

« ON SOUNDINGS »

by

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(Note by the Directing Committee : This article is a description of a new type of Nautical Chart published recently by the United States Coast and Geodetic Survey.)

Since time immemorial « man the chains » has signified to the sailor either an approach to port or an imminent danger. Sounding on approaching land and entering an intended port was a matter of routine and was accepted with delight as a sign of the end of the voyage. Otherwise it was resorted to only when the vessel was in unexpectedly shoal waters. In either case, the lead was used to prevent possible grounding.

In Biblical times such a use of sounding is recorded. In 59 A.D., Paul, the Apostle, was being carried prisoner to Italy in a ship containing « two hundred three score and sixteen souls » and the ship was caught in a blow in the Ionian Sea. When, after days of storm, all the freight and spare gear had been jettisoned, and practically all hope had been abandoned, the seamen's instinct told them that they were approaching land in the night, and they « sounded and found it twenty fathoms ; and when they had gone a little further they sounded again, and found it fifteen fathoms. And fearing lest we should have fallen upon the rocks, they cast four anchors out of the stern, and wished for the day. » (*The Acts*, 27th Chapter, 28-9).

Mariners can well appreciate the simple closing words, « and wished for the day ! » I feel certain that many officers have, as I, « wished for the day », especially when making a landfall after having been in fog and overcast weather for days.

The need for sounding as a matter of precaution when in proximity of land is recognized by all navigators and most of them are familiar with several methods of using soundings to obtain approximate positions. Some mention of the use of soundings in piloting is found in most authoritative works on navigation. Such remarks are generally quite brief, however, and are of little help to the navigator. The tendency is to discourage the use of soundings for position finding except as a check upon positions obtained by other methods. While one would be rash indeed to oppose the accepted authorities on this subject, it is believed that they are in general unduly pessimistic and that their texts should be revised to give consideration to modern improvements in sounding methods and also in the chart itself. Specific mention of echo sounding is rarely to be found and it is only too clear that, in most of them, references are to sounding methods and charts which are being rapidly outmoded. At least we may hope that more space in future editions will be devoted to a more thorough treatment of this subject.

Before the development of echo sounding, soundings in the deeper areas were of practically no value in navigation and the charts of our coasts contained merely a fringe of well-surveyed area along the shore with only a scattering of soundings beyond. But even then, it was possible occasionally to use soundings for reasonable « lines of position ». I recall especially one instance in 1918, during a tour of duty on the old *Maumee*, bound from the Straits of Florida to Narragansett Bay. We ran into thick weather after taking a departure from Jupiter Inlet Light and no check on our position was obtained for several days and we were nearing a landfall. After hours of watchful waiting, one poor sun sight was obtained in the late afternoon, which gave an approximate longitude. A sounding obtained at

about the same time gave the distance offshore. An approximate position was thus obtained which put us at least 60 miles ahead of our dead reckoning, but which enabled us to make a landfall with some certainty.

One sounding, ordinarily, merely gives a line of position, which is the depth curve of that amount. Such lines of position, although they are generally not so considered, may be used in conjunction with another line obtained by other means to fix one's position. Occasions often arise when one reliable sounding and a single bearing on a shore object can be used to obtain a position. In the Gulf of Mexico off the Florida coast, it is customary to take a sounding simultaneously with the noon sight, and as the bottom slopes uniformly westward for many miles at about 1 fathom per mile, a reliable position is obtained.

The custom of sketching danger contours from soundings of large-scale harbour charts and coastwise charts is one practised for many years by all cautious shipmasters. Depth curves may be put to a similar use in foggy weather when it may be possible by soundings to follow a depth curve along the coast which will lead into a desired bay or the desired anchorage.

Echo sounding has increased vastly the opportunities for the use of soundings in navigation, just as it is rendering obsolete the wire sounding machine and the always uncertain chemical tubes. It is now practicable for the navigator to obtain soundings in almost any depth of water, the ship proceeding at full speed, and the most recent development provides a continuous automatic record of the depths passed over.

The same echo sounding instrument is responsible for more accurate and complete charts, and its development for surveying purposes has attained such perfection that depths of less than 40 fathoms can be measured accurately to fractions of a foot. We may even look forward to the day when it will replace the hand lead in most instances and « man the chains » may become a byword.

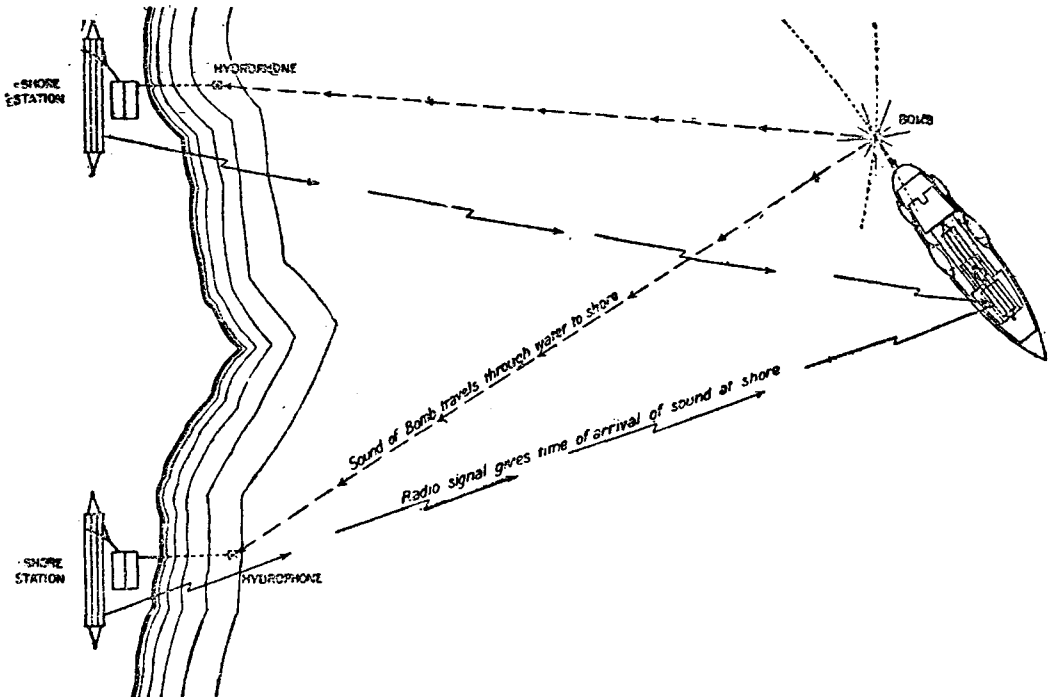


Fig. 1

Two complementary factors are necessary in an accurate chart. Soundings, however accurate, are of little value to the cartographer unless the geographic positions at which they were taken are accurately known. It has always been possible to locate a survey vessel accurately within sight of land and in clear weather, but more distant positions were subject to the usual errors of dead

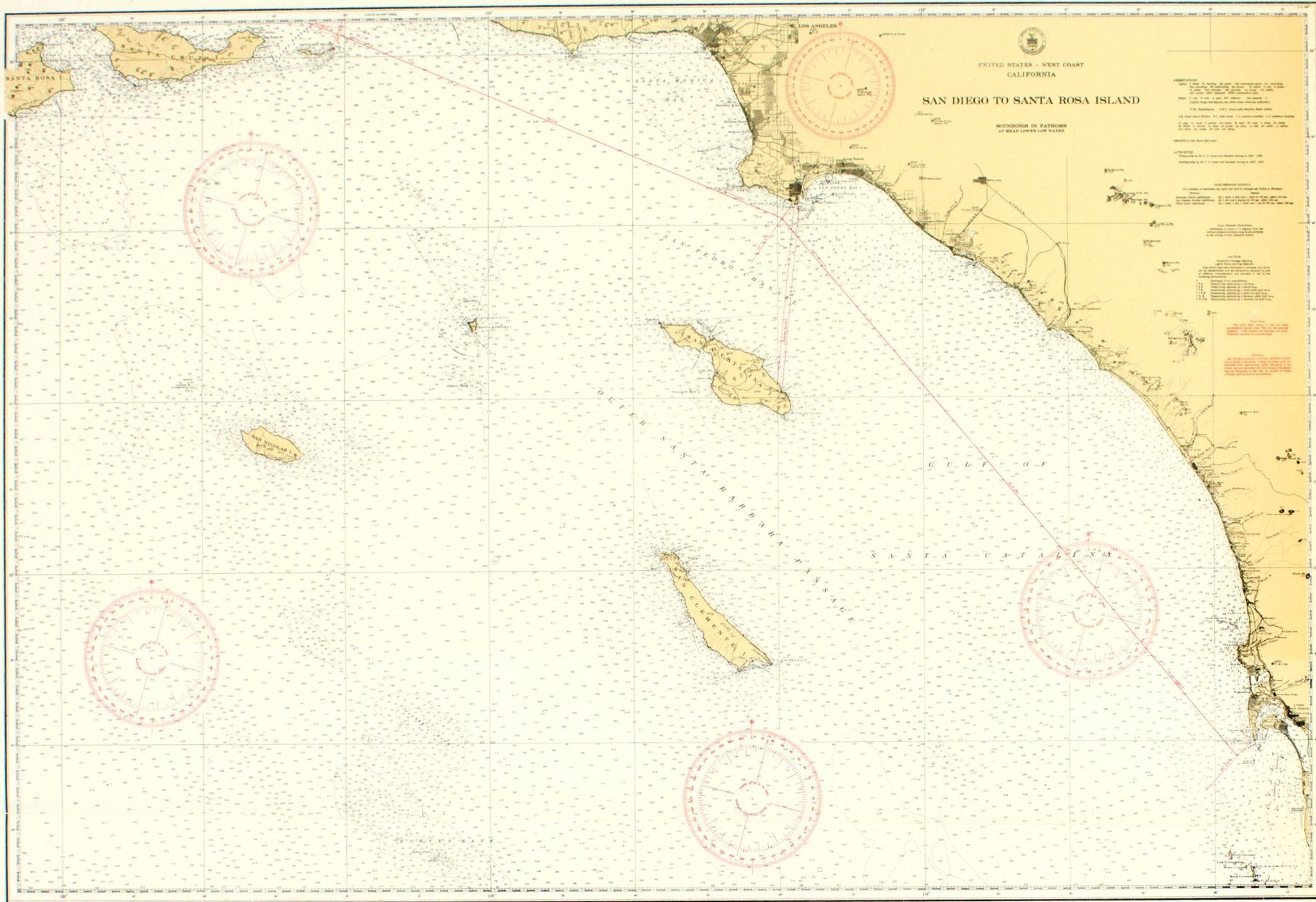


PLATE 1 - CHART 5101
 (Approximately one-fifth actual scale)

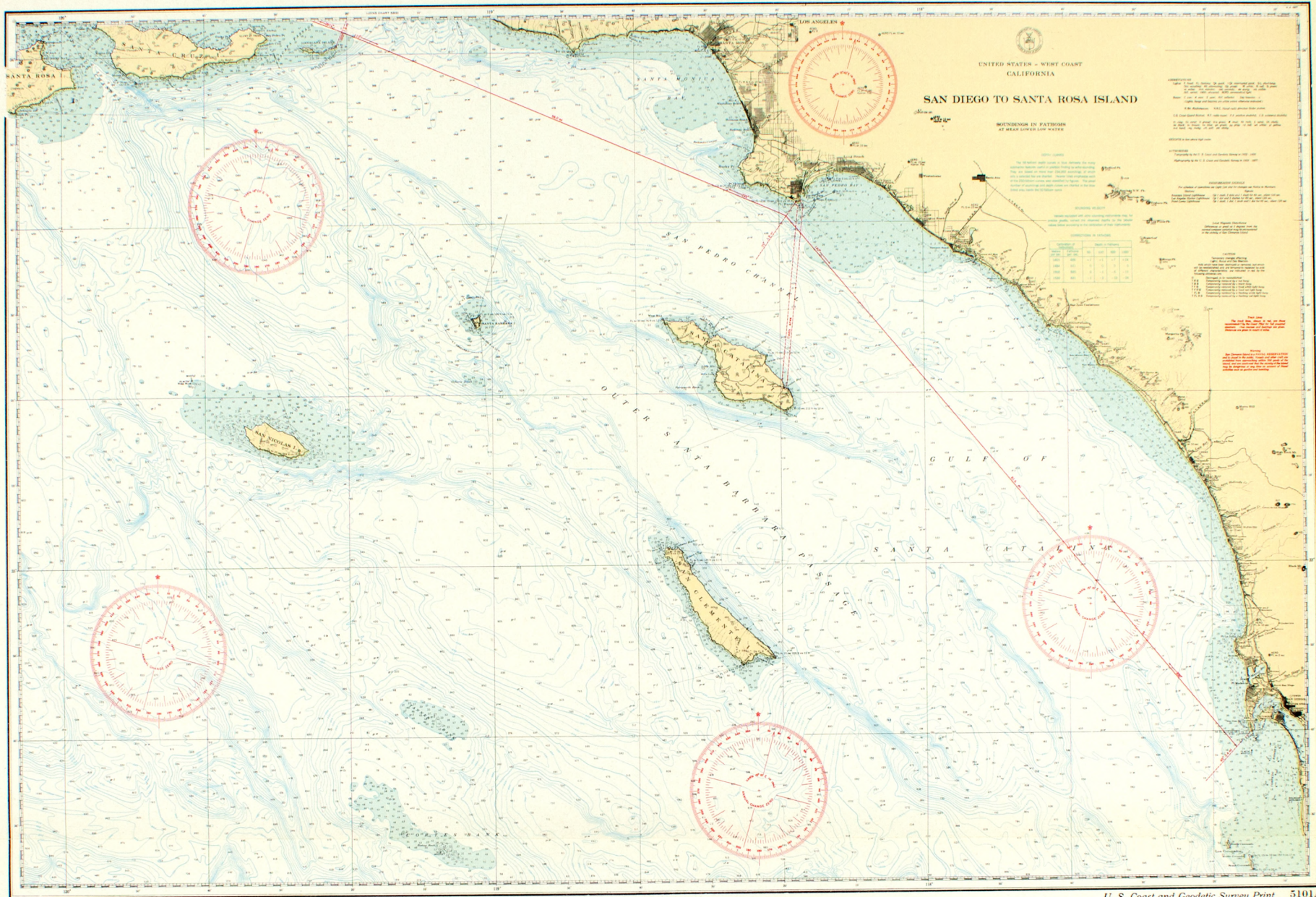


PLATE 2 - CHART 5101A
 (Approximately one-fifth actual scale)

reckoning and astronomic fixes and these errors reduced the charting value of the excellent echo soundings taken some distance offshore. Thus, although instruments for sounding were nearing perfection, there was no method known by which soundings beyond limits of visibility of shore objects could be accurately located.

The problem was ultimately solved by the adaptation of principles of physics to hydrography — specifically by a combination of radio and subaqueous sound. In 1924, as a parallel development to the use of echo sounding in surveying, the Coast and Geodetic Survey began experiments with the method which to-day is known as radio acoustic ranging. A simplified sketch Fig. 1, illustrates the fundamental principles. Without discussing the method at length it may be said conservatively that it provides an accuracy of offshore positions far superior to any known system and it has been used successfully more than 100 miles from land. The history of its development and use may be found in scientific literature of the past decade.

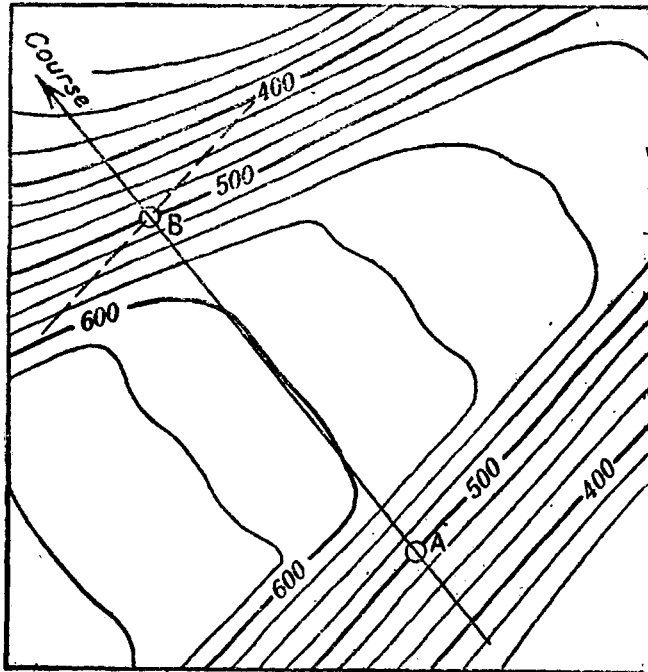
Together, radio acoustic ranging and echo sounding have made possible such a chart as N° 5101 A, issued in March, 1939, by the Director of the Coast and Geodetic Survey (Plate II). I have no doubt that the immediate reaction of all cautious navigators to the blue submarine contours on this chart will be to ask « What is fact and what is fancy ? » For that reason a brief description of the methods used in the construction of this chart will not be out of place.

Chart 5101, San Diego to Santa Rosa Island, embraces about 12,000 square nautical miles of the Pacific Ocean, and the present conventional edition (Plate I) contains in most areas the maximum number of soundings that can be charted at its natural scale of 1 : 235,000, without impairing its legibility. Even so, only about 2 per cent of the total soundings taken during the recent surveys have been charted, and although these were carefully selected, full use could not be made of the remaining 98 per cent of the soundings available. A new method of charting was, therefore, needed in order that maximum use might be made of all the available data, but without too radical a departure from the conventional chart to which the navigator has become so accustomed.

Precisely the same area is covered by Chart 5101 A (Plate II) which differs from Chart 5101 only in the water area, wherein new principles of chart construction were used. Contours were first drawn on the original survey sheets where, because of the larger scales, full use could be made of all the soundings (not just 2 per cent). Such a graphic representation of the conformation of the ocean bottom is, of course, far superior to a mere congestion of numbers. Imagine, if you can, trying to interpret a topographic map covered with a multitude of elevations but without contours. Charted contours or depth curves show at a glance which submarine features along the proposed course are especially suitable for position determination by echo sounding, and in some cases the course may be shaped accordingly.

The choice of a contour interval of most value to the navigator involves many factors. Among them are the thoroughness of the available surveys, the nature of the submarine relief, and the scale of the chart. Above all, the resulting chart must be legible, and free from a confusion of heavy lines or other printed material, so that the navigator may do such pencil work on its surface as is ordinarily necessary. In the construction of Chart 5101 A (Plate II), these considerations were given first importance. The depth curves of 50-fathom intervals printed in blue and numbered at frequent intervals, are based on more than a quarter of a million soundings, taken in the course of the original surveys. Soundings which represent the greatest or least depths over the important features, and a few others to facilitate reading the contours, are all that are needed on this type of chart, because each contour is equivalent to charting a continuous line of soundings of that depth. A light blue solid tint emphasizes all areas less than 50 fathoms deep. Here greater navigation precautions may be necessary and within these areas the conventional number of soundings and depth curves are shown. A table is provided which may be used to correct echo soundings that may be taken by instruments calibrated for a velocity of sound differing from the average determined for the chart. Such corrections are, of course, usually quite small and may be omitted for ordinary purposes of navigation.

The difference between the two charts is most striking. While Chart 5101 contains three times as many soundings as the new chart, the latter discloses a wealth of useful information not discernible on the former. For example, the curves bring into prominence such remarkable features as the steep slopes between San Clemente Island and the mainland. Such abrupt slopes provide the best possible « lines of position » to the navigator equipped with the new chart and an echo sounder. At a speed of 15 knots, the change in depth would be 100 fathoms per minute for 5 consecutive minutes while crossing some of these slopes. Such rapidly changing depths are comparable to sensitive ranges on land for position control, and they offer the additional advantage of being available at all times, even in thick fog or darkness. The area covered by this chart is in general extremely rugged, and good submarine « landmarks » are numerous.



Line of position from echo sounding

Fig. 2

Navigation by echo sounding on such a chart as 5101 A consists merely of fitting the observed soundings to the chart in the correct location. One of the simplest uses may be illustrated by a simple analogy to the Sumner Line. Assume, for instance, that the ship's course lies across a submarine trough as in Fig. 2. When a depth of 500 fathoms is obtained (point A) it is known that the vessel is somewhere on the 500- fathom contour on the southeast slope of the trough. After passing over the flat bottom in depths averaging about 600 fathoms, another log reading at the 500- fathom curve on the northwest slope permits moving the first « line of position » (a section of the 500- fathom contour on the southeast slope) up to point B, and its intersection with the 500- fathom contour on the northwest slope yields a position at B.

It is obvious that positions cannot be determined from a perfectly flat horizontal sea bottom. Fortunately for the navigator the ocean floor is rarely as flat as popularly supposed. Modern surveys are now disclosing frequent changes of 30 or 40 feet in depths on our comparatively even sloping Atlantic continental shelf. Charts of such an area, to be of most value to the navigator, will of course require contours at much smaller intervals than Chart 5101 A contains.

The overprint in red illustrates the use of depth curves in determining a ship's position by echo sounding.

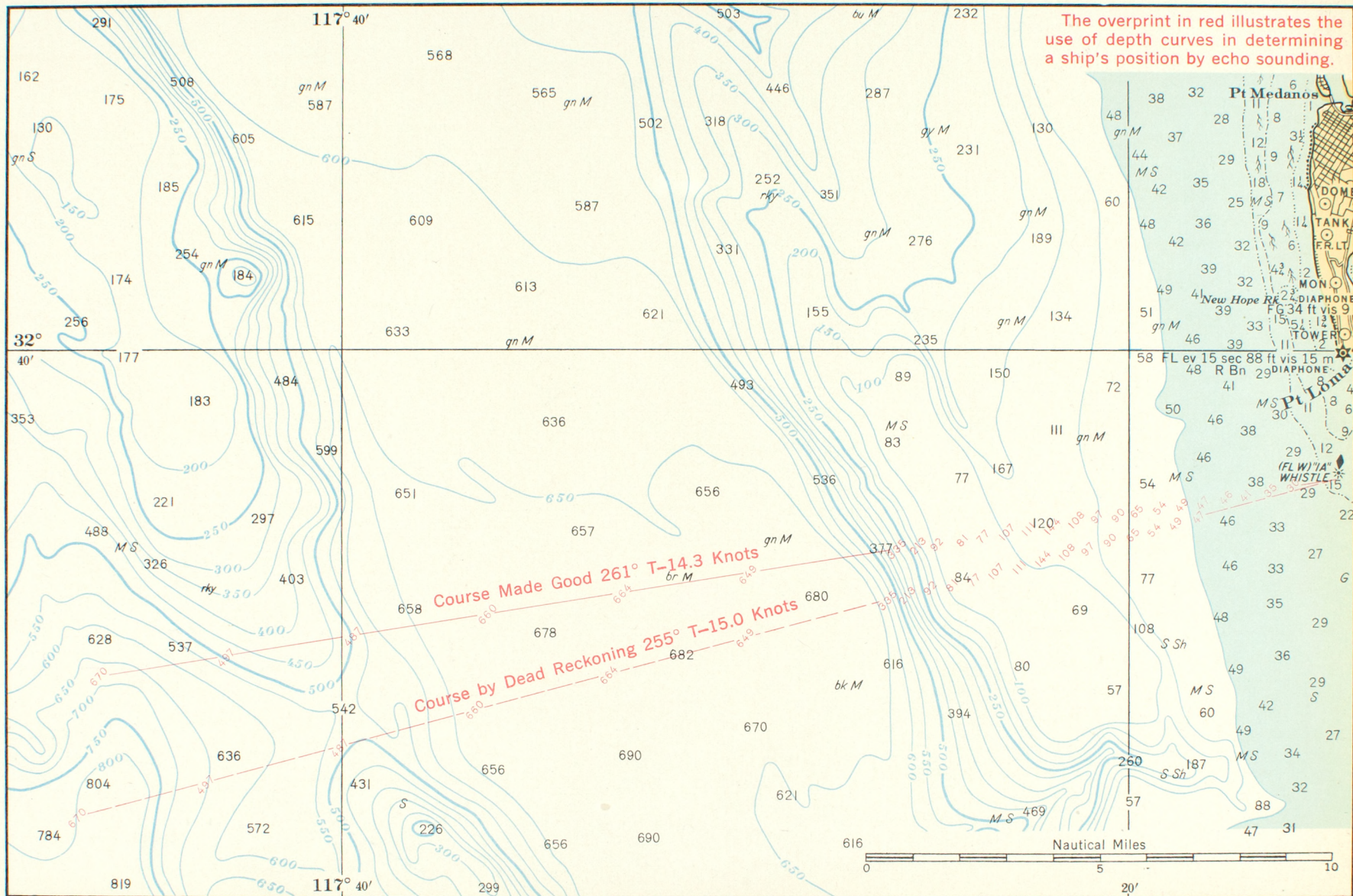
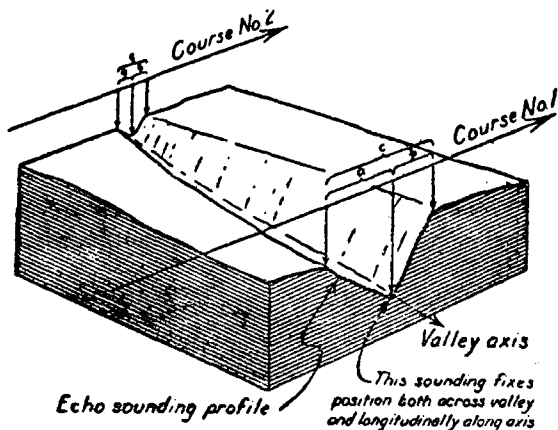


PLATE 3 - SECTION OF CHART 5101A

U. S. Coast and Geodetic Survey Print

Submarine valleys — and we are finding more and more of these as surveys are extended offshore — provide the best possible formations for use in fixing position. They usually are narrow, V-shaped in cross section and have a continuous downward slope along the axis of the trough (Fig. 3). In such a submarine shape there are two opportunities to obtain a fix. The distance by log (or time) across the valley from rim to rim (c) provides one method, because it can be located in only one position. The maximum depth obtained when crossing the axis or bottom gives a strong independent position because it occurs in only one place in the valley bed. The first method may also be adapted to distances between contours of equal depth when the rim is too indefinite for such use. The best method for fixing position when crossing a submarine valley is generally the use of the deepest sounding obtained because the gradients of the bottoms are generally more dependably uniform than the slopes at the rims. There are, of course, exceptions to this statement and each locality and each submarine feature will offer special cases and opportunities which a navigator will be able to evaluate readily when the shapes are delineated by contours.



Position finding from echo sounding
across submarine valley

Fig. 3

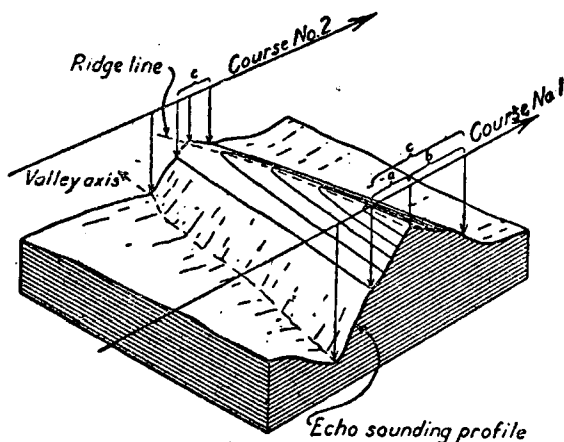
A word of caution is necessary in connection with the use of echo soundings in valleys. Unfortunately, a *sonic* oscillator does not possess directional properties and sometimes the sound is reflected or dispersed from the sides of a steep chasm and no echo is obtained from the bottom of the ravine, especially from great depths. *Supersonic* oscillators are strongly directional and do not have the above limitations.

Submarine mountains and ridges may likewise be used for position finding. The method is obvious, the only difference being that the shoalest sounding obtained is used in lieu of the deepest. Figure 4 illustrates the simple case of a tapering ridge with fairly uniform slope.

When the formation of the bottom is such that the simple methods described above cannot be used, it is generally necessary to compare a series of soundings with the chart. This is accomplished by recording with care and precision a number of soundings and simultaneous log distances and plotting these accurately on a strip of tracing paper at the scale of the chart. Some officers mark the shoalest sounding of a plotted series in red, and the deepest in blue. This gives at a glance the soundings to be compared with the most prominent features, that is, the tops of the ridges and the bottoms of the valleys. The line of soundings on the tracing paper is then simply adjusted to fit the contours by moving it so that it remains approximately parallel to the true course steered. The ideal material on which to plot soundings for comparison with the chart would be something with a surface equal to good chart paper, the transparency of celluloid,

and the elasticity of rubber ! Reasons for the properties mentioned will be obvious to all mariners who may have used soundings for position finding.

Although no actual example of echo-sounding navigation on Chart 5101 A is available at this date (1), a vessel sailing from San Diego several years ago obtained echo soundings across one section of the area (see Plate III). According to the ship's log, the course was 255° true and the speed 15.0 knots. The navigator, of course, did not have Chart 5101 A. The intended course is shown by the dashed red line ; but when the soundings are compared with the depth curves of the new chart, it is disclosed that the course actually made good was 261° true, and the speed was 14.3 knots as shown by the solid red line. The soundings shown in red were those obtained by the vessel and the relative spacing along the line is exactly as recorded in the log. The soundings fix beyond question the vessel's position both in latitude and longitude. Had the new chart been available to the navigator of this vessel, he undoubtedly would have been taking echo soundings continuously in the vicinity of the prominent features shown on the chart. For instance, after crossing the 10- mile plain between the 650- fathom curves, he would have known that the vessel was again approaching a fairly steep slope, and certainly would have endeavoured to obtain the least sounding on the ridge between the 487- and 497- fathom soundings.



**Position finding from echo sounding
across submarine ridge**

Fig. 4

It is sometimes impracticable to have an observer stationed continuously at the echo-sounder and the advantages of a graphic recorder are apparent. Errors of observation and recording are eliminated, and transient « strays » caused by electrical or other disturbances are almost infallibly disclosed in their true nature on the automatic record. A continuous record is often desired for a subsequent check of certain sections of the course. Some regions abound in submarine topography quite useful in position fixing, but in other localities several miles may be run before a satisfactory position may be obtained. When the navigator notes that the vessel has passed over certain prominent submarine features, he can remove that section of the graph for use in plotting his position while the instrument continues recording automatically.

The practicability of following, by sounding, a given depth curve leading into a harbour or anchorage has been mentioned. Another very practical use of depth curves may be made in passing prominent points, such as Point Arguello, California, in thick weather. Northbound vessels could, by the use of echo sounding, follow the 30- fathom curve, and southbound the 50- fathom curve, and

(1) Chart 5101A was issued in March, 1939.

be assured of a passing clearance of 1 1/2 miles, and both courses would be well clear of any hazard of the shore (2). Farther offshore from the same point several valleys of the type shown in Fig. 3 indent the 100- fathom curve. A course laid to pass 5 1/2 miles off Point Arguello would cross these and provide an opportunity to obtain reliable positions in thick weather at intervals of about 2 1/2 miles along the course.

Numerous other examples might be given but the advantages of echo sounding navigation on charts of the type of 5101 A should be apparent. Many officers will realize that the method may be used with a confidence afforded by no other means of navigation, except positions fixed by visual bearings or angles on shore objects which have been *positively identified*.

Experience and judgment are required in the use of the best methods and equipment. Navigation by echo sounding is a comparatively new method, and only by familiarity with it, will navigators be able to determine their positions with the same assurance they would feel in the use of other methods. Experiment is necessary in order that the advantages and limitations may be appreciated. Chart 5101 A is compiled from modern surveys made by the most advanced methods but the contours necessarily have been drawn without anyone having actually seen the hidden landscape. Minor changes in depths not disclosed by any practical offshore survey certainly exist. Even if known, these small details could not be shown at the scale of the chart.



(2) See U.S.C. & G. Chart 5302.