying various combinations of angles and signals, he will be able to determine what the recorded data should have been.

768. Identification of Positions

Each hydrographic position, regardless of the method used in plotting, shall be marked on the smooth sheet by a small prick hole and identified by the position number, the prick hole being accentuated by a fine ink dot of the same color as the position number and day letter (see **7681**). At the beginning and end of each line, at every intermediate fifth position, and at any pronounced change in the direction of the line, the position number shall be accompanied by the day letter.

7681. Position Numbers and Day Letters

Beginning with number 1, consecutive numbers are assigned to positions during each day, and each day's field work by each vessel is identified by a day letter (see **3311** and **3312**). The day letters inked on the smooth sheet must correspond in color and case with the entries in the Sounding Record, and the position numbers must correspond in number with the entries in the Sounding Record, and in color with the day letters. The colors to be used for this purpose are blue, purple, green, and red, preference being given in that order for the predominant color on a sheet. The use of black and yellow is forbidden (see **8121**). A contrast is desirable between two colors used for this purpose on the same sheet.

Position numbers and day letters are usually inked as each sounding line or page of the Sounding Record is protracted. This is generally often enough to avoid errors. In congested areas, it is sometimes convenient to connect the prick holes representing the positions with pencil lines on the overlay tracing, to assist in their subsequent identification on the smooth sheet.

The position number must be so small that it can never be confused with a sounding, and yet should be large enough so that it can ordinarily be read without a magnifying glass. Vertical figures and letters shall be used, and these shall ordinarily not exceed 1 mm in height. In open areas, where the soundings will be inked larger than average, the position numbers and day letters may also be slightly larger than the average, while in areas of close development, where the soundings will have to be inked smaller than average, the position numbers and day letters should be somewhat smaller than average (see **7732** and fig. 163).

Because of their small size, considerable care should be taken in inking the position numbers and day letters, and in their placement on the sheet. Their purpose is to permit ready comparison of the plotted data with the Sounding Record, and if illegibility makes this difficult, the purpose is defeated.

The position number should be placed preferably just below and to the right of the position dot, with enough space left for the entry of the sounding so that when the latter is inked the position number will be close to, but just below and to the right of it, consideration being given to the size of the sounding to be inked at the position. (See also **7762**.)

In congested areas, and especially in those areas in which considerable development has been done, it is usually advisable not to ink the position numbers and day letters

until after the soundings have been penciled, and certainly they must not be inked in a given area until after all of the positions have been plotted in that area, in order that they may be so placed as not to conflict with the soundings on other lines. Under any circumstances the placement of the position numbers and day letters must indicate indubitably the positions to which they refer. This may be accomplished where necessary by the use of fine inked arrows or leaders from the position number to the position dot, using the same color as for the number.

7682. Connecting Positions

Successive positions shall be connected by a pencil line using a well-sharpened 3H or 4H pencil with a round point—not a chisel edge (see **724**). Care must be taken not to engrave this line in the surface of the paper.

The connecting lines represent the path of the survey vessel, and in drawing them on the smooth sheet the path should be assimilated so far as possible. Both the boat sheet and the entries in the Sounding Record as to changes in course should be used as a guide. Instructions for the field survey require that a position be taken at each change in course greater than 10° (see **3463**). However, it is frequently necessary to make changes in course between positions, which are large enough to affect the locations of the soundings between the positions. Changes in course of 1° or 2° between positions may be disregarded in the plotting and the consecutive positions connected by a straight line, but for greater changes the positions should be connected by lines which follow the actual track of the vessel.

Changes in course are not always effective at the time of the order to change. This depends on the momentum of the vessel. In a launch the effect is almost immediate, while in the larger vessels, some time elapses before the change becomes effective. This fact together with a knowledge of the turning radius of the vessel will determine its path.

Each vessel has its own turning radius, being proportionately larger as the size of the vessel increases. When better information relative to the turning radius is lacking, it may be assumed to be, as a general rule, zero for outboard motor boats, 15 meters for the smaller launches, and 150 meters for the smaller vessels. For the larger ships, unless there is evidence to the contrary, turns should be plotted on the assumption that, after a position, the vessel maintains the original course for twice the distance it is on the new course before the next position is taken (see **3463**). If soundings on turns are to be inked on the smooth sheet, the greatest care must be taken in correctly representing the turns. This is particularly true in the case of right-angled and 180° turns. However, where no soundings have been recorded, only the approximate path need be indicated.

Minor changes in course are frequently made by the hydrographer *after* a position has been plotted on the boat sheet and it is learned what change is necessary. Obviously such changes occur some little distance past the position, although the recorded data may not so indicate. In such cases, if no change in course has occurred between the two immediately preceding positions nor between the two succeeding positions, the connecting lines between these may be extended forward and backward and their intersection will usually represent the point where the change in course was effective.

In narrow winding channels and rivers and sometimes on the inshore line along a rugged coast, it is impracticable to take a position at every turn, since the sounding lines must follow the bends in the shoreline. In such cases the connecting lines must be transferred from the boat sheet, on which the hydrographer will have indicated the correct track. (See **3352**.)

769. PLOTTING SUPPLEMENTAL DATA

It is frequently impossible or impracticable to determine the positions of rocks awash, dangerous wrecks, floating aids to navigation, etc., by three-point fixes, or other means described above in section **76**. In areas where the general hydrography is controlled by three-point sextant fixes, such objects are usually *cut in* (see **7415**). In this method of location, cuts may be taken from known shore positions, but more frequently they are obtained during the hydrographic survey by a third observer, who takes a sextant angle to the object simultaneously as the angles for position are being observed. These extra, or third, angles are recorded in the Sounding Record with the position at which they were taken, and the object cut in is described. Three or more cuts from different positions, which will give an adequate angle of intersection, are usually taken to each object.

As the smooth plotting proceeds, these cuts must also be plotted. The boat sheet should be used as a guide for the approximate locations of the objects cut in.

Such cuts rarely result in a perfect intersection and a judicious interpretation of the data is necessary to determine the most probable position of the object. The distance of the object from the vessel, the inherent strength of the position fix, and the size of the angle of the cut must all be taken into consideration. So far as uncertainties in the position fix are concerned, the smaller the angle of the cut the less will be the effect on it due to slight inaccuracies in the fix, especially when the object cut in is at the same approximate distance as the stations used for the fix.

If the object being located is a floating aid to navigation, the direction of the current at each observation should be considered.

Where many cuts have been taken to different objects in an area, it is frequently extremely difficult to be certain which cuts were taken to identical objects, and a careful study of all the facts and data is necessary to avoid the possibility of confusion of cuts.

77. SOUNDINGS AND DEPTH CURVES

The soundings are the most important part of a hydrographic survey, and the greatest care must be taken in putting them on the smooth sheet. They must be clear and legible and, in general, a magnifying glass should not be required to read them. The smooth plotter must always bear in mind that an illegible sounding erroneously transferred to a published chart may possibly result in loss of life and property. The fact that the work is verified before publication does not relieve the plotter from exercising care in the first instance.

All soundings are *penciled* on the smooth sheet in the field. Under no circumstances are they to be inked by the field party. This is accomplished only after verification in the Washington Office.

771. DEPTH UNITS

Only one depth unit (fathoms or feet) shall be used on each hydrographic survey sheet. The depth unit to be used will depend on the general region (in which ocean the survey is located), on the specific locality, and on the unit used on existing charts.

7711. Depth Unit in the Atlantic Ocean

The depth unit of surveys in the Atlantic Ocean and bodies of water tributary thereto shall be integral feet (and occasionally to the nearest half-foot), except—

(*a*) For those offshore surveys which are entirely beyond the limits of charts whose depth unit is feet; in which case the depth unit of the survey shall be fathoms.

7712. Depth Unit in the Pacific Ocean

The depth unit of surveys in the Pacific Ocean and bodies of water tributary thereto shall be fathoms (and decimals), except—

(*a*) Where the major part of a hydrographic sheet is within the limits of a chart whose depths are in feet, that smooth sheet shall be plotted in feet.

(*b*) That the survey adjacent to the shoreline shall be in feet when the sheets can be arranged, without duplication, so that nearly all of the reduced depths on the inshore sheet are less than 25 fathoms.

7713. Fractional Foot Units

On a hydrographic sheet whose depth unit is feet, the depths shall be in integral feet, *except* in the following cases, where they shall be shown to the nearest half-foot:

(*a*) At important points on navigable bars.
(*b*) At critical places in channels of a general depth of 42 feet or less.
(*c*) The least depth on important shoals, rocks, and dangers when less than 42 feet.
(*d*) In shallow enclosed waters and inside routes.
(*e*) On both sides of the low-water line (see **7715**).
(*f*) Where necessary or desirable to define the depth curves better (see **7762**).

7714. Decimal Fathom Units

On a hydrographic sheet whose depth unit is fathoms, soundings shall be plotted as follows: less than 11 fathoms in fathoms and tenths, between 11 and 31 fathoms to the nearest half-fathom, and greater than 31 fathoms in integral fathoms, *except*—

Where the bottom is smooth and the slope gentle (as in parts of the Gulf of Mexico, the Atlantic Continental Shelf, and the Bering Sea), and a Dorsey Fathometer or instrument of equivalent accuracy is used, soundings less than 31 fathoms shall be in fathoms and tenths and between 31 and 101 fathoms to the nearest half-fathom.

7715. Minus Soundings

Soundings that reduce to heights above the sounding datum (plane of reference) are termed minus soundings, since ordinary soundings are depths below the sounding datum and are considered positive numbers. Minus soundings are shown on the smooth sheet preceded by a minus sign (see **7735**) and should fall inshore of the low-water line, such areas being bare at the sounding datum.

In order that the location of the low-water line may be more precisely delineated on the smooth sheet, the soundings in the vicinity of the line should be plotted to the nearest half-foot (see **7713**(*e*)), extreme care being taken to accompany them with the correct sign.

7716. Conversion of Depth Units

The corrected depths in the "Reduced soundings" column of the Sounding Record from which the smooth sheet is plotted are either in (*a*) integral feet, (*b*) feet and decimals, (*c*) integral fathoms, or (*d*) fathoms and decimals. The double depth unit of fathoms and feet is no longer used.

Although the corrected depths in the *Sounding Record* may change from one unit to another within the area of a survey or within the same Sounding Record, they are all finally reduced to the unit to be used on the hydrographic smooth sheet (see **823**). Only one unit (fathoms or feet) shall be used on any one smooth sheet. Fractions or decimals of the same unit may of course be used.

A. SMOOTH-SHEET SOUNDINGS

Where the depth unit on a hydrographic smooth sheet is feet, all soundings are in integral feet (and occasionally half feet). Where the depth unit is fathoms, all soundings are in integral fathoms or fathoms and decimals. To accomplish this a conversion from the unit of the depths in the Sounding Records is frequently necessary. This shall be done in accordance with the following rules which are also illustrated in figure 162:

(1) Where the same depth unit is used on the smooth sheet as in the Sounding Record, but in integers on the sheet, any partial units shall be converted into whole units by changing 0.75 or more into the next greater integral unit, and changing decimals below 0.75 into the next lesser integral unit (e. g., 2.75 to 3.75 feet=3 feet; 12.75 to 13.75 fathoms=13 fathoms).

(2) Where as in (1) the depth unit is the same but the soundings are to be plotted in fathoms and tenths, partial units shall be converted by changing 0.075 or more into the next greater decimal unit, and less than 0.075 into the next lesser unit (e. g., 2.575 to 2.675=2.6 fathoms).

(3) Where as in (1) the depth unit is the same but the soundings are to be plotted in half units, then 0.25 to 0.75 shall become ½, and 0.75 to 1.25 shall become 1 (e. g., 3.25 to 3.75 feet=3½ feet; 3.75 to 4.25 feet=4 feet).

(4) Where the reduced soundings in the Sounding Record are in a different unit from that to be used on the smooth sheet, they shall first be converted to their equivalent values in the smooth-sheet unit and then apply rule (1) or (2), as the case may require to obtain the values for plotting.

Table 26 illustrates the application of these rules:

TABLE 26.—*Conversion of reduced sounding values to smooth-sheet values*

Reduced soundings in Sounding Record		To be plotted on smooth sheet in	Reduced soundings in Sounding Record		To be plotted on smooth sheet in
Feet	*Fathoms*	*Feet*	*Fathoms*	*Feet*	*Fathoms*
−1. 25	−0. 21	----−1	−0. 125	−0. 75	----−0. 1
−0. 25	−0. 04	---- 0	−0. 025	−0. 15	---- 0. 0
0. 75	0. 125	---- 1	0. 075	0. 45	---- 0. 1
1. 75	0. 29	---- 2	0. 175	1. 05	---- 0. 2
2. 75	0. 46	---- 3	0. 275	1. 65	---- 0. 3
3. 75	0. 625	---- 4	0. 375	2. 25	---- 0. 4
4. 75	0. 79	---- 5	0. 475	2. 85	---- 0. 5
5. 75	0. 96		0. 575	3. 45	---- 0. 6
			0. 675	4. 05	---- 0. 7
			0. 775	4. 65	---- 0. 8
			0. 875	5. 25	---- 0. 9
			0. 975	5. 85	

B. CHARTED SOUNDINGS

The soundings on the published nautical charts are either in (*a*) integral feet, (*b*) integral fathoms, (*c*) fathoms and half fathoms, or (*d*) fathoms and quarter fathoms;—but, these charted soundings are from smooth sheets on which the soundings may appear in (*a*) integral feet, (*b*) feet and half feet, (*c*) integral fathoms, or (*d*) fathoms and tenths of fathoms.

CHART			SMOOTH SHEET	REDUCED SOUNDINGS		SMOOTH SHEET	CHART	
FATHOMS	FATHOMS AND QUARTERS	FEET	FATHOMS AND TENTHS	FEET	FATHOMS AND TENTHS	FEET	FATHOMS AND QUARTERS	FATHOMS
			2.8	17	2.8			
2	$2\frac{1}{2}$	16	2.7	16	2.7	16	$2\frac{1}{2}$	2
		15	2.6		2.6	15		
			2.5	15	2.5			
	$2\frac{1}{4}$	14	2.4	14	2.4	14	$2\frac{1}{4}$	
			2.3		2.3			
	2	13	2.2	13	2.2	13	2	
		12	2.1		2.1	12		
			2.0	12	2.0			
	$1\frac{3}{4}$	11	1.9	11	1.9	11	$1\frac{3}{4}$	
			1.8		1.8			
1	$1\frac{1}{2}$	10	1.7	10	1.7	10	$1\frac{1}{2}$	1
		9	1.6		1.6	9		
			1.5	9	1.5			
	$1\frac{1}{4}$	8	1.4	8	1.4	8	$1\frac{1}{4}$	
			1.3		1.3			
	1	7	1.2	7	1.2	7	1	
		6	1.1		1.1	6		
			1.0	6	1.0			
	$\frac{3}{4}$	5	0.9	5	0.9	5	$\frac{3}{4}$	
			0.8		0.8			
	$\frac{1}{2}$	4	0.7	4	0.7	4	$\frac{1}{2}$	
		3	0.6		0.6	3		
			0.5	3	0.5			

FIGURE 162.—Reduced sounding equivalents for smooth sheet and chart.

It is obvious that it may be necessary to convert from the unit on the smooth sheet to another unit for charting purposes and this shall be done in accordance with the following rules (see also fig. 162):

(1) Where the charted soundings are to be in the same integral unit used on the smooth sheet the soundings shall be transferred without change.

(2) Where a sounding in feet on the smooth sheet includes a fraction, the fraction shall be omitted in charting (e. g. 8½ feet=8 feet).

(3) Where the soundings on the smooth sheet are in integral feet and are to be charted in fathoms and quarters, fathoms and half fathoms, or integral fathoms, the odd feet shall be converted as follows:

Sounding on smooth sheet	To be charted in		
Feet	*Quarter fathoms*	*Half fathoms*	*Integral fathoms*
1	0	0	0
2	¼	½	0
3	½	½	0
4	½	½	0
5	¾	1	1

(4) Where the soundings on the smooth sheet are in fathoms and tenths and are to be charted in integral feet, integral fathoms, fathoms and quarters, or fathoms and half fathoms, the decimals of fathoms shall be converted as follows:

Soundings on smooth sheet	To be charted in			
Fathoms	*Integral feet*	*Quarter fathoms*	*Half fathoms*	*Integral fathoms*
0.1	0	0	0	0
0.2	1	0	0	0
0.3	2	¼	0	0
0.4	2	¼	½	0
0.5	3	½	½	0
0.6	3	½	½	0
0.7	4	½	½	0
0.8	5	¾	½	1
0.9	5	¾	1	1

772. PLOTTING THE SOUNDINGS

To avoid soiling the smooth sheet during the penciling or inking of the soundings, it should be kept completely covered, except for the small area actually being worked on. A convenient method is to use a large piece of celluloid about 2½ feet square with a circular hole, 3 to 4 inches in diameter, cut in its center, the celluloid being moved around as necessary during the work. Paper can be used instead of celluloid, but celluloid has the advantage of permitting the work to be seen through it. Other parts of the sheet can be kept covered with convenient sized pieces of obsolete charts or wrapping paper. (See **731**.)

The plotting of the soundings on the smooth sheet follows generally the same procedure used in plotting the positions; that is, the plotter usually begins with position 1 of "A" day and plots the soundings in the order in which they were actually taken in the field. This procedure is, of course, not a requirement, and it may be advantageous to depart from it in special cases.

All soundings that are penciled or inked on the smooth sheet shall be spaced according to the recorded time, or the travel of the paper in the case of fathograms, and spacing dividers (see **4813**) shall always be used for this purpose. No deviation

from the recorded times shall be made for the purpose of improving crossings, or for other reasons, unless other data prove that the recorded times are in error. Such errors usually occur only in the hours or minutes, and if the interval between positions is relatively short, as it usually is in three-point fix hydrography, an error in the minutes is easily detected.

Where the depths between positions are uniform, a slight displacement in the positions of the soundings is immaterial, and no appreciable time should be expended in obtaining precise spacing. In irregular depths, however, the spacing as recorded must be closely followed.

All soundings must be plotted on the pencil lines connecting consecutive positions (see **7682**).

Where soundings fall close to control stations in the water area, care must be taken that the soundings do not obscure the actual station points. In general, in unimportant areas of uniform bottom, soundings should not be shown inside a station symbol. But there should be no hesitancy to break the station symbol to show an important sounding.

7721. Spacing Three-Point Fix Hydrography

In three-point fix hydrography positions are usually taken at regular intervals and at even minutes of time (see **3313**). This simplifies the plotting of the soundings between positions. If the soundings are taken at uniform intervals, as is generally the case in handlead work, the spacing dividers are used to subdivide the distance between positions into the required number of spaces, and the soundings are plotted. If the sounding interval is not uniform, the soundings must be plotted according to their respective times. In such cases the spacing dividers are used as a time-measuring device. (See **343** and **4813**.)

When the speed of the vessel is changed materially between positions it must be taken into account in spacing the soundings. This is particularly important in launch and small-boat hydrography at the beginning of lines near the beach, where the launch or boat starts from a standstill or slow speed, increasing to full speed soon thereafter. A similar allowance is often necessary near the end of a sounding line near the beach where the speed may be reduced as the launch approaches the shore. Occasionally, such changes are made far offshore; as for instance, when it is necessary to slow down to avoid collision with a passing vessel. Because of momentum, of course, the increased or decreased speed is effective only gradually after the time noted in the Sounding Record. (See also **3461**.)

7722. Spacing R.A.R. Hydrography

In R.A.R. hydrography, positions do not necessarily coincide with even minutes of time, and as the soundings are recorded according to time intervals there will not always be a sounding on the position; neither can the soundings be spaced evenly from position to position. In using the spacing dividers the points must be set according to time, starting with the minute immediately preceding or following any R.A.R. position which does not occur at an even minute (see **4813**). Otherwise, soundings controlled by R.A.R. are spaced in a manner similar to that used in other methods of control.

a. Tabulation of crossings on R.A.R. sheets.—Because of the relative weakness of R.A.R. control in certain areas a penciled tabulation of the depths at crossings shall

be made for each R.A.R. sheet and included in the Descriptive Report (see **842K**). This will give some idea of the relative accuracy with which the hydrography has been controlled, if the depths are accurate. This tabulation can be most conveniently made as the soundings are plotted on the sheet. At each crossing the depth differences are computed and when these data are available for the entire sheet, percentages are computed which will give a reasonably fair idea of the accuracy with which the survey has been controlled.

7723. Spacing Echo Soundings

Because of the possibility of obtaining an almost infinite number of soundings when the echo method is used, there are frequently more soundings recorded than can or should be shown on the smooth sheet. Echo soundings are spaced in the conventional manner, except that a certain percentage of those recorded will often have to be omitted from the smooth sheet. In echo sounding, soundings are frequently recorded at irregular intervals, but these are usually more important than those recorded at regular intervals, because they define irregularities in the general slope of the bottom. (See **3423**.)

Where soundings are penciled on the smooth sheet directly from a fathogram, clock time is not necessarily used to determine the spacing. The printed fathograms used on the 808 Fathometer contain equally spaced vertical arcs, by which the spacing of the soundings may be determined. When a fathogram is used, the three-point fixes are often taken at the exact moment the stylus is marking on one of the vertical arcs, and irrespective of clock time, with the interval between positions being determined by the number of spaces between position arcs rather than by the number of minutes and seconds. When soundings from such a record are to be transferred to the smooth sheet, the spacing dividers should be adjusted between any two consecutive positions on the smooth sheet so that each divider point represents a vertical printed arc on the fathogram, if the scale permits. When this is done each divider point on the smooth sheet represents the position of the vessel when the sounding was recorded on one of the vertical arcs. In any case, the divider points should be adjusted to a definite relation with the printed arcs, rather than to the clock time, as is necessary for soundings recorded in a Sounding Record. Where three-point fixes have been obtained which did not coincide with one of the vertical arcs, the method is similar except that fractional parts of the spaces between the position arcs must be considered in making the spacing divider adjustment on the smooth sheet in relation to the positions, so that each divider point will still represent a printed arc.

Mechanical spacing of soundings derived from a fathogram is not to be tolerated. Selection should be made as described in **7726**, plotting the soundings on the smooth sheet in their correct positions between the points of the spacing dividers by reference to their positions between corresponding vertical arcs on the fathogram.

7724. Frequency of Soundings

The scale of the smooth sheet and the sounding interval will ordinarily be selected so as to permit all soundings recorded in the Sounding Record to be shown on the smooth sheet. The frequency of recorded soundings is, of course, greater in shallow than in deep water, and this may result in more soundings being recorded than can be shown on the smooth sheet. In this case selection is necessary (see **7725**).

Where the appearance of the smooth sheet is the only criterion, the following rules may be used for general guidance, always bearing in mind that legibility and clearness are of prime consideration:

(1) Where the horizontal axis of the numeral approximately parallels the direction of the sounding line, 1-digit numerals should be spaced about 7 to an inch, 2-digit numerals about 5 to an inch, and 3-digit numerals about 4 to an inch.

(2) Where the horizontal axis of the numeral is approximately normal to the direction of the sounding line, the most satisfactory spacing is about 7 numerals to an inch.

(3) Where numerous fractions, or decimals, are to be shown, these may be considered as equivalent in width to about one-half digit.

In congested areas at least 50 percent more soundings can be legibly shown in the same space without undue confusion, if care is used (see **7732** and fig. 163).

7725. *Selection of Soundings*

Where all of the recorded soundings are not to be shown on the smooth sheet a careful selection must be made so that those shown will most nearly represent the actual bottom relief. In no case, except where the bottom is practically flat, shall a mere mechanical selection be used, as for instance the selection of alternate soundings. The sounding obtained on a fix should always be shown. Between fixes, where a selection is necessary, the general rule is that both the deepest and shoalest soundings must be shown, interspersed with as many other soundings as can be conveniently shown. It is absolutely essential that the final result show the least depth on shoals, the greatest and least depth in channels, all changes of slope, and those soundings which are essential to the correct delineation of the depth curves.

In penciling soundings on the smooth sheet, it is essential that dangers and important depths be not obscured by numerous soundings of lesser importance. As the progress of penciling reveals the important features it will frequently be found necessary to delete some of the plotted soundings to permit showing those of more importance. To assist in drawing attention to important features, such as rocks awash, sunken rocks, and least depths on shoals, frequent use shall be made of leaders pointing to these (see **7753**).

The low-water line is one of the most important depth curves on the smooth sheet, and it is essential that it be located as accurately as possible. All of the soundings that will aid in defining its location shall be shown in pencil on the smooth sheet. (See **754**.)

At crossings of sounding lines and occasionally where two parallel sounding lines approach one another closely, the soundings of one line will conflict in position with those of another line. In selecting the soundings in such cases, the same considerations must govern as in the case where all the soundings on one line cannot be shown. In general, the least depth should be selected.

Where soundings have been taken over even mud or sand bottom and there is a plethora of soundings of approximately the same depth, it is unnecessary to show them with the frequency used for uneven bottom. In such cases they should be plotted with only about two-thirds the frequency stated in **7724**.

Recorded soundings that are not used in the smooth-sheet plotting should be marked "N.P." in the Sounding Record, the notation being entered in color (see **7624**) after the final reduced sounding.

7726. Selection of Soundings From Fathogram

Where the depths are recorded on a fathogram a different problem is presented. In this case, soundings are selected from a continuous profile of the bottom along the line traversed by the sounding vessel. The smooth plotter must have an appropriate spacing in mind at all times, but he must not select the soundings by any regular spacing. The soundings selected should, insofar as their frequency permits, present a numerical record that will approximate the graphic profile. In all cases the least depth of a rise in the bottom must be selected, and this must be followed and preceded by the greatest depths, where practicable, irrespective of any intermediate soundings. Likewise, the greatest depth of a depression in the bottom must be selected. In very irregular bottom the number of these to be shown will be regulated, of course, by the number of soundings that can be legibly shown on the smooth sheet in a given space. Intermediate soundings shall be selected which will best delineate the actual profile.

773. PENCILING THE SOUNDINGS

In penciling the soundings, the smooth plotter must use every effort to achieve clarity. Critical soundings should never be obscured by placing soundings of lesser importance too close to them. A pencil hard enough to prevent smudging should be used, but it must not be so hard as to indent or cut the surface of the paper. Generally, a 3H pencil will be found satisfactory, but this will depend on the humidity of the atmosphere at the time (see **724**).

As each day's soundings are penciled the plotter shall enter his initials with a colored pencil in the appropriate space in Stamp No. 38, Processing, placed in the Sounding Record at the end of each day's work (see fig. 183).

7731. Style of Numerals

The penciled soundings shall be bold vertical numerals, drawn with single strokes. Hair line or fancy lettering must not be used. The beginner will usually experience some difficulty in penciling soundings neatly with even-sized numerals, but skill is easily acquired with a little practice.

7732. Size of Numerals

Most of the numerals representing soundings should be about 2 mm in height. The size of the numerals, of course, should vary somewhat according to whether the soundings are sparse or congested in any given area. In areas where the soundings are sparse the size should be increased about 10 percent, and in congested areas should be reduced about 10 percent. Ordinarily, no sounding numeral should be less than 1.8 mm in height, although even this limit may have to be lowered for areas in which the soundings would otherwise be illegible. The important things to remember are, first, that *no sounding* should ever be illegible and, second, that in order to present a pleasing appearance a uniform size of numeral should be maintained as far as practicable. (See fig. 163.)

In areas of intensive development where individual lines of soundings are difficult to follow, the numeral representing the least depth should be drawn slightly larger and bolder. Such depths are the most important soundings in the area, and a cursory examination of the sheet should disclose these without the need for a meticulous sounding-by-sounding examination of the areas. (See also **7753**.)

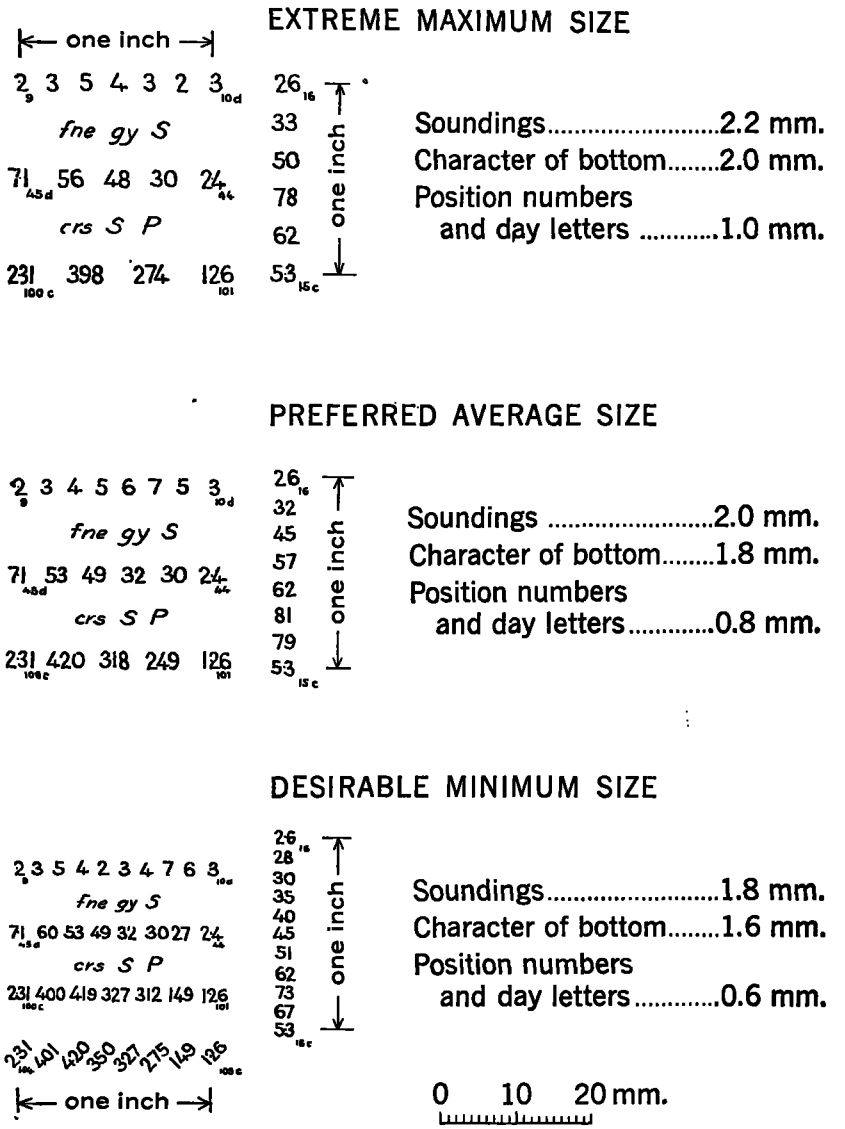


FIGURE 163.—Sizes and placement of sounding numerals and other data on smooth sheet.

When the soundings are inked in the Washington Office the same procedure shall be followed and in addition, care must be taken to maintain the opaqueness of the inked data.

7733. Orientation of Numerals

Regardless of the direction of the sounding line on the projection, all numerals representing soundings shall be oriented to be read from the south. Normally, the horizontal axis of the numbers shall be east and west. Where the numbers contain too many digits or the soundings are too frequent to permit this, they may be inked at any convenient angle, provided they can be easily read from the south (see fig. 163). It should *never* be necessary to turn the sheet to read a part of the soundings easily.

7734. Fractions and Decimals

Figures in a fraction or the decimal parts of a depth unit must be smaller than whole numbers. In general, the over-all height of a fraction should not be more than 15 percent greater than the over-all height of the whole numbers in that vicinity. Where a fraction stands alone the horizontal bar between the numerator and denominator must be included, in order to avoid mistaking the component parts of the fraction for whole numbers. But if the sounding is a mixed number—that is, where a fraction accompanies a whole number—the bar shall be omitted.

The decimal part of a fathom shall be considered as the numerator of a fraction whose denominator is 10, but with the denominator omitted, and shall be so penciled and subsequently inked on the smooth sheet. The horizontal bar which is normally used between the numerator and denominator of a fraction shall be retained as a line under the decimal part of the sounding.

No depth shall ever be shown as a decimal alone. Where the depths are less than 1 fathom, on a smooth sheet whose depth unit is fathoms, the decimal part shall be preceded by zero, as $0^{\underline{3}}$.

Greater care must be taken in penciling and inking fractions and decimals than is necessary with whole numbers, since their smaller size requires greater perfection in the formation of the numerals, in order that they shall be perfectly legible in spite of their reduced size.

In congested areas it is particularly important that fractional numbers be so drawn and so spaced that no doubt can ever arise as to whether a fraction stands alone or is part of an adjoining number.

7735. Zero and Minus Soundings

Where zero soundings are placed on the smooth sheet, extreme care must be taken in drawing these figures in order that they will not be mistaken for off-lying rocks or islets. This is especially important along rocky coasts where small isolated bare rocks or islets are frequent.

A minus sounding (see **7715**) should be preceded by a minus sign (e.g. —2). If the minus sounding is a fraction, the minus sign shall precede the *numerator*, and not be on a line with the bar between the numerator and denominator, since in the latter case it might be mistaken for a part of the bar. (See also **7734**.)

7736. Position of Numerals

The center of the number, including the fraction if any, is considered the position of that sounding and shall be so penciled and inked on the smooth sheet, except for the soundings at positions.

In penciling or inking soundings at positions it is important not to obscure the position dot by any part of the number. Therefore, in those cases, where the number is composed of an even number of digits, considering the fraction, if any, as one digit, the sounding shall be placed with an equal number of digits on each side of the position dot. Where the number is composed of an odd number of digits it shall be placed as follows: (*a*) one-digit numbers immediately to the right of the position dot; and (*b*) three-digit numbers with the first digit to the left, and the second and third digits to the right of the position dot.

7737. *Vertical Casts*

In conjunction with echo sounding, occasional comparisons are made with vertical casts taken by the leadline or wire method. Such simultaneous soundings are both to be placed on the smooth sheet, in pencil; the echo sounding at the correct position and the vertical cast immediately beneath it and connected to it by means of a bracket.

After verification in the Washington Office, only the echo soundings shall be inked in areas of comparatively regular bottom. Where vertical-cast comparisons occur in areas of steep slopes or very irregular bottom, both the echo sounding and the vertical cast are inked, the latter being marked "VC".

774. ERRORS IN SOUNDINGS AND POSITIONS

During the plotting of the soundings and the delineation of the depth curves, the smooth-sheet plotter must be ever alert to detect errors in the Sounding Records, whether in the original entries or in the final reduced depths. In spacing the soundings with the spacing dividers, previously undiscovered errors in the plotted positions may often be disclosed, which may have resulted from original erroneous or inadequate data, or from errors made by the plotter. As the soundings are penciled, errors in the depths may be disclosed by the fact that the soundings on adjacent lines are not consistent, or by the fact that when the depth curves are drawn they are forced into representations of unnatural bottom features.

If errors are discovered or suspected, they must be verified and corrected wherever necessary. But no deviation from the original recorded data shall be made unless this appears reasonable and is supported by other evidence. Where any entry in the Record is amended or rejected, such changes shall be made in colored pencil (see **7741**) and each change fully explained or justified by a note in colored pencil in the "Remarks" column.

Two general classes of errors may occur in the Sounding Records; those which affect the positions of the soundings and those which affect the depths. And of these two classes certain types of errors will affect only isolated soundings or positions, while others will affect an entire area. The latter, of course, are the most difficult to discover.

In **7624A**, there have been listed the kinds of errors found occasionally in the recorded position data which affect the positions of the soundings on the smooth sheet. Errors of position may also result from the following sources:

(*a*) Faulty spacing of the soundings along the sounding line, due to—
  (1) An error in plotting the soundings.
  (2) A failure to take into account variations in course or speed in plotting the soundings.
(*b*) One of the sextants badly out of adjustment.
(*c*) One or more of the control stations incorrectly plotted.
(*d*) In R.A.R. control, the use of an erroneous horizontal velocity of sound for one or more of the distances. (See also **7636**.)
(*e*) Small clock errors.
(*f*) An omission of variations in course or speed in the Sounding Record.

Erroneous soundings may result from an almost infinite variety of causes, of which the following are the more common:

(*a*) A confusion of numbers in the Sounding Records, such as the interchange of 7 and 11 or 15 and 50, where the soundings obtained are transmitted orally to the recorder (see **4623**).

(*b*) A misread sounding; that is, the leadsman or fathometer attendant actually reports a sounding different from that obtained.

(*c*) An inaccurately calibrated sounding apparatus or the misapplication of the corrections, among which may be the following:

(1) Leadline not compared with the standard.

(2) Leadline varied in length between standardizations.

(3) Sounding machine registering sheave not correctly calibrated.

(4) An erroneous velocity of sound used in the reduction of echo soundings.

(*d*) Erroneous application of any of the data used in reducing the soundings.

(*e*) Large clock errors which may result in an erroneous tide reduction.

(*f*) An inaccurate plane of reference; errors from this source may occur where—

(1) The tide gage is located at too great a distance from the area being sounded.

(2) The area being sounded is blocked by shoals from free access of the tide.

(3) The tide gage is so located that the free rise and fall of the tide, particularly the low water, is not correctly recorded.

(*g*) A rough state of the sea—errors due to this condition may be detected where one day's work performed in rough weather is adjacent to another day's work performed in calm weather; or where crosslines have been run in an area under different conditions of sea from those which obtained at the time the principal system of lines was run.

(*h*) Where the leadline or wire is not perfectly vertical—such condition occurs when the sounding line is run in a wind, sea, or current, handlead soundings being particularly vulnerable in this respect (see **3464**); wire soundings in deep water may be similarly affected because of the impossibility or impracticability of maintaining the position of the vessel vertically over the lead (see **3422**).

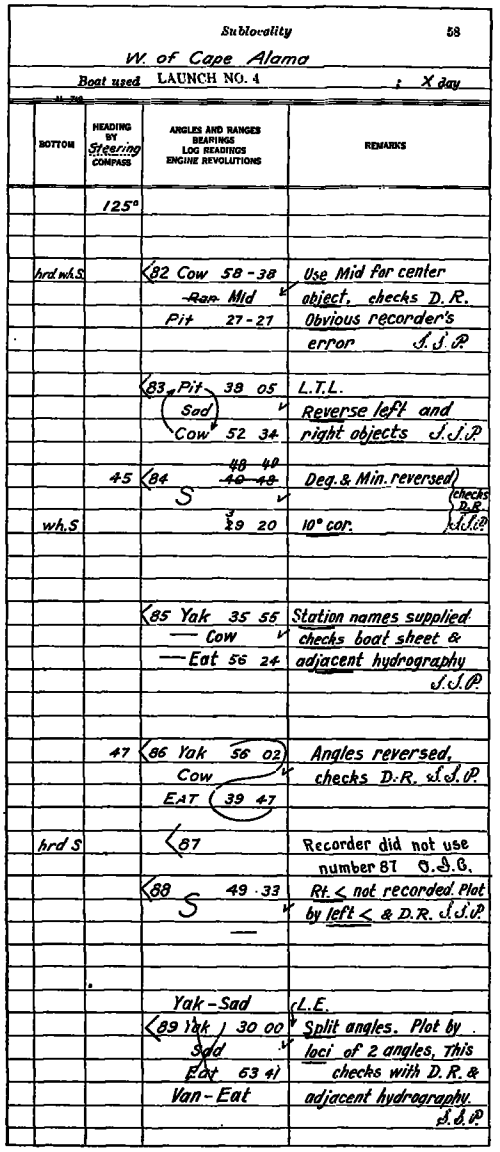
(*i*) Where handlead or wire soundings are taken in an area of very soft or oozy bottom, where it is difficult or quite impossible to detect when the lead strikes the top of the soft layer.

(*j*) Where soundings are taken on abrupt slopes:

(1) In handlead or wire soundings the lead may slip down a rocky slope.

(2) In echo sounding, the sound may be reflected from the side of the slope rather than from vertically beneath the vessel (see **563**).

(3) A small displacement of the position of the sounding may affect the depth by a considerable amount.



Sublocality			58
W. of Cape Alamo			
Boat used LAUNCH NO. 4			X day
BOTTOM	HEADING BY Steering COMPASS	ANGLES AND RANGES BEARINGS LOG READINGS ENGINE REVOLUTIONS	REMARKS
	125°		
hrd wh.S		82 Cow 58-38	Use Mid for center
		~~Ran~~ Mid	object, checks D.R.
		Pit 27-27	Obvious recorder's
			error J.J.P.
		83 Pit 38 05	L.T.L.
		Sad	Reverse left and
		Cow 52 34	right objects J.J.P.
	45	84 ~~40 48~~ 48 40	Deg. & Min. reversed
		S	checks D.R.
wh.S		29 20	10° cor. J.J.P.
		85 Yak 35 55	Station names supplied
		— Cow	checks boat sheet &
		— Eat 56 24	adjacent hydrography
			J.J.P.
	47	86 Yak 56 02	Angles reversed,
		Cow	checks D.R. J.J.P.
		EAT 39 47	
hrd S		87	Recorder did not use
			number 87 O.J.G.
		88 49 33	Rt. < not recorded. Plot
		S	by left < & D.R. J.J.P.
		—	
		Yak-Sad	L.E.
		89 Yak 30 00	Split angles. Plot by
		Sad	loci of 2 angles. This
		Eat 63 41	checks with D.R. &
		Van-Eat	adjacent hydrography.
			J.J.P.

FIGURE 164.—Right-hand page of Sounding Record with corrections properly made (reduced about one-half).

7741. *Corrections to Recorded Data*

The instructions for recording the data forbid erasures, and recorders correct their errors by crossing out the erroneous entry and writing the corrected one above or at one side (see **81**). The smooth plotter may frequently find that the rejected entry, or some part of it, was correct, but that its application may not have been correct.

An example of a right-hand page from the Sounding Record of three-point fix hydrography is illustrated in figure 164. Typical errors and omissions are shown, together with the proper method of checkmarking and correcting them. The corrections should be made by the smooth-sheet plotter according to the following general instructions:

(*a*) All corrections and notes in the Record must be made in colored pencil, the same as used for checkmarking the positions (see **7624**), in order that it will be clear what data were used for plotting the position and that it was not a correction made in the field at the time of recording the data.

(*b*) The original recorded data shall never be erased, no matter how certain the plotter may be as to the correct entries. Such corrections should be made by crossing out the recorded data and, where practicable, entering the correct data above the erroneous data. But in any case, the correct data should be so entered that no mistake in interpretation can be made.

(*c*) The reason and authority, if any, for the revision shall be entered.

After the smooth sheet has been completed, it should be in complete agreement with the corrected Sounding Record. No positions should appear on the smooth sheet except those which are based on data in the Sounding Record, or are fully explained by supplemental entries; neither should any depths be penciled on the smooth sheet which do not appear in the Sounding Record or on the fathogram. It should be possible at any time in the future to justify any information on the smooth sheet by reference to the Sounding Record or fathogram.

775. CONGESTED AREAS

Cases frequently occur where it is impossible to show adequately parts of surveys at the scale of the smooth sheet. Among these are: (*a*) intensely developed small areas; (*b*) soundings taken in small docks and alongside small piers; (*c*) large water areas developed with two or more systems of lines. Clarifications in (*a*) and (*b*) are accomplished by means of subplans at enlarged scales (see **7751**), and in (*c*) by means of overlay tracings (see **7752**).

7751. Subplans

Small congested areas shall be shown at enlarged scales in subplans in otherwise blank spaces on the smooth sheet, where practicable. The scale and extent of the plan

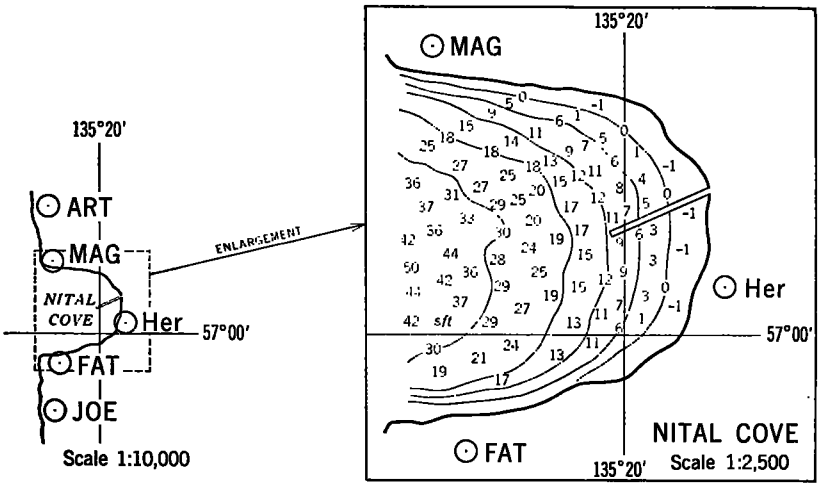


FIGURE 165.—Subplan of small cove on smooth sheet.

shall be large enough to show the positions and soundings clearly, and to include the stations used to control the hydrography to be plotted thereon.

Enlarged subplans, such as those to include the water area of a small bay, bight, inlet, or anchorage area, shall be surrounded by a heavy margin in black ink. Each subplan must include the scale, the name of the water feature, if any, and at least one meridian and parallel. An arrow should be added leading to the plan from that part of the smooth sheet of which the plan is an enlargement, where it can be done without interference with the hydrography. A fine dash pencil line should be drawn around the area on the original scale which has been enlarged. Details shown in the enlargement may be omitted from the original scale. Wherever practicable, the subplan should be located so that its meridian and parallel coincide with two of the lines of the principal projection. (See fig. 165.)

Where soundings are taken in small docks and along the sides and ends of small piers and are located by reference distances to or along the piers, enlarged plans of these

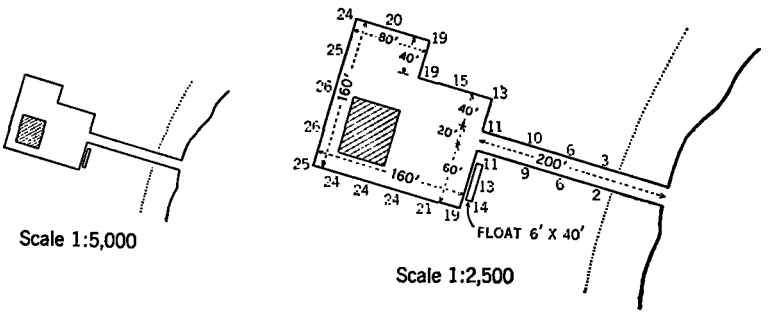


FIGURE 166.—Subplan of pier with soundings alongside.

shall be shown as nearby as convenient to the areas at the original scale. If the enlarged plan cannot be shown adjacent to the area, there shall be an arrow leading to the enlarged pier from that place on the shoreline where the pier is located. Such plans need not contain a scale nor be surrounded by a margin. Each plan shall show in figures the principal dimensions of the pier. (See fig. 166.)

7752. *Overlay Tracings*

Where the subplan method is impracticable, because of the extent of the area involved, or for any other reason, *overlay tracings* shall be used. These are plottings on tracing cloth, at the scale of the smooth sheet, of one or more of the several systems of sounding lines used to develop the area. In order to achieve clarity, it is sometimes necessary to use more than one overlay. The overlays need be only large enough to include the hydrography in question, and need not cover the entire sheet. The protracting is done directly on the tracing using the control points on the smooth sheet. Both positions and soundings on the overlay shall be inked (positions in black and soundings in red).

Each overlay tracing shall be referenced to the smooth sheet by number as "Overlay to accompany H-5236," and shall be marked by a sufficient number of projection intersections, at least two of which shall be identified by their latitudes and longitudes.

Smooth-sheet plotters may determine where overlay tracings are necessary and what portion of the work should be so prepared by the criterion that it must be possible for the verifier to identify each position on the various sounding lines. As a general rule, where the sounding lines are not much less than one-fourth inch apart, two systems of lines may be satisfactorily plotted directly on the smooth sheet, but where there are

more than two systems the additional systems should be plotted on one or more overlay tracings.

If, for example, there are three systems of sounding lines, *A*, *B*, and *C*, in an area, system *A* should be plotted and the soundings penciled directly on the smooth sheet. The position dots should be inked but the position numbers and day letters should be left in pencil at this stage of the plotting. It is often advantageous to identify the positions temporarily by placing the numbers and day letters well outside of the congested area, connected to their respective positions by lightly penciled leader lines. The second system, *B*, if neither *A* nor *B* is too closely spaced, should then be plotted directly on the smooth sheet in the same manner as *A*. In penciling the soundings of system *B* it will be found that some of these occur where soundings from system *A* have already been penciled, and it will be necessary to erase some of the *A* soundings to make space for shoaler soundings obtained on the *B* system. The resultant soundings on the smooth sheet should be an adequate selection from the *A* and *B* systems, depending on the depths obtained. No preference should be given to the soundings of one system over the other. After the soundings have been penciled, the position numbers and day letters can be inked where they will not interfere with the soundings, using short leaders where necessary.

The hydrography of system *C* should now be plotted on the overlay tracing, with the least depth found by that system emphasized by an arrow pointing to it, on which is lettered the depth, position number, and day letter.

Finally, the least depth obtained from all of the systems on any given shoal must be plotted on the smooth sheet and indicated by a leader at whose end in a clear space is given the depth, and the position number and day letter (see 7753).

All overlay tracings must be forwarded to the Washington Office with the smooth sheet. When the latter is verified in the Office the positions will be transferred from the overlays to the smooth sheet, and a selection of soundings made which will adequately represent the depths in the area; after review of the smooth sheet the overlays will be destroyed.

7753. *Least Depths*

The least depth on each shoal, whether or not it contains intensive development, should always be shown slightly larger and bolder than the surrounding depths, in order that it will not be overlooked even in a cursory examination of the smooth sheet. (See **7732**.) And in all cases where there is any doubt about the least depth being readily noticeable, there should be added, in pencil, a legend "Least depth ---- ft" in a clear space (on the land area if necessary) with a fine arrow, or leader, drawn toward the minimum depth. The position number and day letter should also be given if not otherwise clear.

If available, a bottom characteristic should always be added as near the least depth as practicable.

The same general procedure shall be followed when such least depths are inked in the Office, except that the position numbers and day letters will ordinarily not be inked in the legend.

776. DEPTH CURVES

Depth curves, or curves of equal depth, are shown on the smooth sheet for the purpose of bringing clearly to the eye the general configuration of the bottom, and for emphasizing important navigational features, such as shoals and channels. They are also of value in studying the adequacy of the survey in the Office, where areas are often discovered that require additional field examination.

Depth curves are comparable to contours on land, each curve representing an imaginary line on the ground (in the water area), every point of which is at the same depth below the sounding datum. The principles which govern the delineation of land contours are equally applicable to the drawing of depth curves, and a knowledge of topographic expression and submarine relief is essential for their correct representation. A study of the characteristic bottom forms in any region is of value in the interpretation of hydrography, as such forms usually repeat themselves in similar regions, and often in the same region. (See **3531** and **355**.)

Abnormal or improbable depth curves are strong evidence of probable uncertainties or inaccuracies in the hydrographic survey or the reduction of records, and the soundings

or positions controlling such abnormalities should always be verified before acceptance as correct (see **353**).

Depth curves shall be *penciled* on the smooth sheet before it is transmitted to the Office. The colors adopted to represent the various depth curves on hydrographic surveys are listed in table 27. Depth curves on smooth sheets are only inked in the Washington Office after the survey has been verified.

TABLE 27.—*Depth curves*

Curve in fathoms	Curve in feet		To be inked in
0	0	(Plane of reference)	Yellow.
½	3	(*Omit*)	Violet.
1	6		Green.
2	12		Red.
3	18		Blue.
4	24	(*Omit*)	Yellow.
5	30		Red.
6	36	(*Omit*)	Green.
10	60		Yellow.
20	120		Blue.
30	180		Violet.
40	240		Green.
50	300		Red.
100	600		Green.
200			Yellow.
300			Violet.
400			Green.
500			Red.
1,000			Blue.
2,000			Yellow.
3,000			Violet.

7761. Selection of Depth Curves

All of the applicable depth curves listed in table 27, except as modified under this heading, shall be penciled on the smooth sheet. However, if the survey includes significant submarine features which are not emphasized sufficiently by the use of the curves listed, additional curves should be drawn. The nonstandard curves and the reason for using them should be given in the Descriptive Report (see **842*J***).

Although they will ordinarily not be inked (see **7763**), the 4- and 6-fathom curves shall always be penciled on the smooth sheet by the field party, and the ½-fathom curve shall be added where it may be useful in small-boat navigation.

Occasionally some of the depth curves should be omitted for reasons of clarity. On steep slopes the curves may be so closely adjacent as to be confusing; in such cases the shoalest and the deepest curves are generally the most important and should be shown, omitting the less important intermediate ones. Where rocks or steep shoals rise suddenly from much greater depths one or more of the deeper depth curves should frequently be omitted; for instance, if a 5-foot depth on a rock is surrounded by general depths of 20 feet or more, the 6-foot curve must be drawn, but the 12- and 18-foot curves may be omitted. In channels with steeply sloping sides, the curve which gives the maximum through depth is the most important and should be shown at the expense of some of the shoaler curves. Likewise, where islands, shoals, or reefs rise abruptly from

much greater depths and several of the shoaler depth curves are very close to the shorelines of the islands, or edges of the reefs, the shoaler curves should be omitted.

7762. Delineation of Depth Curves

Depth curves shall be penciled lightly as continuous lines, using a 2H pencil, and using as a guide the curves shown on the boat sheet. The hydrographer will have sketched on the boat sheet, many more depth curves than are required for the smooth sheet (see **3533**), and in doing this, certain characteristics of the submarine relief are developed that may not be apparent where the prescribed curves only are drawn. Careful attention must, therefore, be paid to the boat sheet when drawing the curves on the smooth sheet.

Depth curves are drawn so that each depth corresponding to the depth indicated by the curve is either on the curve or within it. Where the curve passes between soundings, it must be located at the correct proportional distance between the two depths. Curves must be broken at sounding numerals and position dots—never continued through them as continuous lines. At position numbers, however, curves should be continuous, the numbers being moved slightly, if necessary.

In comparatively shoal depths where there may be dangers to navigation, one should always err on the side of safety in drawing depth curves. Where the soundings are not spaced closely enough to determine precisely the position of a depth curve, the curve must be drawn to include the part of the area in which a shoal sounding is possible. For example, where there is a shoal of less than 3 fathoms extending offshore, around which the depth curve might be closed just outside of several 3-fathom soundings on a given line, and there is one sounding of 3 fathoms or less on the next adjacent line offshore, the one sounding must not be surrounded by a detached curve, leaving the inference that there are greater depths between the 3-fathom detached sounding and the inshore 3-fathom curve. On the contrary, the curve must be extended to include the isolated sounding, as in figure 167. Similarly, where there is an absence of soundings between two contiguous shoal areas, the depth curve must be drawn to connect both shoals, rather than as a closed curve around each one, since in the latter case the inference would be that depths greater than the depth curve exist between the shoals. (See fig. 167.)

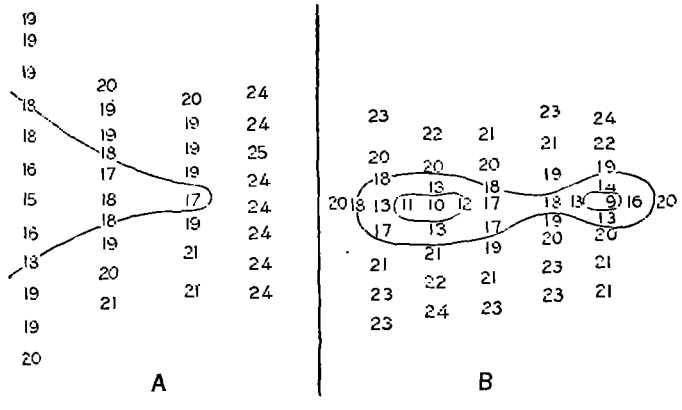


FIGURE 167.—Depth curves in vicinity of shoals (see text).

Without exception, depth curves should never indicate a through channel unless this has been proved by the actual soundings taken.

Over extensive flat areas it is frequently advisable to add fractional depths in the vicinity of the depth curves in order to locate them more accurately (see **7713**).

Depth curves or parts of curves that are not well defined, as where they are dependent on one or two soundings, shall be shown as broken lines, except where close inshore, in which case they shall be omitted entirely.

The low-water line, or zero depth curve, is one of the most important curves on the smooth sheet. Where it is not well defined by the soundings, data from other sources as prescribed in **754** should be used for its delineation.

7763. Inking the Depth Curves

The depth curves are inked in the Washington Office following the colors given in table 27. The word "omit" opposite a depth in the table indicates that ordinarily that curve is not to be inked. Any curves not inked shall be erased by the verifier.

Nonstandard curves penciled by the smooth-sheet plotter to delineate submarine features not sufficiently emphasized by the standard curves (see **7761**), shall be inked in brown on the smooth sheet by the verifier. (See also **9336** and **9342*b***.)

777. INSPECTION OF PLOTTING

After the positions and the soundings have been plotted and the depth curves and the bottom characteristics (**783**) have been added, the work shall be inspected by a responsible person for completeness and accuracy. In addition, the depth curves and the differences in depths at crossings and between adjacent sounding lines should be critically examined.

The inspection should also include an examination of all critical soundings to ensure that they are clear and legible; there should be no doubt, under any circumstances, as to the least depth on any rock or shoal. Neither should there be any doubt about the deepest draft that can be carried safely through any channel, along any recommended course, or through any particular areas where passage of vessels is frequent.

7771. Differences in Depths at Crossings

Where excessive differences at crossings are encountered in a survey, a study of the results should be made in order to discover, if possible, the source of the trouble and to make such corrections as are necessary. Such differences may be due to some fault in the sounding apparatus or in the method, or some error in the record. What is to be considered excessive will depend on the strength of the control, the accuracy of the sounding method, and the character of the bottom. It is impossible to formulate a rule which will cover all of these variable conditions. One experienced in hydrographic work will recognize, for any set of conditions and any given area, what differences are excessive.

Where differences in depth are discovered, all the possible causes must be considered, and almost any one discrepancy may result from either an error in position or an error in depth. It is particularly important to remember this, especially in areas of steep slopes, where a slight displacement in the position of the sounding may account for the difference in depth. (See also **563**.)

The allowable difference in any given case should not be based on a percentage of the depth, but rather on the lateral displacement of the depth curves. In compar-

atively even bottom, such as exists in the Gulf of Mexico, a difference of 2 or 3 feet may be excessive, because of the amount the depth curve is displaced. On the other hand, in areas of steep slopes a difference of several fathoms may be readily allowable since the position of the depth curve may not be affected appreciably.

If the control is strong, excessive differences should not be caused by uncertainty of positions except in cases of pure blunder. Individual cases of excessive differences may result from an error in protracting or from an error in the reduction or plotting of the soundings, and the first step in the elimination of such errors is to verify the positions and depths in the vicinity of the discrepancy. Where crosslines have been run on a different date from the original system of lines, the discrepancies may be due to differences in sea and weather conditions on the two dates; and these should be examined.

A statement shall be made in each Descriptive Report relative to the discrepancies at crossings (see **842*K***). Generally, this may consist of a simple statement of the percentage of crossings at which the differences are 1, 2, 3, etc., percent of the depth. Because of the relative weakness of R.A.R. control in certain areas, a complete tabulation of the depths at all crossings shall be made for each R.A.R. sheet (see **7722*a***).

7772. *Examination of Depth Curves*

The best evidence as to the adequacy and completeness of the survey is whether the depth curves can be completely drawn, and whether their shapes and convolutions are natural. A study of the depth curves may disclose discrepancies from several sources. Where the depth curves do not represent normal types of bottom relief, some source of trouble is to be sought. For example, a tide gage inadequately located with reference to the hydrography will result in depth curves having a jagged unnatural appearance if based on adjoining parallel lines run at different stages of the tide.

A study of the depth curves, and a consequent study of the hydrography in the vicinity, may also reveal discrepancies due to the use of different methods of sounding or the use of different sounding instruments, and may result in actual corrections being made to some of the lines of soundings and in rejections of others.

78. ADDITIONAL DETAILS ON SMOOTH SHEET

781. EXPLANATORY NOTES

A variety of miscellaneous explanatory notes is required on the smooth sheet before it can be considered complete. Such notes should be made as short as practicable and still give the desired information. (See fig. 171.) Those referring to hydrographic features shall be in slanting letters, and those referring to land features shall be in vertical letters. The lettering should be freehand, upper and lower case, the average height of the capital letters being 1.8 mm, the lower-case letters being proportionately smaller. Notes should ordinarily begin with a lower-case letter. The size of the lettering should be consistent throughout each sheet, in order to present a pleasing appearance. In congested areas it may be reduced in order to conserve space, but the letters should never be so small as to require a magnifying glass to read them.

A good deal of latitude may be taken in the placement of notes, as long as it is perfectly clear to which feature a note applies. This may be accomplished in many cases by the use of leaders (see **7914**).

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Unless stated otherwise under the specific paragraphs, all explanatory notes placed in the land area or in clear spaces in the water area shall be inked in black, but those that must be placed in the sounded area should be left in pencil for subsequent inking in the Washington Office, after verification of the survey.

Periods shall not be used under any circumstances in connection with names, notes, or any symbol that appears in the water area, as they might be confused with bare rocks. (See also **783**.)

In addition to the types of notes referred to above and those specifically mentioned elsewhere in this Manual, the following general classes of notes are required. These apply mostly to control stations and landmarks, and should be shown in vertical lower-case letters, and in parentheses (see fig. 171).

(*a*) The name of each marked recoverable topographic station shall be followed by the word "marked".

(*b*) The name of each recommended landmark shown on the hydrographic sheet shall be followed by the word "landmark", together with the elevations above the ground and above mean high water, if known; and if the name is not self-explanatory, a few words describing the object should be added (see **7844**).

(*c*) Each object in the water area used as a signal shall be explained by a note stating whether it is of temporary or permanent nature, and if permanent its character must be described for the information of the cartographer in charting (see **7444**).

(*d*) Each control station that is a natural or artificial object and is permanent or semipermanent shall be briefly described in one or two words immediately following the station name.

(*e*) If the source of the position of a control station is other than the official records of the Bureau, an explanatory note shall be added after the station name to state the source of the data.

782. Rocks, Reefs, Ledges, and Rocky Areas

The representation of these features is one of the most important phases in the plotting of a smooth sheet. Great care is necessary in order that there shall be no ambiguity regarding their true character and that the conventional symbols used for such features conform to the adopted standards in part "O" of the Symbols and Abbreviations chart (see fig. 189, part IX).

In applying these features to the smooth sheet, those that originate solely with the hydrographic survey or that result from an adjustment between the hydrographic and topographic data should be left in pencil by the field party (see **7827**). All other features (and primarily these include information transferred from the topographic survey) should be inked in black unless otherwise noted in this Manual. Similar treatment should be followed in the case of descriptive notes or elevations accompanying such features. (See **7825** and table 28.)

7821. Planes of Reference or Sounding Datums

In the hydrography of the Coast and Geodetic Survey two general planes of reference (sounding datums) and one special plane are in use. They are mean low water (MLW) for the Atlantic and Gulf areas, mean lower low water (MLLW) for the Pacific areas, and mean low water springs (MLWS) for the Pacific entrance to the Panama Canal (see **8224**). The plane of mean high water (MHW) is the datum to which the shoreline and all land elevations are referred (see **2311**).

All rocks, reefs, and ledges shown on the smooth sheet must be referred to these planes, and to no others, and they must be symbolized in accordance with the rules given in **7823**.

7822. *General Definitions*

Three types of rocks may be encountered in a hydrographic survey, characterized as bare, awash, and sunken. By convention and for general purposes, they are defined in relation to the tidal datums of the locality, as follows:

(*a*) *Bare rocks* are those extending above the plane of mean high water.

(*b*) *Rocks awash* are those exposed at any stage of the tide between mean high water and the sounding datum, or that are exactly awash at these planes.

(*c*) *Sunken rocks* are those covered at the sounding datum, that are potentially dangerous to navigation.

For cartographic purposes, however, the general definitions have been modified in order that the charted symbols may reflect the most probable condition of the rock as seen by the mariner. On smooth sheets, therefore, the rules in **7823** shall be followed in the delineation of the data relative to rocks, reefs, and ledges. (See also fig. 168). The rules are, of course, not inflexible, and in their application consideration should be given to the character of the area, whether exposed or protected; the proximity to shore; the range of the tide; and the extent of the minus tides; the controlling factors in all cases being the emphasis on dangers and the probable visibility of the rock at some stage of the tide. (See **9334***a*.)

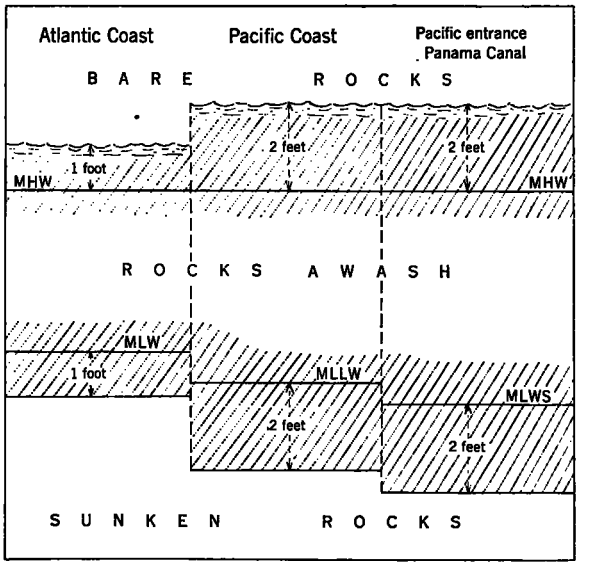


FIGURE 168.—Relationship of rocks to tidal datum planes.

Regardless of the sounding datum, references to Atlantic Coast include all areas in the Atlantic Ocean and the Gulf of Mexico, and references to Pacific Coast include all areas in the Pacific Ocean and in Alaska.

7823. *Rules of Application*

a. Bare rocks.—Rocks with elevations of 1 foot or more above mean high water on the Atlantic Coast, or 2 feet or more on the Pacific Coast, shall be shown as bare rocks. The actual shape of the rock should be shown if it is more than one-half millimeter in diameter on the survey sheet, otherwise it should be indicated by a dot. (See fig. 169.)

b. Rocks awash.—Rocks shall be represented by the *awash* symbol where their summits are in the zone between 1 foot above mean high water and 1 foot below the sounding datum on the Atlantic Coast. On the Pacific Coast the limits are 2 feet. The same applies to reduced soundings in rocky areas, that are surrounded by depths considerably greater than the soundings. These limits are for reduced depths in the Sounding Record.

The symbol for a rock awash is three crossed lines, one of which is parallel to the lines of latitude.

c. Sunken rocks.—Rocks potentially dangerous to navigation, whose summits are below the lower limit of the zone for rocks awash, are classed as sunken rocks, and are represented on the smooth sheet, either by symbol (a simple cross), or by a sounding accompanied by the legend "*Rk*" depending on the nature of the available information.

(1) The symbol should be used where the depth over the rock has not been definitely determined, as in case of transfer from the topographic survey, or where breakers have been cut in but no soundings taken, or where the depth obtained does not represent the least depth over the rock.

(2) The sounding, with legend "*Rk*" appended, should be used in all cases, where the depth on the rock is known, and where the rock, at the sounding datum, is covered 1 foot or more on the Atlantic Coast or 2 feet or more on the Pacific Coast.

(3) The abbreviation "*Rk*" may be appended to the sunken-rock symbol where there is risk that the latter may be overlooked or mistaken for a defect in the paper.

(4) Under no circumstances shall both the least depth and the symbol be used to represent the same rock.

d. Accuracy of location.—Any specific rock (bare, awash, or sunken) which has been accurately located by a rod reading, a three-point sextant fix at the rock, or sextant or planetable cuts forming a good intersection at the rock, shall be encircled by a dotted line to distinguish it from those rocks whose positions are estimated, or are from generalized symbolization.

If a rock is so located by the topographic survey, the dotted line shall be in black ink. If located by the hydrographic survey, the dotted line shall be left in pencil to be inked in red after the smooth sheet is verified in the Washington Office (see fig. 169).

It is to be noted that the dotted line is *not* to be used around rocks located by estimated distances from a sounding line.

7824. Reefs and Ledges

A *reef* is a rocky or coral elevation dangerous to surface navigation, which may or may not be above the sounding datum in elevation. A rocky reef is always detached from shore, but a coral reef may or may not be connected with the shore. A *ledge* is a rocky formation connected with and fringing the shore, and is generally above the sounding datum in elevation. These terms should always be so used in the Sounding Records, and will be construed in accordance with these definitions, unless information from other sources indicates otherwise.

These features when bare or awash at the sounding datum must be clearly marked on the smooth sheet to show their nature and extent. They may be represented by symbol or by broken line and legend depending on which method will show the feature correctly and clearly with the least amount of work. A small reef or ledge, for example, might be shown by symbol but a large reef or ledge extending a considerable distance along the shore may be indicated more economically by a broken line with an appropriate legend.

There is no distinctive symbol for a submerged reef or ledge, and where the limits have been determined they should be indicated by a broken line, enclosing sunken-rock symbols or an appropriate legend (see **7826**).

No distinction is made between the symbol for a rocky reef and a ledge. Where a reef is continuous at the sounding datum, the standard rocky-ledge or coral symbol, as the case may be, should be used (see fig. 189, part II), but where the reef is generally submerged and projects only in spots above the sounding datum, rock-awash symbols should be used to represent the protuberances, and sunken-rock symbols, the depressions.

From their very nature, the exact delineations of reefs and ledges are sometimes unobtainable from a single source. Therefore, in plotting such features on the smooth sheet, their limits and extent should be based on all available information from the Sounding Records, the boat sheet, and the topographic survey. Care should be taken to distinguish between positions outlining a reef, and those outlining a sandy low-water line interspersed with rocks awash.

7825. Elevations and Notes

All notes and elevations relative to rocks should be referred to the precise datum planes applicable, and not to a generalized one. For example, "uncovers 2 ft at MLW"

should be used and *not* "uncovers 2 ft at LW". Bare rocks should be referred to *mean high water* (MHW) and rocks awash to the sounding datum (MLW, MLLW, or MLWS), except that rocks awash at mean high water should be so designated (see **7823**). Elevations above any datum should be given in feet to the nearest whole foot. Descriptions, such as "breaks at half tide", "breaks in heavy weather only", and the like, are of value for charting and should be shown on the smooth sheet wherever the information has been obtained. Judgment is required in the selection and proper placement of notes in order to avoid crowding the sheet with a multitude of unimportant notes, but no important danger should ever be shown by symbol alone.

a. Bare rocks.—The elevations in feet of bare rocks should be shown by slanting figures, in parentheses, close to the feature. If they originate with the topographic survey they shall be shown in red otherwise in pencil to be subsequently inked in black in the Washington Office. (See also **755** and **782**.)

b. Rocks awash.—Elevations of rocks awash above the sounding datum may be indicated either by notes, such as "uncovers 2 ft at MLW" or by slanting figures alone, in parentheses and underscored, as for example (2). (See part "O" of the Symbols and Abbreviations chart, fig. 189, part IX.) If awash at the sounding datum or at mean high water, a note such as "awash at MLLW" should be used. No rigid rules need be followed, however, in the use of one form or the other. It is left mostly to the discretion of the smooth-sheet plotter. Generally, however, it is desirable to use notes in the case of isolated rocks, or for the highest rock in a group of offshore rocks, or for the outermost rock of a number of alongshore rocks. In congested areas or for the many less important rocks the underscored figure should be used.

c. Reefs and ledges.—The above considerations also apply to the notes and elevations of reefs and ledges above the sounding datum or to the rocks awash in a generally submerged reef or ledge.

7826. Rocky Areas

Where, owing to heavy seas, low tide, draft of vessel, etc., it has been impossible to sound in an area with a rocky bottom, but which is otherwise clear of rocks, the approximate danger limit should be indicated by a line of sunken-rock symbols.

Where, owing to a multitude of scattered rocks, it is needless to sound in an area, the positions of the off-lying rocks should be determined and the unsounded area should be marked "foul—unsurveyed". (See also **7824**.)

Where large areas, unimportant for navigation, have not been thoroughly surveyed, as where thick beds of kelp border the shore or where an extensive foul area exists in a remote locality, the outer limits should be shown on the smooth sheet and an appropriate legend added inside. For kelp, the symbol should be used and the area should contain the legend "heavy kelp, not navigable, not thoroughly surveyed". For a foul area, a dash line should be used enclosing the legend "foul, not thoroughly surveyed". (See **3623***b* and **367**.)

7827. Reconciliation of Topographic and Hydrographic Data

As is noted in **75**, discrepancies between the topographic and hydrographic surveys as to the location and character of rocks should be harmonized in the field by a further examination if necessary, and all differences reconciled in the Sounding Records, on the sheets, and in the Descriptive Reports before submitting the survey to the Office.

Where it is not feasible to investigate the discrepancies further, or to consult the topographer, the smooth-sheet plotter should then evaluate all the information available from both sources, taking into consideration the strength of the position determination, the proximity of the surveyor to the feature, the stage of the tide, etc., and resolve the

differences in favor of the weightier evidence. Generally, the following rules will be found applicable:

a. Bare rocks.—Their locations and elevations should be accepted from the topographic survey except where there is unmistakable evidence of incorrectness, or where it is obvious that the topographic location is weak. Where discrepancies between the two surveys result from the rules given in **7823** for interpreting the sounding data, then the source that makes the rock a bare rock shall govern. (See **7825***a*.)

b. Rocks awash.—The locations of such rocks should generally be accepted from the topographic survey and should seldom be modified by the hydrographic survey. Their elevations above the sounding datum should be taken from the hydrographic survey because of the more definite tidal information available, and the closer proximity of the hydrographic party to such features.

c. Sunken rocks and breakers.—The locations of sunken rocks and breakers, and notes relating thereto should be accepted from the hydrographic survey, but it should first be determined that the identical feature is involved.

Changes in the character of rocks should not be made on the topographic survey where the differences are consistent with the stage of tide at the time of survey, but an explanatory note should be added to the topographic Descriptive Report.

783. BOTTOM CHARACTERISTICS

After the soundings and depth curves have been penciled the bottom characteristics should be *penciled* on the smooth sheet. Standard abbreviations have been adopted for such information (see part "S" of Symbols and Abbreviations chart, fig. 189, part XI) and these must be used on the smooth sheet, even if nonstandard abbreviations have inadvertently been entered in the Sounding Record. It should be noted that lower-case letters are used throughout for adjectives, to distinguish them from nouns which all begin with capital letters. Periods must not be used after abbreviations, nor are hyphens or other connecting symbols to be used between abbreviations, but there should be a slight space between them. A standard bottom characteristic should appear on the smooth sheet thus: "*hrd S Sh P*". (See also **384**.) Attention is called to the fact that "*rky*" is the abbreviation for rocky bottom, but the abbreviation "*Rk*" is used only for a rock which rises from much greater surrounding depths, and not for even rocky bottom (see **7823***c*).

In placing the bottom characteristics on the smooth sheet a judicious selection should be made. If a large number are recorded, as is usually the case in areas surveyed by handlead or wire sounding, probably only part of those need be shown on the smooth sheet. On the other hand, where echo sounding is used, comparatively few bottom characteristics are obtained, and probably all obtained should be shown on the smooth sheet, including those whose locations are somewhat indefinite. Bottom characteristics obtained when anchoring and picking up buoys and when observing temperatures and salinities should be shown on the smooth sheet, if an approximate location has been given.

Harbors, anchorages, and shoals are the areas where bottom characteristics are most important. Each shoal must show a bottom characteristic, if one has been obtained thereon. In harbors and anchorages, a sufficient number should be plotted to show, particularly, where changes in the character of the bottom occur; but where there is a monotonous sameness in the character and quality of the bottom, too many characteristics should be avoided. (See **3842**.)

Bottom characteristics should, if practicable, be placed on the smooth sheet reasonably close to and a little below and to the right of the soundings which they

accompany. Where such placement interferes with the clarity and legibility of the sounding, the bottom characteristic should be placed in any convenient space in the immediate vicinity of the accompanying sounding. The abbreviations should be lettered in single stroke slanting letters, the capital letters having an average height slightly less than the soundings and the lower-case letters correspondingly smaller. (See fig. 163.)

After the smooth sheet has been verified, the bottom characteristics will be inked in black in the Washington Office. At that time, if it appears that an insufficient number were obtained, the new survey may be supplemented, on direction of the Chief of Surveys Branch, with bottom characteristics from prior surveys (see **3842** and **9333***b*).

7831. Silted Areas

The fathograms of echo-sounding instruments operating at supersonic frequencies show quite clearly, under certain conditions, layers of silt or other loosely distributed sediment overlying the substrata. These are commonly found in bays, lakes, or estuaries, where silt-laden streams have deposited their loads, or in offshore basin areas where unusual conditions may permit the deposition of silt.

A record of the existence and limits of such sedimentary layers is often of considerable importance. Where encountered in an area being surveyed, the Washington Office shall be notified of the apparent features and special instructions will be issued if a smooth-sheet record is desired.

In such cases the silted areas shall be noted on the smooth sheet, at the time the soundings are plotted, and the approximate outline of each area more than 1 inch in diameter or 1 inch wide, shall be shown by a dash pencil line. A notation explaining their significance shall be made on the title sheet and in the Descriptive Report. The outlines will be inked in a brown dash line after verification in the Washington Office, and at the time of inking the depth curves.

Where silted areas are so frequent that they will be confusing on the smooth sheet or may be confused with the depth curves, their limits shall be shown in brown dash ink lines on a tracing-cloth overlay. The overlay shall be referenced to the smooth sheet by projection intersections throughout the area and shall be identified by a title, as "Overlay showing silted areas on H-5236." A notation shall be placed on the title sheet (Form 537) that such an overlay accompanies the smooth sheet.

Where silted areas are disclosed by the fathograms a discussion of their estimated frequency, sizes, and apparent thicknesses shall be made in the Descriptive Report, irrespective of whether their outlines are shown graphically on the smooth sheet or on an overlay.

784. AIDS TO NAVIGATION

All aids to navigation, fixed and floating, within the area of the survey, shall be shown on the smooth sheet. The positions of fixed aids located by triangulation shall be shown by standard triangulation station symbols; where located by topographic or hydrographic methods, control station symbols shall be used if the aids were so used during the hydrographic survey; otherwise, nautical chart symbols should be used (see fig. 169). The positions of floating aids, irrespective of method of location, shall be indicated by the actual aid symbols and colors used on the nautical charts of the Bureau. (See part "L" of Symbols and Abbreviations chart, fig. 189, part VIII.)

The smooth-sheet plotter shall compare the plotted information with that shown on the charts and with that given in the most recent edition of the Light List published by the United States Coast Guard, and any material disagreement as to position or characteristics shall be noted in the Descriptive Report (see **842***P*). The positions of all fixed aids shall also be reported on Form 567. (See also **383**.)

Hydrographic survey parties are required to obtain the depths at all aids to navigation located in the water area, and these shall be shown in pencil similar to other soundings.

Where items **7841** to **7847** inclusive specify that certain data are to be left in pencil by the plotter, they shall be inked in black after verification at the Washington Office.

7841. Fixed Aids to Navigation

Fixed aids fall into two classes, lighted and unlighted, and their correct respective designations are "lights" and "beacons."

In the case of lights, the light sector shall be shown graphically and the limit of visibility in miles given, in pencil, if these have been determined during the hydrographic survey. The characteristics of the lights need not be shown on the smooth sheet.

All fixed aids that have been rebuilt since the date of a previous determination of position, whether or not they are reported to have been rebuilt in the same position, are relocated by the survey party, but must not be referred to as recovered stations. The earlier determinations are *lost* stations and no reference to them shall be made on the smooth sheet. (See also **3831**.)

Where an abandoned light structure is still prominent, its position shall be determined. If it is not located by triangulation, nor used as a control station, it shall be shown on the smooth sheet as a landmark (see **7844**).

7842. Floating Aids to Navigation

Floating aids to navigation are divided into two classes, buoys and lightships. Their positions are usually determined by the hydrographic party, either by three-point fixes or by cuts (see **3832**). Standard symbols are used to represent them on the smooth sheet (see **784**). The small dot at the lower end of the buoy symbol or the small circle at the bottom of the lightship symbol indicates the position of the aid. The type of buoy should be indicated by the correct symbol, and the number of masts on a lightship should also be indicated by the symbol used.

The symbol for a buoy is an elongated diamond shape with its longer axis 2.7 mm in length and its shorter axis 1.2 mm. The dot is 0.8 mm distant from the shape on line with the long axis.

Buoy symbols are best made by means of a celluloid template cut to a slightly larger size than the above dimensions so that when the pencil outline is drawn on the sheet, it will be of the required size. (See fig. 153.)

7843. Names of Aids to Navigation

Care must be taken that the aids to navigation are identified by their correct names, which in all cases shall be assumed to be those given in the latest edition of the Light List. (See fig. 169.)

(*a*) The Light List names of all aids to navigation must be shown on the smooth sheet. If the aid has a station name which is identical with that given in the Light

List, it shall be shown in accordance with **744**. If an arbitrary station name has been used in the hydrography, the Light List name shall then be added in *red*, upper and lower case, slanting letters, in parentheses, immediately below or adjacent to the station name.

There are also frequent cases in which the position of a fixed aid has been determined in the past and it is designated in the triangulation records by a name differing from the correct one. In such cases the name, as given in the Light List, shall be shown, immediately followed by the incorrect name and date of location in parentheses. *Example: Bay Shaft Light* (SAND POINT LIGHTHOUSE, 1887).

(*b*) Beacons, where shown by chart symbols, should be identified by their numbers only, thus: *No. 31*, with the number underlined in blue where located by sextant. Where they are shown by control station symbols, the designation should also indicate the color of the beacon. *Example:* (*B Bn No 31*). This should be placed immediately below the station name, and in parentheses. (See fig. 169.)

(*c*) Buoys do not ordinarily have station names, but they must be identified by their classification and number placed immediately adjacent to the symbol. *Examples: N 12, C 5, S 3*, etc.

(*d*) Where the position of an abandoned light structure is shown, the name must be followed by the word "unused", in black ink and in parentheses, to show it is not in use as a light. *Example:* BIRD ISLAND LIGHTHOUSE (unused).

(*e*) The size of the lettering to be used for names of aids to navigation should be somewhat smaller than that used for station names (see **744**).

7844. Landmarks

A special report on recommended landmarks for charts is required on Form 567 (see **8534**). Each landmark, so reported, that is within the limits of the topographic or hydrographic survey must be plotted on one or the other of such sheets. If a landmark is located by triangulation, the triangulation station symbol shall be used; where located by topographic or hydrographic methods, control station symbols should be used if the objects were used as control stations during the hydrographic survey; otherwise, the landmark symbol, a small black ink circle, 2 mm in diameter, should be used. If shown on the topographic sheet, it is not necessary that it also be shown on the hydrographic sheet, if it is not otherwise needed thereon. It is probable that most of the landmarks so reported will have been used as signals to control the hydrography, and therefore, will be indicated by station symbols with their corresponding station names. To identify these as recommended landmarks, the landmark name as reported on Form 567 shall be shown in black ink and in parentheses after the station name, and the word "landmark" in black ink shall be placed in parentheses below the station name, accompanied by the elevations (also in black ink) of the landmark above the ground and above mean high water, if these are known. (See fig. 169 and **8534A**.)

The hydrographer frequently determines that certain large buildings and structures, not recommended by the topographer, are suitable for landmarks. If these have not been used as signals they should be plotted on the hydrographic survey, the position of each being indicated by the landmark symbol, accompanied by the landmark name (also in black ink) as reported on Form 567. The word "landmark" and the elevations should be given as required above. If in a large structure, a definite part such as a spire or cupola, is recommended as a landmark, it is necessary that the smooth sheet show its position relative to the remainder of the building (see fig. 155).

It is particularly important that the elevations of landmarks be known both above the ground and above mean high water, and the legends must make these elevations clear. They are necessary for the charts and for the Coast Pilot.

7845. Ranges, Bearings, and Sailing Lines

All ranges, bearings for clearing dangers and other purposes, and recommended sailing lines on courses or ranges, shall be shown on the smooth sheet *in pencil* where they have been determined by the hydrographic party, and the following symbols shall be used: A range shall be shown as a broken line of short equal dashes; a bearing shall be shown as a dotted line; and a recommended sailing line shall be shown as a continuous line broken at irregular intervals so as not to be drawn through soundings (see fig. 169). It should be noted that that part of a range line which is to be followed by a vessel is a sailing line and should be so symbolized. The objects which determine the ranges or to which the bearings apply shall be correctly shown and identified, and the names of the objects and the purpose of the range or bearings indicated in pencil along the lines. (See **356**.)

Where a range (indicated by brackets in the Light List) formed by two lights or by two beacons, is located within the limits of the survey, there are specific instructions for the determination of its azimuth by the survey party (see **3833**). Only if the azimuth has been determined by the hydrographic party shall this line be shown on the smooth sheet. The instructions for such locations call for obtaining strong sextant fixes on the range at a sufficient distance from the front range mark to produce a long azimuth line for accurate scaling. In the case of ranges established at an entrance for use in crossing a bar, a sextant fix should be obtained on or outside the bar. These fixes are indexed in the Sounding Records and must be plotted accurately on the smooth sheet. From these plotted positions the ranges are penciled. The azimuths are then scaled by protractor and noted in pencil along the range lines.

7846. Overhead Clearances

Bridge clearances and the clearances of overhead cables are important to navigation and should be shown on the smooth sheet for the information of the chart compiler. They should be left *in pencil* by the field party.

a. Bridge clearances.—The vertical and horizontal clearances should be given for all bridges over navigable waters if such information has been obtained (see **3836**). Where a discrepancy exists between the field data and the data given in the "List of Bridges Over the Navigable Waters of the United States," published by the United States Corps of Engineers, the field data should be given on the smooth sheet, but attention should be called to the discrepancy in the Descriptive Report (see **842***P*). The notation on the smooth sheet should include the name of the bridge, if it has one; the type of bridge, whether fixed, draw, etc.; the horizontal clearance in feet; and the vertical clearance in feet above mean high water. The note should be in the form shown in figure 171.

b. Overhead cables.—The locations of all overhead cables, transmission, telephone, or telegraph, over navigable waters shall be shown on the smooth sheet by dash pencil lines in a manner that will interfere least with the plotted soundings. The note on the smooth sheet should state "overhead cable" and should give the clearance in feet at mean high water (see fig. 171).

STATIONS:

Triangulation and traverse ..... △ VALES, 1942

Marked topographic ..... ⊙ LICK (marked)

Hydrographic and ordinary buoy ⊙ COD

R. A. R. and sono-radio buoy ◎ ESAU

Tide ..... ○ Tide Station

Arbitrary name assigned △ KIM (BERT, 1942)

Topographic ..... ⊙ Sow

Spotted from photographs ○ Cup

In water area (description) ⊙ Far (temp pile)

Current ..... ○ Current Station

SHORELINE:

	Fast, solid land		Marsh, swamp, and mangrove
From topographic or air photographic survey (0.4 mm.)		(0.2 mm.)	
Revision by accurate methods (0.4 mm.)		(0.2 mm.)	
Revision sketched by hydrographer (0.4 mm.)		(0.2 mm.)	
Piers and waterfront areas (0.4 mm. and 0.2 mm.)			

LOW-WATER LINE:

Zero depth curve from reduced soundings

Sketched from hydrographic data .....

Rodded by topographer at low water

Sketched from topographic data .....

ROCKS: Bare ⊙ (shape or dot)

	Awash	Sunken
	✳	+
Awash, individually located by topographer	✳	+
Awash, individually located by hydrographer	✳	+

(in pencil on smooth sheet, inked at Washington Office only)

AIDS TO NAVIGATION:

Lighthouse – name from Light List ..... △ *Bay Shaft Light*

and (from list of geographic positions) ..... (SAND POINT LIGHTHOUSE, 1887)

Structure not used as aid ..... △ BIRD ISLAND LIGHTHOUSE, 1857 (unused)

Beacons — topographic location	used as station	⊙ Win *(B Bn No 33)*	⊙ Low *(R Bn No 32)*
	not used as station	▲ *No 33*	▲ *No 32*
— hydrographic location	used as station	⊙ Oak *(B Bn No 33)*	⊙ Moo *(R Bn No 32)*
	not used as station	▲ *No 33*	▲ *No 32*
Buoy – (hydrographic location identified by position number)		*C 33*	*N 32*

LANDMARKS:

Used as control station ..... ⊙ TAX (STACK, white, concrete) (landmark: 102 ft. above ground, 134 ft. above MHW)

Not used as control station ..... ⊙ TANK, ELEVATED (Country Club Hills) (landmark: 60 ft. above ground, 241 ft. above MHW)

MISCELLANEOUS:

Offshore limit of breakers (in pencil) breakers

Recommended sailing line (in pencil) –24——21—

Range line (in pencil)

Bearing line (in pencil) .....

Eddies

Tide rips

FIGURE 169. — Special symbols for use on hydrographic sheets. (These are in addition to and are sometimes used instead of those shown in figure 189).

7847. Cable Crossings

The shore ends of submerged cables shall be shown on the smooth sheet by dash pencil lines indicating the general direction of the cable. Each end should be marked "submerged cable" (see fig. 171).

785. SYMBOLS FOR SMOOTH SHEET

The symbols to be used on the smooth sheet are generally those used on the charts which are illustrated in figure 189. It is not necessary that the symbols on the smooth sheet be as perfect as those on the charts, nor that the drafting be as artistic (see **721**). Slight modifications in the direction of simplicity may be made, the important thing being that they convey the information neatly and unmistakably.

There are certain exceptions to the use of chart symbols for smooth sheets, and these have been discussed in detail in preceding paragraphs. Examples of this divergence are the depth curves, which are shown in color on the smooth sheet but are symbolized on the charts; and lights and beacons which are almost invariably shown by their station symbols rather than by the chart symbols.

Figure 169 illustrates the symbols and lettering to be used on the smooth sheet, which differ from the symbols used on the published charts.

786. MISCELLANEOUS DATA

In addition to those mentioned heretofore, as many of the following details as have been obtained by the field party shall be shown on the smooth sheet. They should be left in pencil unless otherwise noted, to be subsequently inked at the Washington Office after verification.

7861. Tide Rips

These occur in places where strong currents are found and are usually encountered in the vicinity of shoals or where the bottom is uneven. A knowledge of these is of importance to the mariner and they should be shown on the smooth sheet either by legend or by symbol and legend, and qualified as heavy, moderate, or light. Where the feature is extensive, the approximate limits should be outlined and an appropriate descriptive note added.

7862. Breakers and Shoal Areas

The limits of breakers, whether offshore or alongshore, should be shown by a dash line with the notation "breakers" added. Where cuts are taken to single breaks, 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 encircled with a broken line enclosing the word "breakers".

Shoal areas covered at the sounding datum, over which sounding lines have not been run, should be outlined with a dash line within which the estimated depth is inserted.

The low-water limits of shoals, bars, mud flats, sand banks, etc., that bare at the sounding datum but which have not been accurately surveyed, should be taken from the best available source and shown on the smooth sheet in accordance with **754**. The estimated height above the sounding datum should be given if available.

7863. Marine Vegetation

The limits of grass and other marine vegetation extending near the surface must be indicated. Wherever a distinctive symbol has been adopted for such vegetation it should be used, except that limits only of extensive beds should be outlined by symbol, the character of the vegetation within being indicated by appropriate legend.

The symbol for grass or any other land vegetation should not be used to represent marine growth. If the bottom is grassy, the standard bottom characteristic abbreviation for grass should be used.

7864. Kelp

Kelp is one of the most important of the seaweeds encountered on a hydrographic survey and should be indicated on the smooth sheet wherever located. One of its principal characteristics is that it generally grows in rocky bottom and for that reason its presence indicates a possible danger. This is particularly true in Alaska where the only indication of many submerged pinnacle rocks may be a strand or two of kelp. In exposed waters kelp may grow in depths of 9 or 10 fathoms and in protected waters it may grow in even greater depths. Dead detached kelp should not be confused with live kelp attached to rocks; the former floats on the water in masses, while the latter streams away level with the surface. (See also **3623***b*.)

Kelp should be shown by symbol where the patch is a small one. Only the limits of extensive beds need be delineated by symbol, the remainder being indicated by appropriate legend. Where the kelp is towed under at certain stages of the tide such information should be added to the smooth sheet.

7865. Tide and Current Stations

The locations of all tide and current stations shall be shown on the smooth sheet by blue circles, slightly larger than a hydrographic station symbol, accompanied by the name "Tide Station" or "Current Station" lettered in blue.

7866. Wire-Drag Finds and Clearance Depths

Where a contemporary wire-drag survey has been made, all drag finds, including the bottom characteristics, should be transferred to the hydrographic sheet in green ink and in the same depth unit as the soundings. Where a wire-drag examination has been made to determine the least depth on a shoal or obstruction, the least depth found (if less than that of the hydrographic survey) should be plotted in pencil, and a note with a leader added giving the least depth with position number and day letter, and the clearance depth obtained.

7867. Ferry Routes

Each ferry route should be shown by a single dash line representing the actual route as nearly as it can be determined without sextant angles. Each terminus should be marked "ferry."

7868. Wrecks

Within the area of the survey, wreckage not afloat is located and should be shown on the smooth sheet in accordance with the symbols shown in part "O" of the Symbols and Abbreviations chart (fig. 189, part IX). Wrecks are of two kinds, stranded and

sunken, the former applying where any portion of the hull is above the sounding datum, while the latter applies to those with less than 10 fathoms over them or where the masts only are visible. The topographer, presumably, will have located all stranded wrecks, and these will be transferred from the topographic sheet to the smooth sheet along with the other topographic information. Sunken wrecks are located by the hydrographic party and their positions must be plotted from the data in the Sounding Records. It should be noted that the symbol for a stranded wreck differs from that for a sunken wreck, and that where masts are visible in the latter case, the notation "masts" must be appended to the symbol.

A special symbol is provided for use in showing the depth by which a wreck or other obstruction has been cleared by the wire drag.

Where there are a number of wrecks, or an amount of wreckage, so extensive that the individual items were not located, the outer limit of the dangerous area shall be indicated by a dotted line within which the word "wreckage" is shown.

7869. Obstructions

A variety of obstructions which may be dangerous to navigation is encountered in hydrographic surveys, all of which must be shown on the smooth sheet. If the obstruction has not been cleared by the wire drag, it is indicated by the least depth obtained by other methods, surrounded by a dotted circle, and accompanied by the word "obstruction" or its abbreviation. If the obstruction has been cleared by the wire drag, a special symbol is provided which shall be used to indicate the safe depth of water over the obstruction (see part "O", Symbols and Abbreviations chart, fig. 189, part IX).

787. GEOGRAPHIC NAMES

7871. Authority of the Smooth Sheet

The hydrographic survey and, therefore, the smooth sheet shall be the authority for all geographic names of hydrographic features, such as channels, sloughs, rivers, inlets, reefs, rocks, shoals, and of topographic features offshore from the high-water line, such as small rocks and islets. Even if the topographer does obtain and verify a portion of these names, the hydrographer is responsible for their correctness and their correct placement on the smooth sheet. In addition to the above names, the names of some of the more prominent topographic features should be added to assist in correlating the hydrographic survey to the land features. (See also section **16.**)

Although not all geographic names may be charted, it is desirable that all features for which there are local names be named on the smooth sheet. These should be distinct names applicable to definite places or areas. Where names are indefinitely applied, it is best not to show them on the smooth sheet, but they should be mentioned in the Descriptive Report. It is incumbent on the smooth-sheet plotter to take extreme care that the names are spelled correctly and that they are applied to the correct features.

7872. Placement of Names

Geographic names should not be added to the smooth sheet until after the positions and soundings have been plotted. They should be placed so as to indicate clearly and without ambiguity the features designated. Where it is impracticable to place the names closely adjacent to the features, they may be placed some little distance away and connected to the respective features by leaders or arrows.

Geographic names must not obscure nor confuse the soundings. On an inshore hydrographic survey, it is generally necessary to place all the topographic names and many of the hydrographic names inshore from the high-water line. This is especially important in the placement of the names of small streams, sloughs, and inlets. Where names have to be lettered in the water areas, particularly in very congested areas, a judicious placement of the name and spacing of the letters will often avoid obscuring the hydrography. In such cases the lettering may be spread out or closed up as the conditions require.

Geographic names should be oriented on the smooth sheet so as to be read from the south regardless of the direction of the projection on the sheet (see fig. 170). Most names should be lettered in a straight line parallel to the parallels of latitude and, if

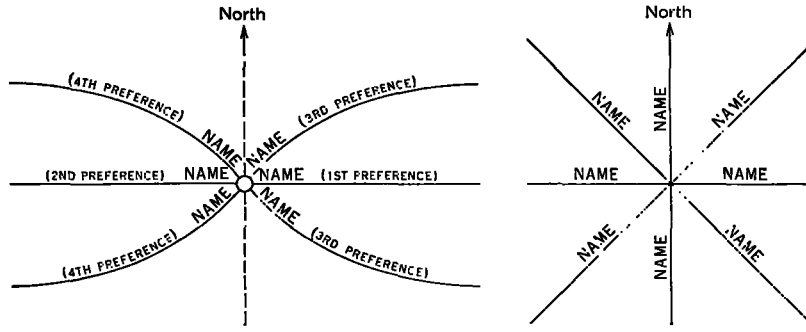


FIGURE 170.—Orientation of names on survey sheets.

practicable, placed immediately east of the feature named. Where it is necessary to place a name on a curve, the beginning or end of the name should be nearly parallel to the parallel of latitude. A name should not be lettered on a reverse curve. Most preferable is a compound curve with the flat part of the curve as nearly as practicable parallel to the parallels of latitude.

If the geographic feature to be named covers a considerable area, as an island or bay, the name should be placed preferably in the approximate center of the area. It should extend across the longest part of the feature and, if practicable, should follow the general curvature of the feature. Such names should never extend beyond the limits or even close to the limits of the feature in question. If the name is composed of several words they should not be too widely separated in order to extend the full length of the feature. Instead the name should be repeated a second, or even a third time.

Where it is necessary to letter a geographic name along a perfectly straight feature, such as a boundary line, railroad, or channel, that does not extend east and west, the following rules should be followed:

(1) Where the direction of the feature is from east of north to west of south, the name should begin at the southern end and extend toward the northern end.

(2) Where the direction of the feature is from west of north to east of south, the name should begin at the northern end and extend toward the southeast.

(3) In the rare case of a feature whose direction is exactly north and south, the beginning of the name should be at the southern end and extend toward the north.

7873. Lettering Geographic Names

All geographic names on the smooth sheet shall be left *in pencil.* They shall be made with single stroke capital letters. The names of the topographic features,

which in general are the names of everything above mean high water, shall be vertical letters. The names of the hydrographic features, and in general of all features below mean high water, shall be lettered in slanting letters. In the latter classifications are included, of course, shoals, reefs and banks, rocks awash, and sunken rocks.

The names of the most minor features on the smooth sheet shall be lettered in characters 0.1 inch in height and this height shall be increased according to the importance of the feature to a largest permissible height of 0.25 inch. For an equal importance of names it is essential to remember that slanting letters should be slightly smaller than vertical letters because an optical illusion makes the same size of vertical lettering appear slightly smaller.

7874. Inking Geographic Names

Geographic names must never be inked by the field party or by the Processing Office. This is done in the Washington Office after the geographic names have been reviewed and approved (see **9321**). The inking of the geographic names of hydrographic features is often deferred until after the soundings have been verified and inked.

All geographic names are inked in black using a mechanical lettering set.

788. LIMITS OF ADJOINING SURVEYS

The limits of adjoining surveys or the overlapping soundings must *not* be shown on the smooth sheet by the field party. (See **3233** and **3256**.) These will be added in the Office at the time of verification. However, it is incumbent on the smooth-sheet plotter to make a comparison with the overlapping soundings on adjoining surveys in order to determine whether *holidays*, or excessive differences exist, and to permit the drawing of the depth curves in the area based on all soundings obtained. The comparison is also necessary as a basis for information required to be included in the Descriptive Report (see **842*J***).

Comparison is best made by tracing the overlapping soundings of one survey and superimposing the tracing on the other. Where adjoining surveys are on different scales, the soundings on the smaller scale should usually be superimposed on the larger scale. The tracings, properly labeled, should be forwarded to the Office with the smooth sheet.

79. THE COMPLETED SMOOTH SHEET

The completed smooth sheet shall be considered the authority for the hydrography and for the topographic details within its limits offshore from the high-water line (see **75**). The smooth sheet as submitted by a field party or by a Processing Office should be complete, except that certain portions are left in pencil for inking after verification in the Washington Office (see table 28). After the sheet has been inked and reviewed there should be no necessity for reference to either the Sounding Records or the boat sheet, or to any other records, in order to interpret the data shown thereon. (See fig. 171.) A smooth sheet is, of course, supplemented by information in the Descriptive Report of a nature which cannot be shown easily by graphic means (see section **84**).

The Chief of Party must supervise in a general way the preparation of the smooth sheet to assure himself that it is being done in accordance with standard practice. If the plotting is executed while the party is still on the working ground, he shall take special care to see that any errors, omissions, or discrepancies in the field work are

corrected in the field. On completion of the sheet he shall make a final inspection of the sheet and all the accompanying records and shall report this fact, with his approval (see **7941**).

791. Completion of the Smooth Sheet

To assure completeness of the smooth sheet, constant checking is necessary throughout its production. Much of the work done on the sheet is self-checking and it is the duty of the smooth-sheet plotter to check his work as he proceeds. However, certain specific steps mentioned in this Manual do require verification (in the field) by a person other than the plotter (see, for example, **746**).

After the plotter has completed the routine work on the sheet, it must be inspected thoroughly and special attention given to those parts of the work which are not routine, such as comparison with the Sounding Records and the boat sheet (see **7911** and **7912**).

7911. Details From Sounding Records

The completed smooth sheet should depict graphically all the information which has been entered in the Sounding Records. To assure that this has been done, a systematic page by page comparison with the Sounding Records shall be made after completion of all the plotting. Special attention should be given to all entries in the "Remarks" column and to all other entries that are not routine, such as cuts to rocks and aids to navigation, and notes relative to the distance the sounding vessel passes any object. Each detached position should also be verified in order to ensure that it has been plotted and that the correct depth has been shown.

7912. Details From Boat Sheet

The boat sheet often contains supplemental details and notes which are helpful in interpreting the Sounding Records and all of these should be considered in connection with the smooth sheet. Occasionally, the boat sheet is the sole source of rocks, breakers, or kelp, but such information should be used with discrimination. It is incumbent on the plotter at this time either to transfer this data to the smooth sheet or to void it by deletion or by indicating on the boat sheet that it is valueless.

As part of the smooth-sheet inspection, a detailed systematic comparison should be made with the boat sheet, in order to ensure that all essential information has been transferred to the smooth sheet. It is important that hydrographers in the field realize that after review of the smooth sheets in the Washington Office, the boat sheets are retained only a short time before they are disposed of.

7913. Importance of Clarity

It is important that the completed smooth sheet is clear and legible and that no information thereon is indistinct or ambiguous. (See **721**.) The most important features on a smooth sheet are the locations of and least depths on shoals. Before submitting the sheet to the Washington Office, the smooth-sheet plotter should verify these items. The least depth on any shoal should be apparent at a glance without the necessity of a minute inspection of the area, and should be emphasized according to **7753**. If for any reason an important feature is obscured or shown in a manner that there is risk of its being overlooked, a note should be added calling attention to it (see **7914**). Dangers and shoals should be emphasized and it is more important that they be shown with distinction than that a routine symbolization be followed.

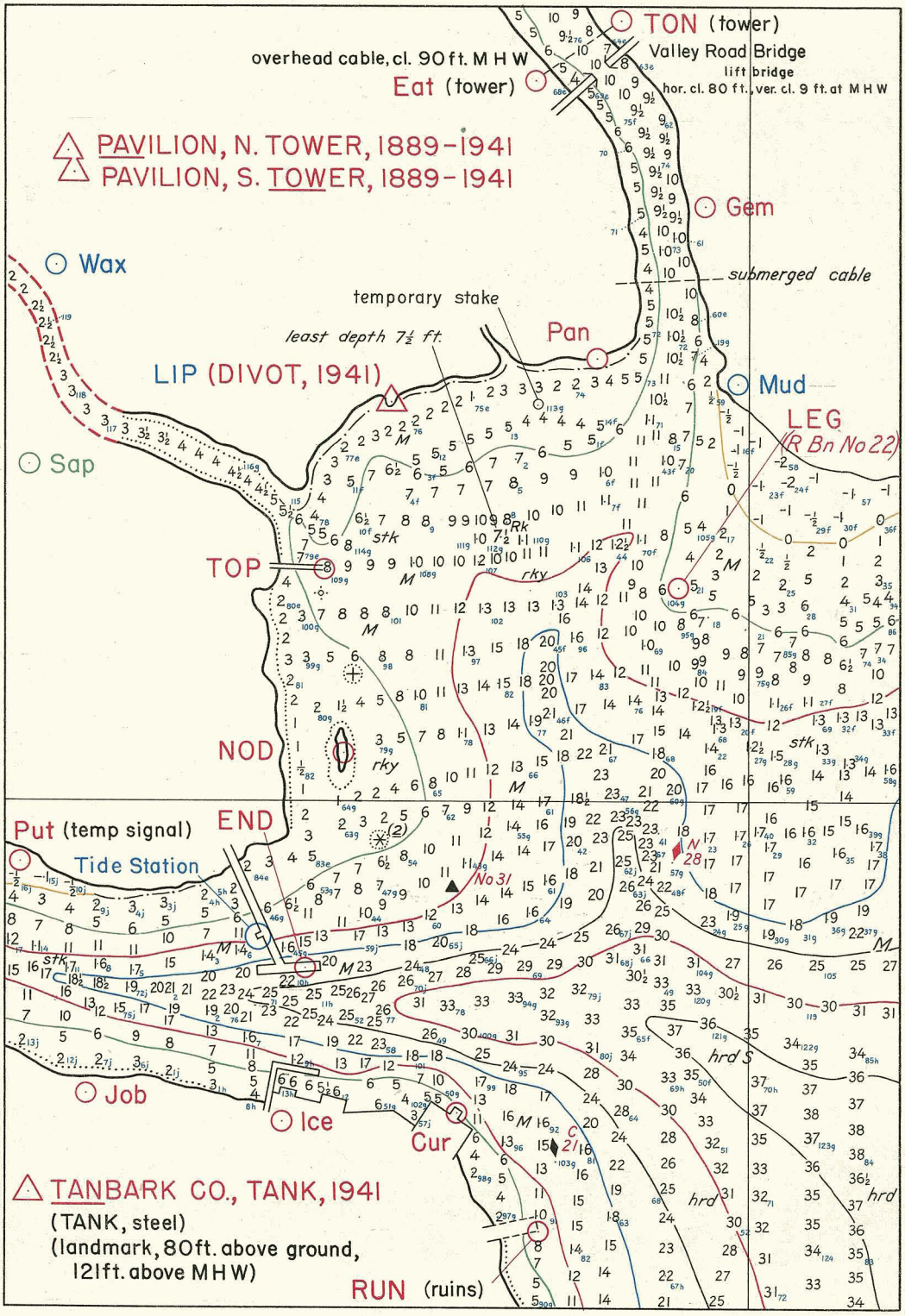


FIGURE 171. Section of completed smooth sheet (reproduced at actual scale)
(The black 24- and 36-foot curves represent pencil lines.)

This plate and the following should face each other to form one illustration.

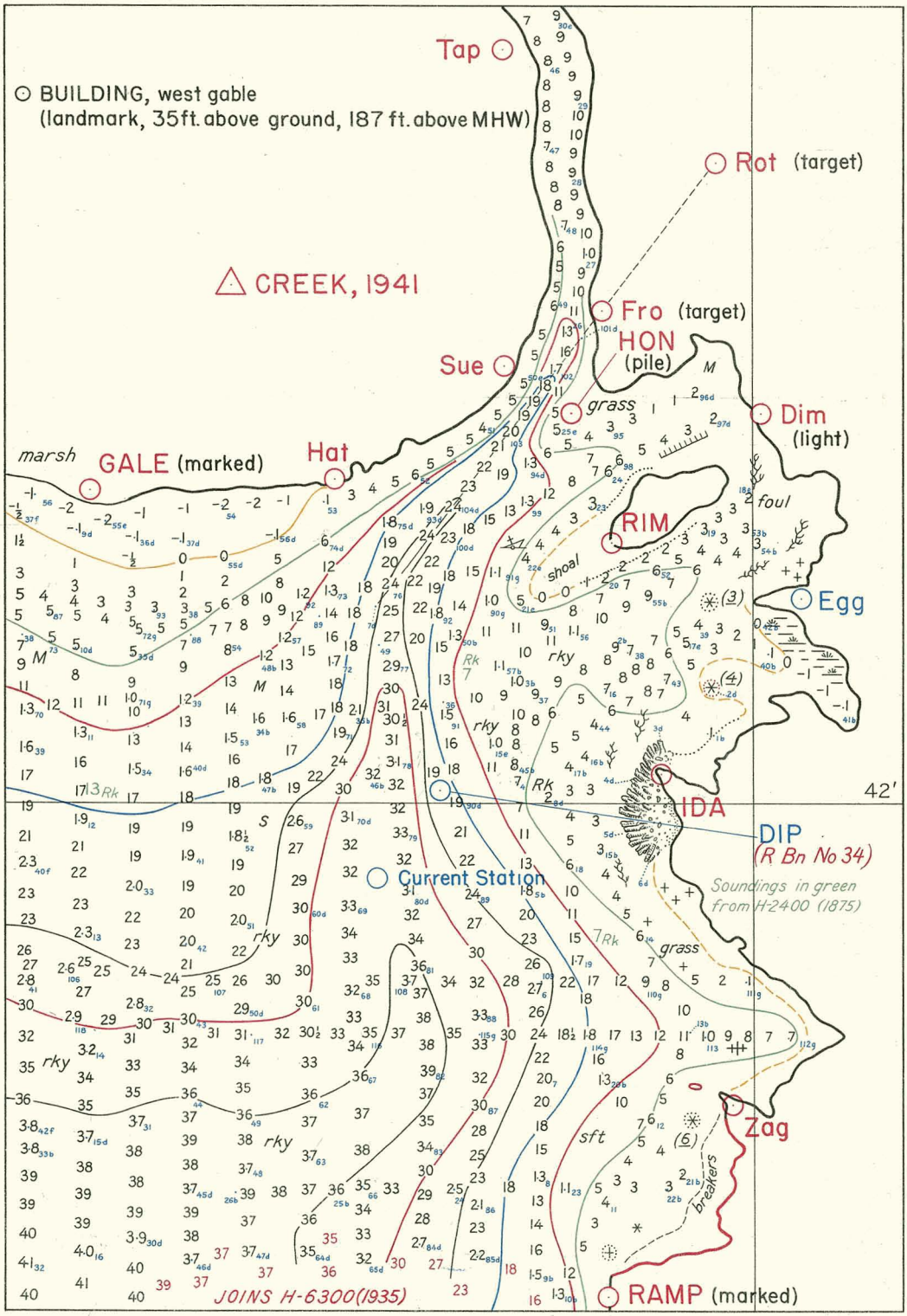


FIGURE 171. Section of completed smooth sheet (reproduced at actual scale).
(The black 24- and 36-foot curves represent pencil lines.)

7914. Use of Leaders

Explanatory notes are occasionally used on the smooth sheet to avoid possible misinterpretation of the data (see **781**). In order that these may be placed where they will least interfere with the hydrographic data it is often necessary to use a fine leader, or arrow, leading from the note toward the feature to which it refers. Such leaders or arrows are frequently of advantage to emphasize the least depths on shoals (see **7753**).

7915. Removal of Temporary Notes

All temporary pencil notations made on the smooth sheet during the plotting, should be removed before the sheet is transmitted to the Washington Office.

7916. Initials of Plotter and Verifier

During the construction and plotting of a smooth sheet various specific steps are performed. The records must show clearly responsibility for each step, whether it is of plotting or verification. Rubber stamps are provided for this purpose. Stamp No. 42, Hydrographic Survey, is placed in the lower right-hand corner of the smooth sheet and the initials of the plotter and verifier of the phases of work indicated thereon must be appropriately entered (see **746**). Rubber Stamp No. 38, Processing, (fig. 183) is entered in the Sounding Records at the end of each day's hydrography, and the plotter must enter his initials in the appropriate spaces using a pencil of the same color he used to checkmark items in the Sounding Records during the protracting and plotting of the data (see **76** and **773**).

792. SCHEDULE OF PENCILED AND INKED DETAILS

For the guidance of the smooth-sheet plotter, table 28 lists the various details that are to be shown in pencil and in ink on the smooth sheet when it is forwarded to the Washington Office. It is to be noted particularly that practically all the topographic information offshore from the high-water line is to be shown in black ink if it originates with the topographic survey and has been verified by the hydrographer, but like information originating with the hydrographic survey is to be left in pencil.

793. REGISTRY NUMBERS AND TITLES

At the beginning of each field season each survey sheet is assigned a temporary field number by the Chief of Party (see **1541** and **3213**). These field numbers are used for reference purposes during the early part of the season, but are subsequently replaced by permanent registry numbers assigned by the Washington Office. The registry number should be available on completion of the smooth sheet, and if so, this number should be shown in pencil on the back of the sheet in the middle of each end, with the corresponding field number just above it. The registry number should be used in referring to the smooth sheet or to any of the records pertaining thereto, after it is available. (See **1542** and **1543**.)

After the smooth sheet is received in the Washington Office and registered, it becomes a part of the permanent archives, and thereafter is never taken from the Washington Office.

600490—44——7

TABLE 28.—*Schedule of penciled and inked details*

Pencil	Black ink	Various colored ink
Registry number. Soundings. Bottom characteristics. Geographic names. Sailing lines. Notes concerning rocks, least depths, etc. Tide rips. Swirls. Marine vegetation (in general). [illegible]ges and bearings. [illegible]th curves. [illegible]-water line. [illegible]s connecting positions. [illegible]tors. [illegible]r arrows in sounded area. N[illegible]unded area. A[illegible]ts between topographic and hydrographic data. F[illegible]utes. Sub[illegible]ged cables. **From hydrographic survey:* Rocks (bare, awash, or sunken). Reefs. Ledges. Wreckage. Breakers. Limiting danger lines. Foul areas. Kelp. Fish stakes. Spoil areas. Bare rock elevations.	Projection lines. Projection numerals. Datum note. Geographic position of reference triangulation station. High-water line. Large buildings. Landmarks (symbol, name, elevation). Notes in land area. **From topographic survey:* Rocks (bare, awash, or sunken). Reefs. Ledges. Wreckage. Breakers. Limiting danger lines. Foul areas. Kelp. Fish stakes. Spoil areas.	Position numbers. Day letters. Position dots. Station names. Station symbols. Tide gage locations. Current station locations. Survey buoy symbols. R.A.R. distance circles. R.A.R. distance arcs. Navigational aids. Shoreline by hydrographer. Bare rock elevations by topographer.

*These features, if they originate with the hydrographic survey, are to be left in pencil on the smooth sheet, when transmitted to the Washington Office; if such data originate with the topographic survey and are verified by the hydrographic survey, they are to be inked in black ink.

The title of the hydrographic survey must *not* be penciled or inked on the smooth sheet by the field party. This is accomplished in the Washington Office. However, the information necessary for the title is reported on Form 537, Hydrographic Title Sheet (see **8412**).

794. FINAL INSPECTION

After completion of the smooth sheet the plotter should inspect the entire work thoroughly to make sure there are no errors, omissions, or discrepancies, and that the style and appearance conform to the standards prescribed in chapter 7. He should also assure himself that all temporary notes have been removed (see **7915**) and that the initials of the plotter and verifier have been appropriately entered on the smooth sheet and in the Sounding Records in the stamps provided for that purpose (see **7916**).

If the hydrographer who was in actual charge of the field operations can do so, he shall inspect the smooth sheet and make a thorough comparison with the boat sheet, to assure himself that the smooth sheet is complete and accurate, and that it delineates clearly the results of his field survey. Because of his intimate knowledge of the area, it is always possible that his inspection may disclose an erroneous interpretation made by the plotter. This is particularly true in the case of rocks, shoals, breakers, and so forth, for which the information in the Sounding Records is sometimes inadequate or ambiguous.

7941. Final Inspection by Chief of Party

After the completion of the smooth sheet, and before it is transmitted to the Washington Office, the Chief of Party shall inspect the sheet and all of the records. He shall also furnish on a separate sheet of paper as part of the Descriptive Report a statement to the effect that the sheet and accompanying records have been inspected by him, and are approved. (See **8437**.)

795. PRINCIPAL DEFICIENCIES OF SMOOTH SHEETS

In the past, hydrographic smooth sheets received in the Washington Office, have occasionally been found deficient in various respects, and to assist in eliminating these in the future a list of principal deficiencies is furnished herewith. This is not intended as a complete list of all of the deficiencies, but it does contain those which cause most trouble during the verification and review.

(*a*) Positions have been incorrectly plotted due to the use of a protractor out of adjustment.

(*b*) Incorrect spacing of soundings; omission of soundings from a failure to utilize properly the space available; insertion of soundings not recorded in the Sounding Record.

(*c*) Omission of too large a percentage of the recorded bottom characteristics.

(*d*) Excessive size or careless lettering of position numbers and day letters; very infrequently making their size too small; careless placing of them.

(*e*) Positions plotted with angles differing from those in the Sounding Record with no correction or note having been made in the Record.

(*f*) Certain notes in the Sounding Records have been ignored.

(*g*) Soundings penciled in a straight line between positions where the vessel followed a curved path.

(*h*) Limits and numbers of adjoining sheets shown in ink (these should be omitted entirely).

(*i*) Geographic names inked (these should be left in pencil).

(*j*) Failure to check and investigate depths which appear erroneous, or excessive differences at crossings.

(*k*) Inaccurate transfer of the shoreline from the topographic survey.

(*l*) Failure to have some of the operations checked, or failure to enter in the place provided the initials of the person performing or checking the operation.

(*m*) The use of too hard a pencil.

(*n*) The omission of a reference triangulation station and the geographic datum.

(*o*) The omission of the minus sign from soundings above the sounding datum; the low-water line incorrectly drawn with reference to the half-foot soundings above and below the sounding datum.

(*p*) The omission of important notes which appear only on the boat sheet, having been omitted from the Sounding Record.

(*q*) Inking the low-water line (this should be in pencil).

796. SHIPMENT TO WASHINGTON OFFICE

Completed smooth sheets shall be shipped to the Washington Office only in special metal or heavy cardboard tubes, which may be obtained on requisition. For shipment, smooth sheets shall never be rolled to a diameter smaller than 4 inches, and shall be forwarded by registered parcel post or express. The boat sheet shall be shipped separately. (See also **836**.)

Each smooth-sheet shipment shall be accompanied by a copy of the transmitting letter (Form 413), on which it is listed, the original being forwarded under separate cover.

NAUTICAL CHART

SYMBOLS AND ABBREVIATIONS

USED BY THE

COAST AND GEODETIC SURVEY

General Remarks

(1) *Soundings are expressed in feet or fathoms as stated in the title of the chart.*

(2) *The visibility of lights is in nautical miles for an observer's eye 15 feet above water level.*

(3) N.A. 1927 *at the upper right-hand corner of the chart is an abbreviation for "North American datum of 1927".*

(4) *Longitudes are referred to the Meridian of Greenwich.*

(5) *The coastline is the line of mean high water, except along mangrove and marsh.*

(6) *Nautical charts, unless otherwise noted in the title, are constructed on the Mercator projection, and are computed for the middle latitude of the chart or the middle latitude of a series of charts.*

(7) *Heights of land and conspicuous objects are given in feet above mean high water, unless otherwise stated in the title of the chart. Elevations of rocks, lighthouses, contours, and hills, are in feet above mean high water. Underlined elevations of mountain peaks are in feet above mean sea level.*

(8) *Dredged channels are shown by limiting dash lines with the depth, month, and year of latest examination.*

(9) *Explanation of marginal notes may be found in the Coast Pilot, and in the Chart Catalog.*

(10) *The use of capitals and the style of lettering given on this sheet is not always rigidly adhered to on the charts.*

(11) *Caution note:*

CAUTION

Temporary changes affecting
Lights, Buoys and Day Beacons

Aids which have been destroyed or removed, but which will be reestablished and are temporarily replaced by aids of different characteristics, are indicated in color by the following abbreviations.

D	*Destroyed, to be reestablished.*
T R B	*Temporarily replaced by a red buoy.*
T B B	*Temporarily replaced by a black buoy.*
T F B	*Temporarily replaced by a fixed white lighted buoy.*
T F R B	*Temporarily replaced by a fixed red lighted buoy.*
T FL B	*Temporarily replaced by a flashing white lighted buoy.*
T FL R B	*Temporarily replaced by a flashing red lighted buoy.*
T FL G B	*Temporarily replaced by a flashing green lighted buoy.*

(12) *The use of colors is optional and some of them may be changed for special reasons.*

Symbols and abbreviations are numbered in accordance with a standard form proposed by the International Hydrographic Bureau.

Vertical figures indicate that the symbol or abbreviation is in accordance with the I. H. B. standard.

Symbols or abbreviations which differ from those of the I. H. B., or which do not appear on the standard are indicated by slant figures.

Figures in parentheses indicate that the symbol or abbreviation is in addition to those shown on the standard.

No periods are used after abbreviations placed in water areas.

FIGURE 189. — Symbols and abbreviations for nautical charts (part I).

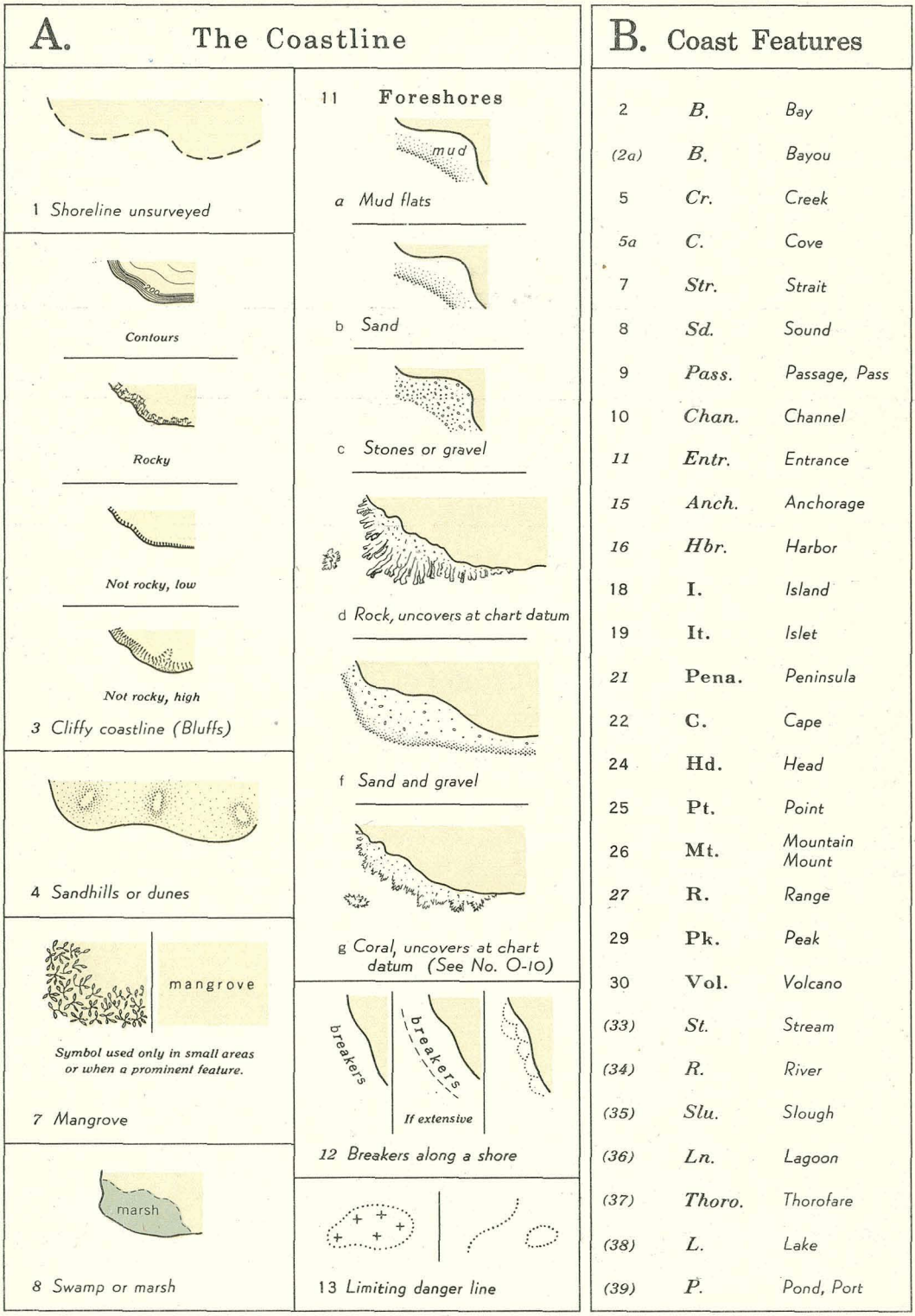
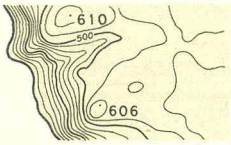
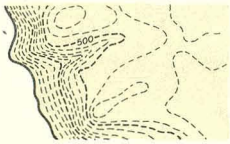


FIGURE 189. — Symbols and abbreviations for nautical charts (part II).

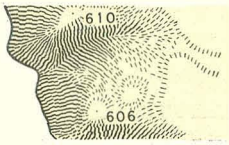
C. The Land



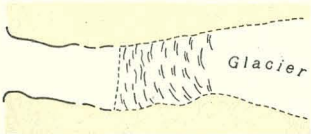
1 Contours or form lines



(a) Contours or form lines, estimated



2 Hachures



3 Glacier

TREE

A conspicuous clump or single tree of any kind useful as a landmark.

5 Isolated trees

wooded

9 Deciduous woodland (woodland of any kind)

2050 (tree tops)

(11) Elevation of top of trees

D. Control Points

1	△		*Triangulation point*
3	·256		*Summit of height (Peak) (when not a landmark)*
(a)	256		*Peak, accentuated by contours*
(b)	256		*Peak, accentuated by hachures*
(c)			*Peak, when elevation has not been determined*
(d)	256		*Peak, when a landmark*
4	⊕	Obs. Spot	*Observation spot*
5		B.M.	*Bench mark*
6	∘	See View	*View point*
(9)		Astr.	*Astronomical*
(10)		Tri.	*Triangulation*
(11)		U. S. E.	*United States Engineers*

E. Units

1	hr.	*hour*
2	min.	*minute*
3	sec.	*second*
4	m.	*meter*
5	km.	*kilometer*
6	in.	*inch*
7	ft.	*foot*
8	yd.	*yard*
9	fm.	*fathom*
11	m.	*nautical mile*
12	kn.	*knot*
13	lat.	*latitude*
14	long.	*longitude*
17	cor.	*correction*
(18)	alt.	*altitude*
(19)	ht.	*height*

FIGURE 189. — Symbols and abbreviations for nautical charts (part III).

F. Adjectives

and other abbreviations

1	gt.	great
3	lrg.	large
4	sml.	small
7	mid.	middle
9	anc.	ancient
12	conspic.	conspicuous
16	dist.	distant
17	abt.	about
(19)	aband.	abandoned
(20)	extr.	extreme
(21)	concr.	concrete
(22)	bet.	between
(23)	estab.	established
(24)	exper.	experimental
(25)	discontd.	discontinued
(26)	fl.	flood
(27)	mod.	moderate
(28)	maintd.	maintained
(29)	elec.	electric
(30)	priv.	private, privately
(31)	prom.	prominent
(32)	std.	standard
(33)	subm.	submerged
(34)	approx.	approximate
(35)	cor.	corner
(36)	Cl.	clearance
(37)	No.	number

G. Harbors

1		Anch.	Anchorage, large vessels (see No. P-12)
2		Anch.	Anchorage, small vessels
3		Hbr.	Harbor
6		Bkwr.	breakwater
8			jetty (partly below M H W)
(8a)			jetty (small scale)
9			pier
11			groin (partly below M H W)
12	Anchorage prohibited		Anchorage prohibited
13	spoil grd.		spoil ground
14	trap		fish traps (actual shape charted)
(14a)		fsh. stk.	fishing stakes when dangerous
16		Ldg.	landing place
18		Whf.	wharf
21		dol.	dolphin
26		Quar.	Quarantine
29		Cus. Ho.	Customhouse
33		B. Hbr.	Boat Harbor
35			dock
36			dry dock (actual shape shown on large scale charts)
37			floating dock (actual shape shown on large scale charts)
39			patent slip (marine railway)
40	Lock		lock
45		Obsy.	Observatory

FIGURE 189. – Symbols and abbreviations for nautical charts (part IV).

H. Topography

Roads in open country

Roads on small scale charts

1 Roads (Rds.)

2 Track, footpath, or trail

M. & N. W. Ry.

Same grade *Ry. above* *Ry. below*

3 Railway (single or double track)
Railway (Ry.) *Railroad* (R.R.)

Overhead cable
Cl. 140 ft.
Tower Tower

4 Overhead cable (Ovhd. Cab.)

5 Power transmission line

8 River (R.) or *Stream (St.)*

9 Intermittent stream

10 Lake (L.)

12 Marsh (See No. A-8)

Canal Lock
Ditch Sluice

13 Canal or ditch

Cl. 30 ft.
Cl. 30 ft.

14 Bridge (fixed)

15 Drawbridge, in general

16 Swing bridge, that can be opened

17 Pontoon bridge, that can be opened

Cl. down 20 ft.
Cl. up 67 ft.

(17a) Lift bridge

(b) Bascule bridge, that can be opened

Ferry
Ferry

19 Ferry

21 Dam

(25) Levee

(26) Lava flow

(27) Log boom

subm. pile *pile* *stumps* *snags*

(28) Submerged piling, piling, stumps, and snags

(29) Tunnel (railroad or road)

Viaduct

(30) Viaduct

FIGURE 189. – Symbols and abbreviations for nautical charts (part V).

I. Buildings

When the buildings are prominent, they may be shown by landmark symbol with descriptive note. (See No. L-63)

1			*City or town (large scale)*
(1a)			*City or town (small scale)*
3		Vil.	*Village*
4		Cas.	*Castle*
5		Ho.	*House*
8		Ch.	*Church*
18		Cem.	*Cemetery*
19			*Fort (actual shape charted)*
23	Airport		*Airplane landing field*
24			*Airport (large scale)*
			Small scale
(24a)			*Airport (military)*
(24b)			*Airport (commercial)*
26	First St.		*Street*
(26a)	Main Ave.		*Avenue*
27		Tel.	*Telegraph*
29		P.O.	*Post Office*
30		Govt.	*Government*
32		Hosp.	*Hospital*
34		Magz.	*Magazine*
35	MONU.		*Monument*
36	CUP.		*Cupola*
37		elev.	*elevation elevator elevated*
40			*Ruins*
41	TR.		*Tower*
(42a)	WINDMILL		*Windmill when landmark*
44	CHY.		*Chimney*
44a	STACK		*Stack*
46			*Oil tank*
47		Facty.	*Factory*
(56)	GAB.		*Gable*
(57)		Sch.	*School*
(58)		H.S.	*High School*
(59)		Univ.	*University*
(60)		Inst.	*Institute*
(61)		Co.	*Company*
(62)		Corp.	*Corporation*
(63)		Cap.	*Capitol*
(64)		C.H.	*Courthouse*
(65)		Cath.	*Cathedral*
(66)		Bldg.	*Building*
(67)		Pav.	*Pavilion*

FIGURE 189. – Symbols and abbreviations for nautical charts (part VI).

J. Miscellaneous Stations

2	Sta.	*Station*	9	Sig. Sta.	*Signal Station*
3	C. G.	*Coast Guard (similar to L. S. S.)*	19	F. S.	*Flagstaff*
(3a)	C. G. WALLIS SANDS	*When the building is a landmark*	(20)	W. B. SIG. STA.	*Weather Bureau Signal Station*
6	L. S. S.	*Lifesaving Station (See No. J-3)*	(21)	F. P.	*Flagpole*
8	PIL. STA.	*Pilot Station*	(22)	F. TR.	*Flag tower*
			(23)	LOOK. TR.	*Lookout tower*
			(24)	S.PIPE	*Standpipe*
			(25)	BELL	*When on land*

K. Lights

See General Remarks, note 11.

1		*Position of light*	31	Rev.	*Revolving*
2	Lt.	*Light*	(39)	min.	*minutes*
3	Lt. Ho.	*Lighthouse*	(40)	sec.	*seconds*
4	AERO	*Aeronautical light*	42	ev.	*every*
5		*Lighted beacon (Post light)*	44	vis.	*visible*
6		*Lightship*	(44a)	m.	*nautical mile*
7		*Lighted buoy*	47	Gp.	*group*
10	REF.	*Reflector*	49	SEC.	*sector*
(17)	Priv. maintd.	*Private light (maintained by private interests; to be used with caution)*	63	Bu.	*blue*
21	F.	*Fixed*	64	G.	*green*
22	Occ.	*Occulting*	66	R.	*red*
23	FL.	*Flashing*	67	W.	*white*
24	Qk. FL.	*Quick flashing*	68	OBSC.	*obscured*
(24a)	I. Qk.	*Interrupted quick*	69	(U)	*unwatched*
26	Alt.	*Alternating*	71	Irreg.	*irregular*
27	Gp. Occ.	*Group occulting*	73	Temp.	*temporary*
28	Gp. FL.	*Group flashing*	80	Vert.	*vertical*
(28a)	S-L.	*Short-long*	81	Hor.	*horizontal*
29	F. FL.	*Fixed and flashing*	(82)	D.	*destroyed*
30	F. Gp. FL.	*Fixed and group flashing*	(83)	V. B.	*vertical beam*
			(84)	Exper.	*experimental*
			(85)	R.	*range*
			(86)	AERO	*aeronautical*

FIGURE 189. – Symbols and abbreviations for nautical charts (part VII).

L. Buoys and Beacons

On entering a channel from seaward, buoys on starboard side are red with even numbers, on port side black with odd numbers. Lighted buoys on starboard side of channel are red or white, on port side white or green. Mid-channel buoys have black and white vertical stripes. Obstruction buoys are green, or have red and black horizontal bands. The dot of the buoy symbol, and the small circle of the light vessel and mooring buoy symbols, indicate their positions.

1	•	Position of buoy
2		Lighted buoy
3	BELL	Bell buoy
(3a)	GONG	Gong buoy
4	WHISTLE	Whistle buoy
5	C C	Can buoy
6	N N	Nun buoy
8	S S S	Spar buoy
(8a)		Checkered buoy
12		Lightship
14		Fairway buoy (Mid-Channel)
18		Junction buoy
19		Isolated danger buoy
20		Wreck or obstruction buoy
22		Mooring buoy
24	Y Quar.	Quarantine buoy
(27)		Fish trap buoy
(28)		Anchorage buoy
(29)	Priv. maintd.	Maintained by private interests; to be used with caution
31	H. B. / H. S.	Horizontal bands / Horizontal stripes
32	V. S.	Vertical stripes
33	Chec.	checkered
41	W.	white
42	B.	black
43	R.	red
44	Y.	yellow
45	G.	green
(46)	Br.	brown
52	△ ▲ ▲	Fixed beacons (unlighted daymarks)
(52a)	MARKER	Private aid to navigation
53	Bn.	Beacon (See No. L-52)
63	⊙	Landmark
(64)	REF.	Reflector

M. Radio Stations

1	R.S.	Radio station
3	R.Bn.	Radiobeacon
7	R.C.	Radio Direction Finder Station
9	R.Tr.	Radio tower
(10)	R.Tr. (WEAF)	Commercial broadcast
(11)	N.R.C.	Naval Radio Direction Finder Station

N. Fog Signals

1	Fog Sig.	Fog Signal Station
6	SUB-BELL	Submarine fog bell (mechanical)
7	SUB-OSC.	Submarine oscillator
8	HORN	Nautophone
9	DIAPHONE	Diaphone
11	SIREN	Fog siren
12	HORN	Fog trumpet
13	HORN	Fog horn
14	BELL	Fog bell
15	WHISTLE	Fog whistle
16	HORN	Reed
17	GONG	Gong
(18)	D. F. S.	Distance Finding Sta.

FIGURE 189. — Symbols and abbreviations for nautical charts (part VIII).

O. Dangers

(27)

1 Rocks which do not cover; with their elevations above M H W

* uncovers 2 ft. at L W

*(2)

2 Rocks that cover and uncover, with heights in feet above chart datum

(3a) When rock of No. 2 is considered a danger to navigation

+

(4a) Sunken rock below chart datum; depth not known

(4b) When rock of No. 4a is considered a danger to navigation

2 Rk

(4c) Shoal sounding on isolated rock replaces symbol

21 Rk 21 Wk 21 Obstr

(6a) Sunken danger with depth cleared by wire drag (Feet or fathoms)

reef line

10 Coral or rocky reef (below chart datum) See No. A-11g

11 Stranded wreck (any portion of hull above chart datum)

masts

12 Sunken wreck with only masts visible

14 Dangerous sunken wreck with less than 10 fathoms of water over it (See No. 6a)

wreckage

(14a) A number of sunken wrecks

21 Obstr

(14b) Obstruction of any kind

16 Sunken wreck, not dangerous to surface navigation or over which the depth exceeds 10 fathoms

foul

17 Foul ground

tide rips

18 Overfalls or tide rips

eddies

19 Eddies

20 Kelp, any kind

21	Bk.	bank
22	Shl.	shoal
25		breakers (see No. A-12)
27	Obstr.	obstruction
28	Wk.	wreck
(28a)	Wks.	wreckage
33	cov.	covers
34	uncov.	uncovers
35	rep.	reported
(35a)	9 reported	shoal reported
41	P. A.	position approximate
42	P. D.	position doubtful
43	E. D.	existence doubtful
44	Pos.	position
45	D.	doubtful

FIGURE 189. — Symbols and abbreviations for nautical charts (part IX).

P. Various Limits

1		Leading line (Range line)
4		Limit of sector
5		Channel or course recommended
(5a)		Alternate course
7	Gable area	Submarine cable
8	Pipe line Pipe line area	Submarine pipe line
9		Maritime limits in general
10		Limit of fishing zone (fish trap areas bounded by orange lines)
11		Limit of dumping ground (see Nos. P-9 & G-13)
12		Anchorage limit
13	Airport	Limit of airport
16		International boundary (also State boundary)
18		Ice limits
(21)	Bdry.	Boundary
(22)	Bdry. Monu.	Boundary monument
(23)		Reservation line

T. Tides and Currents

1	H W	high water
(1a)	H H W	higher high water
2	L W	low water
(2a)	L L W	lower low water
3	M T L	mean tide level
4	M S L	mean sea level
(8a)	M H W	mean high water
(8b)	M H H W	mean higher high water
(9a)	M L W	mean low water
(9b)	M L L W	mean lower low water
17	St.	stream
18		current, general
19	2 kn	flood stream
20	2 kn	ebb stream
23	vel.	velocity
24	kn.	knots
(25)	0 1 2 3 4 5 6 7 8 9 10 11	Current Diagram

Q. Soundings

2	27	No bottom sounding
5	30 FEET MAY 1939	Dredged channels (controlling depth may be shown in separate note)
9	17 119	Swept areas (shown by green tint) (not yet covered by sufficient hydrographic surveys to show adequate soundings)
(16)	6 5 2 ft	Stream

R. Depth Contours & Tints

Feet	Fathoms
0	0
6	1
12	2
18	3
24	4
30	5
36	6
60	10
120	20
180	30
240	40
300	50
600	100
1,200	200
1,800	300
2,400	400
3,000	500
6,000	1,000
12,000	2,000
18,000	3,000
Or 10 fathoms and greater	

10

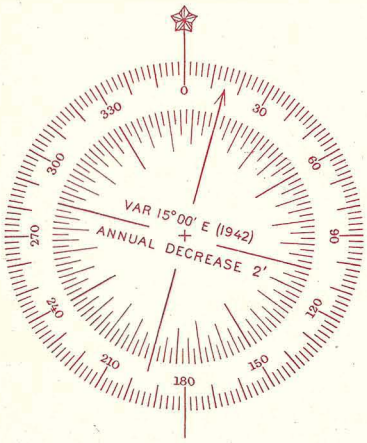
Or 100

FIGURE 189. — Symbols and abbreviations for nautical charts (part X).

S. Quality of the Bottom

1	Grd	ground
2	S	sand
3	M	mud
4	Oz	ooze
5	Ml	marl
6	Cl	clay
7	G	gravel
9	P	pebbles
10	St	stones
(10a)	Sp	specks
11	Rk	rock
(11a)	Bld (s)	boulder (s)
12	Ck	chalk
14	Co	coral
(14a)	Co Hd	coral head
(16a)	Vol Ash	volcanic ash
17	La	lava
18	Pm	pumice
21	Cn	cinders
23	Sh	shells
24	Oys	oysters
26	Spg	sponge
27	Grs	grass
33	Gl	globigerina
34	Di	diatom
39	fne	fine
40	crs	coarse
41	sft	soft
42	hrd	hard
43	stf	stiff
44	sml	small
45	lrg	large
46	stk	sticky
47	brk	broken
(47a)	rky	rocky
50	spk	speckled
51	gty	gritty
53	fly	flinty
54	glac	glacial
56	wh	white
57	bk	black
59	bu	blue
60	gn	green
61	yl	yellow
63	rd	red
64	br	brown
66	gy	gray
67	lt	light
68	dk	dark

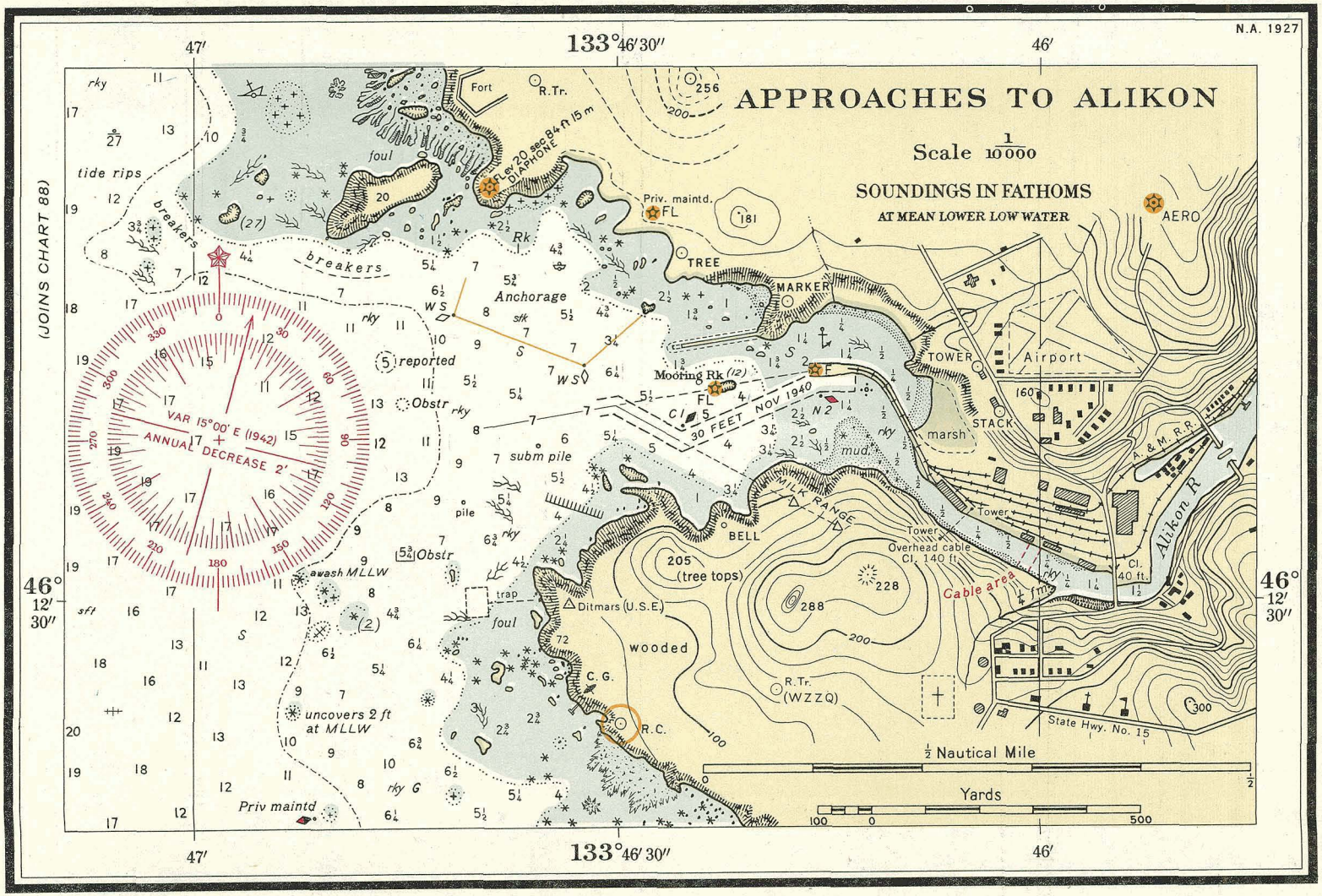
U. Compass



The outer rose is in degrees with zero at true north. The inner rose is in points with the arrow at magnetic north.

1	N.	north
2	E.	east
3	S.	south
4	W.	west
5	NE.	northeast
6	SE.	southeast
7	SW.	southwest
8	NW.	northwest
21	brg.	bearing
23	mag.	magnetic
24	var.	variation
(27)	deg.	degrees
(28)	dev.	deviation

FIGURE 189. — Symbols and abbreviations for nautical charts (part XI).



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