

CORRECTION TO THE ECHO-DEPTH FOR THE DENSITY OF WATER IN THE PACIFIC OCEAN

by

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The general principle of the sonic-sounding consists of evaluating the depth from the velocity of sound and the time-interval taken in the vertical travelling of the sound signal between the surface and bottom of the sea. It is, however, very inconvenient to calculate the depth according to the said principle. In the usual case, therefore, the apparatus is so designed that the depth can be read directly from it. Thus the dial or linear scale of the apparatus is graduated in depth instead of time. A particular value is assumed for the mean vertical velocity of sound, and the indicator (lighted spot or the like) translates with a constant speed over the graduation for depth.

For the assumed velocity of sound in sounding, a value between 1450 and 1500 m/sec. is adopted in the usual apparatus, and this is a constant of the instrument. But the mean vertical velocity of sound in sea-water, on the other hand, is a function of the physical conditions of the waters and changes from place to place. Therefore, the depth read off from the apparatus should be corrected for the conditions of the waters.

The mean vertical velocity at a position can either be determined directly or it can be calculated on theoretical grounds from certain properties of the waters in the vertical column at the position which are determined from their physical conditions. In the direct determination of the velocity by means of the comparison of sonic-sounding with wire-sounding, the drift of the ship introduces uncertainty into the result. Hence in all of the latter investigations, the velocities are calculated indirectly from data of the oceanographical observations.

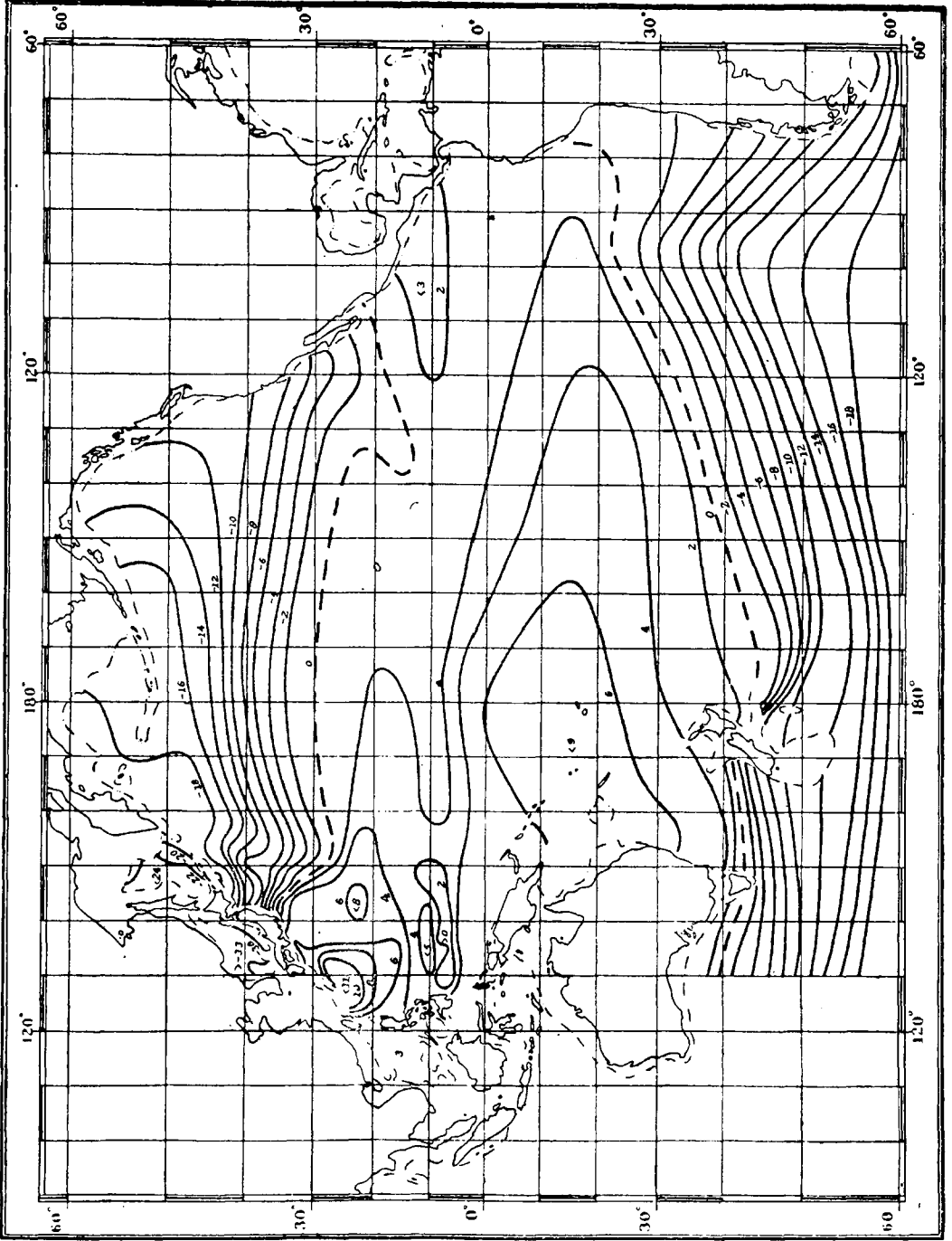
Dr. A. SCHUMACHER has prepared a table of the velocity of sound for sounding to correct the echo-depths in the Atlantic Ocean and in the eastern part of the Mediterranean. (1) The table gives the velocities for the designated depths from 100 m. to about 5000 m. at each of the four typical stations in the Atlantic and for those from 500 to 2000 m. in the Mediterranean.

The British Admiralty has published a velocity table for use in the sonic-sounding for the seas throughout the world. (2) In this table, the whole world sea is divided into 24 regions and the velocities are given for a typical oceanographic station in each region at the intervals of 200 m. of depth up to 4000 m. in general. The designated depths are extended up to 5600 m. for a few regions. For the calculation of these velocities, the tables of the velocities of sound for various physical conditions of water have been specially prepared, and they are given in the same pamphlet. In this case, however, the horizontal distribution of the velocity is discontinuous, and the correction for the echo-depth exceeding 4000 m., for most of the regions, must be made by extrapolating the velocity; besides it is very tedious to calculate the correction from the mean vertical velocity.

Captain S. KISINDO of the Hydrographic Department of the Imperial Japanese Navy, has calculated the velocities of sound from the results of the recent oceanographical ob-

(1) A. SCHUMACHER: "*Hydrographische Bemerkungen und Hilfsmittel zur akustischen Tiefenmessung*". *Ann. d. Hydro.*, (1924), 87-95.

(2) HYDRO. DEP., ADMIRALTY: "*Tables of the Velocity of Sound in Pure Water and in Sea Water for Use in Echo-sounding and Sound-ranging*". *H.D.* (1924), 283.



*Curves of equal values of the local correction for echo depths above 1000 m.
 Courbes d'égal valeurs de la correction locale pour les profondeurs d'écho supérieures à 1.000 m.*

servations carried out by the Department ⁽¹⁾. The calculation of the velocities was referred to the velocity tables by N.H. Heck and J.H. Service, U.S. Coast and Geodetic Survey. ⁽²⁾ He divided the northwestern part of the Pacific Ocean by the parallels of latitude into three regions, 0°-33° N-38° N and 38° N, and has given average velocities for sounding for each of these regions at the intervals of 200 m. of depth up to 8600 m.

Both the above tables of the velocity of sound are for use in the sonic-sounding (the mean vertical velocity). For the correction of the echo depth by such a table, therefore, some arithmetical computation with a calculating machine or a logarithmic table is necessary, since the depth usually has four figures in metres. Sounding by the sonic method can be made in a very short time compared with that by wire, and a great number of sonic soundings may be made in a short period of survey. Accordingly, if we rely on the above method of correction, the calculation of the sonic soundings in a survey is a very laborious and time consuming work.

For the purpose of simplifying the correction of the echo depth, N.H. Heck and J.H. Service have calculated the correction factors which are applicable to the echo depths in the Pacific Ocean. ⁽³⁾ The correction factor is the ratio of the mean vertical velocity of sound and a standard one. Adopting a value 1463 m/sec. for the basic (standard) velocity, they have given the correction factors for the depths from 600 to 5400 fms. at the intervals of 200 fms. for the areas between and along the designated parallels of atitude. In the calculation of these factors, the mean vertical velocities were computed by referring to the velocity tables by the authors themselves.

The correction to the echo depth for the density of water varies not only with latitude but with longitude. In order to correct the echo depths obtained by the "Carnegie" expedition during the period 1928-29, C.C. ENNIS has prepared a table of the regional correction factors applicable to the 14 regions in the Pacific Ocean. ⁽⁴⁾ The factors are deduced from the mean vertical velocities which are calculated from the results of the oceanographic observations carried out by the "Carnegie" herself, by referring to the velocity tables of the British Admiralty and the basic velocity of 1450 m/sec. The additive correction to an echo depth based on the assumed velocity 1450 m/sec. may be obtained by multiplying the correction factor by the depth. The Ennis table made some progress in accuracy of the tabular values compared with that by Heck and Service. But it is the same with the previous tables of this kind that his table gives a constant correction to a particular area, and, moreover, the partitions of the areas are not completed for some part of the Pacific.

Though the correction of the echo depth by the correction factor is simpler than that made by using the mean vertical velocity, yet it needs a multiplication which must be executed with a slide rule.

In the present paper, the author investigated the subject fundamentally, searching for a simpler method.

In accordance with oceanographical observations effected in the Pacific Ocean, the author has drawn up tables giving vertical velocities for certain depths. He has also utilised the velocity tables which he published in the Japanese Journal of Astronomy and Geophysics, Vol. XVI, 1-17, and in the Hydrographic Review, Vol. XVI, N° 2, page 128 and seq. He

(1) S. KISINDO: "On the Correction to Depths obtained by Echo-Sounding". *Hydro. Bulletin*, 14 (1935), 469-471.

(2) H.N. HECK AND JERRY H. SERVICE: "Velocity of Sound in Sea Water". *U.S. Coast and Geod. Survey, Special Publication* 108 (1924).

(3) N.H. HECK AND J.H. SERVICE: "Correct Values of the Velocity of Sound for Echo-sounding in the Pacific". *Proceedings of the Third Pan-Pacific Science Congress, Tokyo*, I (1926) 202-204.

(4) C.C. ENNIS: "Use of Regional Constant Correction Factors for Reduction of Echo-soundings". *Proceedings of the Fifth Pan-Pacific Science Congress, 1933, Toronto, Canada*, (1933) 2075-2082.

has deduced therefrom the following table, which gives for depths per 100 metres down to 10900 metres, the mean corrections to be applied to echo soundings in the Pacific Ocean, the results of which have been calculated on the basis of 1500 m. per second :

Echo-Depth (m.)	0	100	200	300	400	500	600	700	800	900
0	0	1	2	2	2	1	0	- 1	- 3	- 4
1000	- 5	- 7	- 8	- 9	- 10	- 11	- 13	- 14	- 14	- 15
2000	- 16	- 16	- 16	- 16	- 16	- 16	- 16	- 16	- 16	- 16
3000	- 15	- 15	- 14	- 13	- 12	- 11	- 10	- 9	- 8	- 6
4000	- 5	- 3	- 1	1	3	5	7	10	12	15
5000	18	21	24	27	31	34	38	41	45	49
6000	53	58	62	67	71	76	81	86	91	96
7000	101	106	112	117	123	129	135	141	148	155
8000	161	168	175	183	190	198	206	214	222	230
9000	239	247	256	265	274	283	292	301	310	319
10000	329	338	348	358	367	377	387	397	407	417

To this mean correction must be added a supplementary correction according to the spot in the Pacific Ocean where the sounding takes place. The author has drawn up 5 charts of the Pacific Ocean for depths of 200, 400, 600, 800, 1000 metres and above, on each of which are drawn the curves of supplementary corrections. This avoids any discontinuity on the border line of regions of similar corrections. Below 1000 metres, the local supplementary correction is practically independent of the depth. We reproduce herewith the last chart only, which we consider the most important, and refer the reader to the author's interesting article in which the method followed and data employed are fully explained. A reduction table is also included, by means of which soundings based on velocities between 1490 m. and 1510 m., can be converted into the figures which would have been obtained on the basis of the standard velocity of 1500 m.

