DETERMINATION OF THE SLOPE OF THE SEA BOTTOM BY A SINGLE ACOUSTIC SOUNDING.

Communicated by

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Ingénieur Hydrographe Principal Pierre MARTI, who has already made so many important contributions to the subject of acoustic sounding, presented a very interesting paper at a meeting of the Paris *Académie des Sciences* on the 1st August, "*On the possibility of determining the slope of the sea bottom by means of a single acoustic sounding*". (Vide p. 528 of the Academy's proceedings).

He expressed himself as follows :-

"If the sound-wave emitted is powerful enough, the ship receives several consecutive echoes owing to the fact that each time it returns the sound-wave is reflected by the surface of the sea and goes back to the bottom to be reflected anew.

"To simplify matters, let us suppose that the immersion of the sound appliances and the distance apart of the emitter and the receiver are negligible.

"If the bottom is horizontal, it is clear that successive echoes are separated from one another by equal time-intervals, each one of which can be used to determine the depth.

"In the case of a declivity, on the other hand, the successive echoes do not follow one another at equal time-intervals, and a precise comparison of these intervals enables us to determine the slope of the sea bottom, at least when this slope is sufficient for an appreciable difference to exist between the echo sounding (shortest distance between ship and bottom) and the depth of water along the vertical.

"Further, the comparison furnishes the correction to be applied to the echo soundings to obtain the depth of water along the vertical. This fact, which has been verified experimentally, is an argument in favour of only depths of water measured along the vertical being inscıibed on charts.

"Let A be the sounding ship, at a distance $AB = P$ above a plane bottom inclined at an angle α to the horizontal (see Fig. 1, a vertical section passing through a line of greatest slope of the bottom).

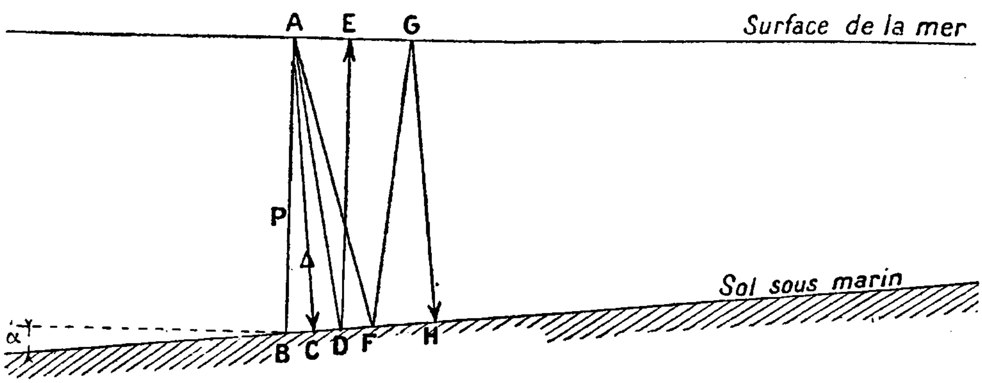

Fig 1

"The first echo is formed by the rays of sound propagated along the track ACA, perpendicular to the bottom at C; it enables us to determine the distance $AC = \Delta$, represented on the trace of the echo apparatus (Fig. 2) by the length $ac = d$.

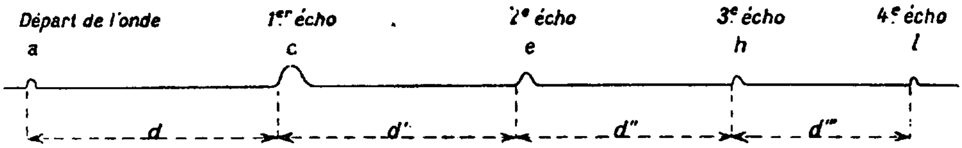

Fig. 2.

"The second echo is formed by the rays of sound propagated along the track $ADEDA$, perpendicular at E to the surface; it enables us to determine the sum of the distances $AD + DE$, represented on the trace by the length $ae = d + d'$.

"The third echo is formed by the rays of sound propagated along the track $AFGHGFA$, perpendicular to the bottom at H; it enables us to determine the sum of the distances $AF + FG + GH$, shown on the trace by the length $ah = d + d' + d''$.

"And so on (1).

"It is easy to show that if we designate by e the difference between the lengths d and d' on the diagram, we will get, on the one hand,

$$d - d' = e, \qquad d' - d'' = 2e, \qquad d'' - d''' = 3e, \ldots\ldots\ldots ;$$

on the other hand,

$$\tan \alpha = \sqrt{\frac{e}{d}} ;$$

and finally,

$$P = \Delta \left(1 + \frac{e}{2d}\right).$$

"And so, having obtained the record of two consecutive echoes on the sounding diagram, all that is required to obtain the vertical depth of water is :–

"1. to measure by the scale on the machine the two apparent depths sounded, Δ between the departure of the wave and the first echo and Δ' between the first and second echoes;

"2. to find the difference $S = \Delta - \Delta'$;

"3. to add $S/2$, the half of this quantity, to the first apparent depth Δ, the depth of water measured along the vertical being

$$P = \Delta + \frac{S}{2} \text{ .''}$$

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(1) The double journey travelled by the nth echo is equal to $2\,\Delta \dfrac{\sin n\alpha}{\sin \alpha}$. (P. V.).

Ingénieur Hydrographe MARTI has been kind enough also to communicate the results of experiments which he carried out this year off Toulon with a view to checking the accuracy of the above formulae. The verification proved very satisfactory.

The mean of the elements obtained from seven soundings at a well-determined spot,

where P measured by lead line = 355 metres
and α from the chart = 13°, actually gives

$\Delta = 344$ m., $\Delta' = 321$ m., $\Delta'' = 283$ m., $\Delta''' = 216$ m.

Having found teh difference, $\Delta - \Delta' = e = 23$ m, we get the following degree of agreement :-

From the formulae	From the measured elements
$\Delta' - \Delta'' = 2e = 46$ m.	$\Delta' - \Delta'' = 38$ m.
$\Delta'' - \Delta''' = 3e = 69$ m.	$\Delta'' - \Delta''' = 67$ m.
$P - \Delta = \frac{e}{2} = 11.5$ m.	$P - \Delta = 11$ m.
$\alpha = tan^{-1} \sqrt{\frac{23}{344}} = 14.5°$	$\alpha = 13°$

The facts thus give good confirmation of the theoretical study, and the following rules can be adopted :–

(1) The vertical depth below the emitter is equal to the echo distance marked by the first echo, augmented by half the difference between this distance and the lesser distance marked by the second echo ; *i. e.*

$$P = \Delta + \frac{\Delta - \Delta'}{2} ;$$

(2) The slope of the bottom is given by the formula

$$tan\, \alpha = \sqrt{\frac{\Delta - \Delta'}{2}} .$$

The application of these rules assumes that the ship is over a bottom that remains roughly plane from B to D at least (BD = about 82 m. in the case of the above experiment), which is not always the case. Over an irregular bottom they cannot be applied ; fortunately, however, one is seized of this fact by the disappearance of the successive echoes, which consequently makes any attempt to apply the rules impossible.

It was difficult off the coast of Provence, the submarine formation of which is particularly complex, to find regular areas of bottom of sufficient dimensions to cause the third and fourth echoes to appear. Even the second echo often disappears there at depths of 1000 to 1500 metres (547 to 820 fms.), at which the bottom is still definitely rough. It would doubtless reappear at depths of about 2000 metres (1094 fms.), where the bottom becomes more regular.

We include herewith the faithful reproduction of two records taken at different places over sloping bottoms. The three first echoes can be distinguished.

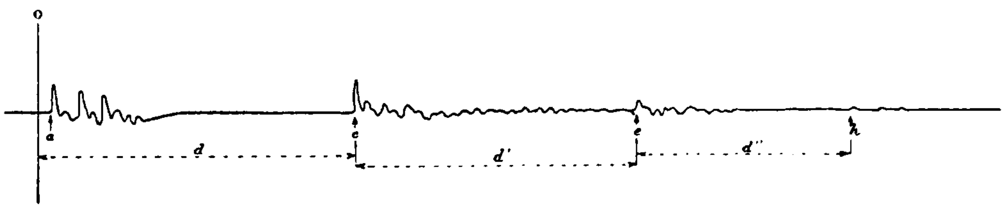

FIG. 3

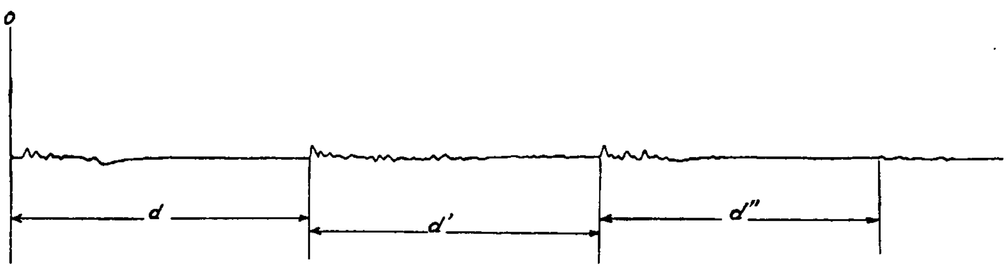

FIG. 4

The acoustic phenomenon used, produced by a rifle-shot fired roughly vertically at the surface, is actually composed of several waves following each other at intervals of about 3/100 of a second (say 4 millimetres on the records). This peculiarity does not in any way complicate the identification of the different echoes, provided the depth is sufficient; on the contrary it often enables weak echoes to be identified with greater certainty.

On the records shown here, the ordinate of departure precedes the registering of the departure of the wave by a certain quantity, because the receiver was situated at a certain distance from the point of emission of the waves and consequently only indicated the departure after a certain lag.

P. V.