A NOTE ON DEPTH WHEN THE BOTTOM IS SOFT MUD

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IHB Note. — The article printed below complies with the *Conclusions* of proposal P. 34 which figured in circular letter 19 of 1958 : *Questions left in abeyance by the 1957 International Hydrographic Conference.*

The Bureau invites States Members in their turn to make known their point of view on this question by means of articles which will be published in the Review.

Contrarily to the case where the bottom of a port consists of sand or rocks, it is rather difficult to determine the navigable depth when the bottom is of soft mud composed of small particles, especially when this is mixed with an organic substance forming coagulation. In this case, the boundary of the mud surface is not well demarcated, and particles can float, well mixed with water, in the upper layers of the sedimentation. In the very deep layers the mud sedimentation is compact and hard, while going upwards towards the surface the water content increases and the density of particles per unit of volume of the sediment decreases, and its dynamical features change appreciably, becoming similar to viscous liquid. This state may be referred to as "soft" mud. Dynamically speaking, the deeper, hard mud may be considered as being elastic, and the soft mud as being of a visco-elastic nature. Close to the boundary, the particles are almost free, mixed with the water and resembling a solution. In such circumstances the determination of the navigable depth needs particular consideration.

The problems are :

(1) What is the navigable depth in the case of a muddy bottom ?

(2) How to determine the depth by means of an appropriate, efficient method ?

The navigable depth must be defined from the standpoints of safety of navigation and economy. Thus, the depth should be taken as being as deep as possible, but not so that the ship's movement is hindered by mud, nor so that the bottom of the ship would be damaged by the pressure from the sediment. Further, we should also take into account the protection of sea connections.

This navigable depth is naturally connected with the physical parameters of the mud at that level, e.g., the density, water content, etc. Thus, if we could know, say, the critical density below which the ship's bottom would be damaged, it would be possible to define the navigable depth as

the level of that density. This investigation would be accomplished by means of some appropriate experiments on the motion of a ship, or experiments using a model to ascertain the damage caused by mud sediment.

The second problem is to find out how to determine the depth of that particular density of the mud, either through echo or lead sounding. It is a well known fact that echo sounding gives rather smaller values and lead sounding greater values when the sea bottom consists of this peculiar mud formed by very small particles or organic coagulation.

Since there exist some ports with these peculiar bottom features in the islands of Japan, the Hydrographic Office has been interested in these problems. The first preliminary investigation was carried out in order to solve the second problem. Though the investigation is still in progress, we shall give here, as an illustration, some of the preliminary results obtained from investigation at a certain port. In this case the demarcation between the "hard" or compact mud, which was rather elastic, and the "soft" mud was comparatively clear, and there existed a region of concentrated mixture of mud with water resembling a solution (fig. 1). The depth was determined by lead and echo soundings, using sound waves of frequencies 14, 50, 75 or 100 kc/s. As naturally expected, the higher frequencies gave lower values, and the depths obtained by lead sounding were much greater than any depth determined by echo sounding. Assuming that the critical depth coincides with the demarcation between the soft and the compact mud, sounding by 50-kc/s waves seems to give this depth. Figure 1 shows the vertical distribution of the specific weight of the mud ascertained by means of core sampling as well as the various depths obtained by lead and echo sounding (left hand side of the figure). The probable errors in the values obtained by echo sounding are of the order of $\pm$ 5 cm, therefore the differences in measured depths due to the frequency difference can be regarded as significant.

This preliminary investigation reveals the possibility of obtaining the critical depth by choosing a suitable wavelength. Also, we have tried to determine the depth by lead sounding. For this purpose we devised a special lead with a plate beneath it (marked as A in figure 1), which gave correctly the critical depth. Since the depth obtained by echo sounding depends not only on the frequency but also on the intensity of the transmitted wave, we are now planning to find out the correlations between the density of the mud and the depths obtained with various frequencies and intensities. It seems to be quite important to take the intensity into account for the purpose of determining the critical depth.

In conclusion, it seems necessary to solve the two problems mentioned above : for the first problem, it is important to study what parameters (density, water content, hardness, etc.) will be best for the safety of navigation; and for the second problem, it is indispensable to investigate the possibility of obtaining any level in the mud sediment that is specified by a certain value of some physical parameter like density. Thus, it is likely to be necessary in the future to specify the definite frequencies *and* intensities employed for echo sounding, or to characterize shape, dimension

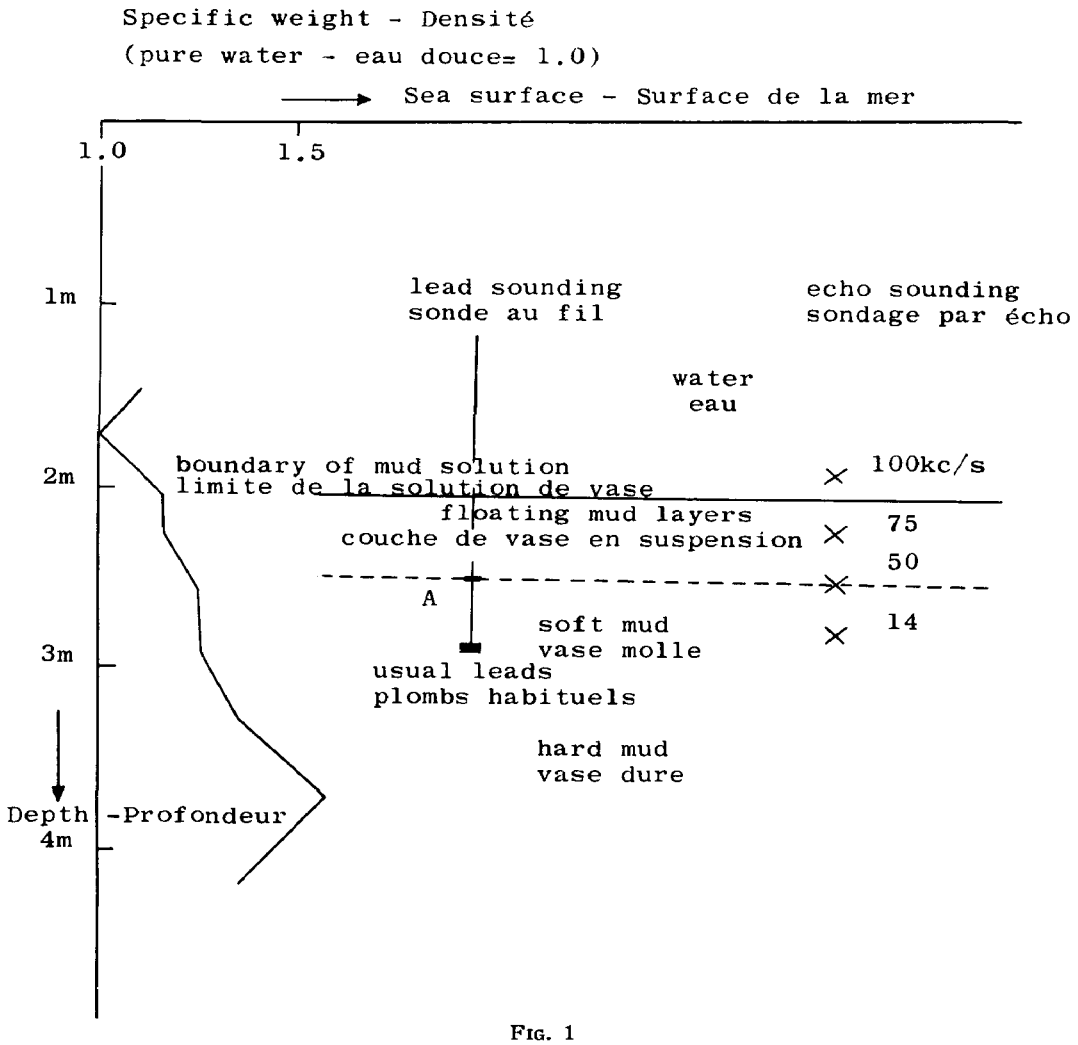

FIG. 1

and weight of the lead, when a hydrographer measures the depth of water in areas where the bottom consists of soft mud of very fine grain or containing coagulating organic substance.

Until a definite method for determining the navigable depth is established, the following tentative ways are proposed :

(1) to employ sonic waves of frequencies around 50-70 kc/s;

(2) to use a lead with a plate beneath it such that the resultant basic pressure is of the order of 0.01 kg/cm^2.

However, it is difficult to determine the depth even by these methods; therefore, to ensure the safety of navigation, it would be better at the present stage to recommend that all the depths to be shown on nautical charts should be measured with echo sounders with comparatively high frequencies (say 100 kc/s) to give the upper limit of the mud solution, and that the notice "Floating mud exists here" should be given in the area concerned.