ECHO SOUNDING.

Lecture by DOCTOR H. MAURER read on 12th April, 1929, by CAPTAIN CLAUSSEN before the Delegates to the First Supplementary International Hydrographic Conference

(*Translated by G. S. S.*)

The German vessel *Meteor* crossed the Atlantic Ocean fourteen times in an East and West direction and twice in a North and South direction. During this cruise she took 67,000 soundings at 34,000 stations. The elaboration of these brought forward the question as to how they should be treated.

Sonic-soundings give the interval of propagation of a sound which, being produced near the ship, travels to the bottom and returns to the ship. Half of this interval multiplied by the velocity of sound gives the depth (echo-distance) subject to two hypotheses, *viz* :—

(1) that the direct distance between the points of production and reception of the sound be negligible as compared with the depth and
(2) that the point from which the echo is returned (echo-point) lies vertically below the vessel.

If the first hypothesis be not fulfilled it is easy to make the necessary corrections. As for the second hypothesis, there are two different cases :—

Usually the sound is emitted equally in all directions and thus the echo-point may be to one side of the vessel. This would give an oblique echo-distance which is less than the depth. Indeed, the *Meteor* found the sonic soundings 1.6 % smaller than the wire soundings at 310 stations where both methods were used and where the velocity of sound was known accurately.

An attempt was made to eliminate this error in the sonic soundings by calculation. It was thought that it might be possible to determine the slope of the bottom from two neighbouring soundings by assuming that the bottom was flat and sloped in the direction of the course of the ship. This was obviously a false idea. Any one sounding gives but the surface of a sphere as the geometrical locus of the echo-point, the centre of the sphere being the ship and its radius being the echo-distance. Nothing further can be deduced from two neighbouring soundings than that no echo-point can lie within these echo-distance spheres, and this gives but a minimum for the depth. In the experience of the *Meteor* the depths were frequently much greater than the echo-distances. Out of 245 comparisons of depths of over 2,000 metres (1,094 fathoms) no less than 56 cases gave a difference exceeding 100 metres (54 fms.) and the maximum difference amounted to 650 metre (355 fms.) when the wire gave 4,840 metres (2,647 fms.) depth.

The other case is that of a directed emission of ultra-sonic waves by Prof. LANGEVIN'S method. In this case the echo-point cannot be far out of the vertical from the vessel unless, on account of an inclination of the ship, the narrow cone of sound emitted be much inclined. If the cone be very narrow or the depth be sufficiently great, it is possible that a slight list of the ship or slope of the bottom will be sufficient to make the echo imperceptible at the point where the receiver is located. From this it is probable that the observed echo-distance may always be assured to be equal to the depth. It would be very interesting to compare directed and non-directed echo-soundings with wire soundings taken all at the same point over a mountainous and sloping bottom (*e. g.* over the steep-sided bank near Cape Ortegal, see *Hydrographic Bulletin*, Monaco, N° II, 1929, page 48).

To calculate the true echo-distance, the mean velocity of sound between the ship and the bottom must be known. The fact that velocity of sound varies according to the temperature, salinity and pressure, is well known. The most accurate and convenient tables are those which were published by the Hydrographic Department of the British Admiralty in 1927, under the number H. D. 282 and which are entitled: "Tables of the Velocity of Sound in Pure Water and Sea-Water for use in Echo-Sounding and Sound-Ranging". The velocity of sound varies, within the local layers, from 1,400 metres (765 fathoms) per second, in cold fresh water, to 1,620 metres (890 fathoms) per second, at the bottom in the greatest depth in the world. By means of the British tables it is possible to calculate the mean velocity in any column of water between the surface and the bottom at any place where the run of the temperature and salinity in the column is known, which is the case in but a few isolated spots.

However, such data may be taken to be the same over fairly large areas for which a constant table would give the mean velocities as functions of the depths. On this principle Publication H. D. 282 gives tables for 23 areas, the limits of which are shown on a chart of the world. The *Meteor* took temperatures and salinity in all layers at 310 stations in 6 of the 23 areas of this chart. The mean velocities deduced from these observations agree fairly well with the British tables in most cases. But the northern limit of the Equatorial Area, N° 10, is placed somewhat too far south and in the cold water areas the velocity of sound is less than is shown in Table N° 10. Amongst the soundings taken at the *Meteor*'s 310 stations, only 8 differ by more than 20 metres (11 fms.) from the true depths.

Thus, in the Atlantic areas covered by the *Meteor* the velocity of sound may be obtained sufficiently accurately from the tables in H. D. 282. If this be the case also for the other and less explored seas, the crude echo-distances can very well be converted into true distances by means of these tables. These true distances are equal to the depths at such places where the point on the bottom which is vertically under the ship is also the nearest point to her. This, unfortunately, is not so in the cases which are important in navigation. For navigating, the depth is of value at such places only where it can be used for fixing position and these are not in areas where the depths are uniform but in those where there are significant changes in the depth.

If, in such places, the charts gave the true depths, it would be impossible for the navigator to compare such figures with the echo-distances obtained with his sonic-sounder. It would be more practical if the seaman were given, on the chart, the echo-distance which his sounder will give him at the same place. These crude echo-distances should be given in figures which differ from those which indicate depths, but echo-distances of less than 200 metres (109 fms.) should be converted into depths and be shown on the charts in the type of figure used for depths.

Thus, on German charts, the results of sonic-sounding (over 200 metres) are entered as echo-distances, all of which are deduced from one constant velocity on which all German echo-sounding machines are based. This velocity is 1,490 metres (815 fathoms) per sec. With reference to the *Meteor*'s soundings, 7,000 sounding stations have already been inserted on the charts and the average horizontal distance between two such stations is 10 sea-miles.

It would not be convenient to enter more soundings.

The crude echo-distances calculated on a single constant velocity are the most useful, not only for the seaman, for whose use the chart is primarily provided, but also for science, for thus the velocity used for deducing the figures is known immediately and with certainty and it is possible to correct them according to the most recent data available. Results of sonic-sounding which are given in the form of depths, without any indication whatsoever of the velocity on which they are based and possibly of attempts made to rectify oblique echo-distances, are practically useless to accurate science. In fact it may be said that an oblique echo-distance has never been converted into a depth, although the U. S. Coast and Geodetic Survey has published a diagram for such conversion based, unfortunately, on the false idea mentioned earlier.

It would appear, also, that crude echo-distances have never been converted into true distances; it will be done in the report of the *Meteor*'s observations, but the crude echo-distances only are inserted on the chart. With reference to the deepest spot in the world, the "Emden-Deep", on the chart the crude distance of 10,430 metres (5,703 fathoms) has been inserted and the true distance of 10,790 metres (5,900 fathoms) has been announced, this latter being based on the local velocity which is 1,542 metres (843 fathoms) per sec. The fine observations made by the Americans, the profile from Newport-News to Gibraltar determined by the U. S. S. *Stewart* in June 1922 and the bathymetric chart covering nearly 100,000 square kilometres (33,000 square sea-miles) produced by the U. S. Ships *Corry* and *Hull* between San Francisco and Cape Descanso in November 1922, were both based on a constant velocity. This was 800 fathoms (1,463 meters) per sec. and is far below the true velocity. According to the British tables the depths of the *Stewart*'s profile should be increased by from 2.5 to 3.9 %, the greatest depth recorded being 3,326 fathoms (6,083 metres) instead of 3,200 fathoms (5,852 metres), and the very full details of the *Corry-Hull* bathymetric chart must be extensively corrected in several places; for example, the 2,000 fathom line, as shown, passes through depths which should really be 1,960 fathoms. This change of 40 fathoms in depth represents, in some places, a horizontal displacement of the contour of 10 sea-miles, which is very considerable for fixing the position of a ship.

If the *Meteor's* soundings were calculated on the U. S. basis of 800 fathoms, 131 of the 310 stations, namely 42 %, would give echo-distances too short by over 100 metres (54 fms.). The distance at the deepest station would be 5,880 metres (3,215 fathoms) instead of 6,100 metres (3,335 fms.) and the echo-distances for the deepest spot in the South Atlantic Ocean would be 7,960 metres (4,353 fathoms) instead of 8,255 metres (4,516 fathoms). A depth of 10,240 metres (5,600 fathoms) would have been proposed for the "Emden-Deep" instead of the true echo-distance of 10,790 metres (5,900 fathoms).

As may be seen from the above, the figures used on charts for echo-distances must be different from those used for depths obtained with the sounding-line and, furthermore, it is necessary to state the sound-velocity on which the echo figures are based. An international agreement of this subject is desirable, and there are three possible ways in which this may be attained.

A single standard velocity may be selected for use at all times and everywhere. This is the simplest way and excludes all uncertainty and is, besides, the most practical for navigational purposes, since all the echo-soundings would be based on a scale of constant velocity of sound. Instead of the value 1,490 metres per sec. used by Germany, that proposed by Japan, namely the round number of 1,500 metres per sec., may just as well be adopted. The mean of all the values contained in N^os 3 to 20 of the British tables (see attached table), for depths between 200 and 4,000 metres, omitting the two extremely warm seas (N^os 1 and 2) and the three very cold seas (N^os 21, 22 and 23), is 1,496 metres per sec. The British Admiralty gear employs a scale based on a sound velocity of 1,496,5 metres (4,910 feet) per sec.

The second method consists in adopting a *Standard Scale*, which would be used everywhere, the values in which would vary according to the depth. I have calculated a Standard Scale by taking the means, at all depths, of the figures of the British tables for Areas N^os 3 to 20 (See Mean Scale column in the annexed table.) The next columns show the maximum differences between the local sound-velocities and this Mean Scale as well as the differences from the Average Mean Value: — 1,496 metres per sec. It will be seen that the variations in sound velocity in different areas at equal depths are very great; the greatest differences from the Mean Scale are even larger than the differences from the Average Mean Value; a Standard Scale cannot, therefore, be recommended.*

(*) *Note*.— Even in quite a small area such a scale may show very great differences. This can be shown, for example, by comparing the scale proposed by MURAMOTO for Japanese waters with the British scales (H. D. 282) for the northern extremity of HONDO Island (N° 21) and for the southern extremity of the same island (N° 16).

DEPTH Metres	*VELOCITY OF SOUND in M/SEC.* TABLE		
	MURAMOTO	N° 21	N° 16
200	1507	1461	1515
1000	1495	1469	1493
2000	1489	1476	1490
3000	1493	1484	1494

The third way would be to have a *large number of scales for different areas,* such as, for instance, British Publication H. D. 282. By this means more accurate echo-distances would indubitably be obtained than with a single sound-velocity for all areas. But this would prove very inconvenient for the practical needs of the seaman whose echo-sounding machines have scales based on a constant sound velocity. Besides it would lead to uncertainty at the boundaries of neighbouring areas the tables for which differ largely (for instance, between areas N^os^ 3 and 10, or N^os^ 11 and 20). Anyway the actual goal aimed at, which is to transform echo-distances into depths, cannot be reached owing to the fact that it is impossible to take the slope and unevenness of the sea bottom into account.

These are the reasons for the German proposals. The principal objections to them which have been raised are the following :—

> "Fixing the position at sea is so uncertain that, when a given echo-distance is obtained, it cannot be said definitely that it is at the same spot as that at which the original observer had taken his echo-distance".

Against this assertion it may be stated that, shortly, in certain areas, lines of equal echo-distance will be drawn on charts. These may be used as position lines which are of the order of accuracy of that of the original observer's work. A seaman will have recourse to this expedient when his own determination of position is unsatisfactory and thus he will attain the same degree of accuracy as was attained in the original observations made under more favourable circumstances; naturally the Hydrographic Offices must check the accuracy of the fix at any observation the result of which is to be inserted on a chart.

Such new method of fixing position will prove advantageous, not only on the continental shelf where, owing to the moderate depths, an error in velocity will have but little effect, but also on the high seas in such places where characteristic depth variations occur, such as, for instance, on the ridge which extends throughout the Atlantic Ocean from North to South.

According to another objection the use of different types of figures for soundings is to be avoided and it is stated that it should be left to each Hydrographic Office to correct echo-soundings as they may consider suitable. In this connection, it should be remembered that the number of soundings by wire will very shortly be much less than the number of echo-soundings, and that there is no great difficulty in using two different types of figures, for instance, upright and sloping figures. The difference between echo-distance and depth may be considerable, especially in those cases where erroneous velocities of sound have been adopted and of which, furthermore, no information is given. Echo-sounding is a new method and it would perhaps be imprudent if the subsequent correction of earlier echo-soundings were to be rendered impossible. This will happen, however, if it be impossible to recognise which figures represent echo-soundings and the velocity of sound which was employed In any case, it would be wiser to put up with the slight inconvenience which results from the use of a special type of figures for non-directed echo-soundings.

Velocity of sound in areas

Depth m.	AREA 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
	1.400 m +														
200	141	112	127	127	114	110	89	118	136	125	122	122	131	107	116
400	140	111	123	116	110	108	90	108	125	109	113	111	115	104	104
600	139	112	119	111	106	108	90	103	115	101	105	105	106	103	98
800	140	113	114	110	103	107	90	99	108	96	100	101	100	101	94
1000	141	114	111	108	101	105	89	97	103	92	95	99	97	98	92
1200	142	115	108	108	100	104	89	96	100	91	93	98	95	96	90
1400	144	117	106	108	100	102	89	94	98	90	92	97	93	94	90
1600	145	118	106	107	99	100	89	94	96	90	91	96	93	93	89
1800	147	120	105	107	99	100	89	94	96	90	91	96	92	93	89
2000	148	122	105	107	99	99	91	94	95	91	91	95	92	93	89
2200		123	105	107	99	99	92	94	95	91	92	96	92	93	90
2400		124	106	107	100	99	93	95	95	92	92	96	92	93	90
2600		127	106	107	100	100	94	96	96	93	93	96	93	94	91
2800		129	106	107	101	100	95	96	97	94	94	96	94	94	92
3000		131	107	106	102	101	96	97	97	95	95	97	95	95	93
3200			107	107	103	102	97	98	98	96	96	98	96	96	94
3400			108	107	104	103	97	99	99	97	97	99	97	97	95
3600			109	108	105	104	99	100	100	98	98	100	98	98	97
3800			110	109	106	105	100	101	101	99	100	101	99	99	98
4000			111	110	107	106	102	103	102	100	101	102	101	100	99

1) Red Sea.............. 22° N, 38° E.
2) Mediterranean....... 40° N, 11° E.
3) Sargasso Sea .... 24° N, 53° W.
4) Arabian Sea.......... 9° N, 54° E.
5) African Aera.........
6) Gulf Stream.......... 40° N, 40°W

7) N. E. Atlantic Current...................... 54° N, 23° W.
8) Central Indian Ocean....................... 9° S, 65° E.
9) Fiji Islands Area............................ 10° S, 180°.
10) Equatorial Atlantic Ocean .... 5° S, 32° W.
11) Central South Atlantic Ocean............ 20° S, 20° E.
12) Equatorial counter-current, Indian ocean 5° S, 51° E.

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AREA								Mean Scale.	MAXIMUM DIFFERENCE IN M.							
									from Mean Scale.				*from Average. Mean - 1496.*			
16	17	18	19	20	21	22	23	3 - 20	3 - 20		1 - 23		3 - 20		1 - 23	
								m.	+	—	+	—	+	—	+	—
115	78	94	69	80	61	73	43	1510,0	*26*	*41*	31	*67*	*40*	*27*	45	*53*
104	76	89	69	78	63	71	48	1502,9	22	34	37	55	29	27	44	48
98	76	85	70	75	65	70	51	1498,6	20	29	40	48	23	26	43	45
95	76	83	71	74	67	70	54	1496,9	17	26	43	43	18	25	44	42
93	76	82	72	74	69	67	56	1493,6	17	22	47	38	15	24	45	40
91	78	82	73	74	70	67	58	1491,4	15	20	51	35	12	23	46	38
90	79	82	74	75	72	67	60	1489,8	18	16	54	30	12	22	48	36
90	79	82	75	76	73	67	63	1488,6	18	14	56	26	11	21	49	33
90	81	83	77	78	75	68	65	1488,9	18	12	58	24	11	19	51	31
90	82	83	78	79	76	69	66	1490,2	17	12	*58*	*24*	11	18	*52*	*30*
91	84	84	79	81	78	70	68	1491,3	16	12	32	23	11	17	27	28
91	85	85	81	82	79	71	69	1492,4	15	9	32	23	11	15	28	27
92	86	86	82	84	81	72	71	1493,8	13	12	33	23	11	14	31	25
93	88	87	84	85	82	74	72	1494,6	12	11	34	23	11	12	33	24
94	89	89	85	87	84	76	74	1495,6	11	11	*35*	*22*	11	11	*35*	*22*
95	91	90	87	88			76	1496,6	10	10	10	21	11	9	11	20
96	92	91	88	90			77	1497,6	10	10	10	21	12	8	12	19
97	94	92	90	91			79	1498,8	10	11	10	20	13	6	13	17
99	95	94	91	92			80	1499,9	10	9	10	20	14	5	14	16
100	97	95	93	94			82	1501,3	10	8	10	19	15	3	15	14

Average Mean 1496

13) Pacific Ocean .... 5° N, 180°.

14) South Indian Ocean .... 33° S, 83° E.

15) Caroline Islands Area.......... 10° N, 180°.

16) Pacific Ocean .... 10° N, 120° W.

17) Cold waters of North America. 42° N, 64° W.

18) Pacific Ocean .... 40° N, 180°.

19) Pacific Ocean .... 50° N, 180°.

20) Easterly Current .... 40° S, 44° W.

21) Bering Sea .... 55° N, 170° W.

22) Norvegian Sea .... 69° N, 5° E.

23) Antarctic Ocean .... 54° S, 31° W.

As for directed echo-soundings, it would be best to convert them, as best possible, into depths, and to enter them on the chart in figures of the type used for ordinary soundings.

Naturally each nation can carry on as it thinks best, but, at the very least, it should make non-directed sonic-soundings recognisable and should publish the rules used for their calculation in order that the velocity applied in each case may be known without having to make special enquiry.

Finally I will recapitulate the German proposals.

The echo-distances (over 200 metres and obtained by non-directed sonic methods) should all be calculated on the same standard velocity and then be inserted on the charts.

The standard velocity suggested is 1,490 metres (815 fathoms) per sec. or 1,500 metres (820 fathoms) per sec. These echo-distances should be shown in figures of a type which differs from that used for depths.

Non-directed echo-soundings of less than 200 metres, and all directed echo-soundings, should be converted, as best possible, into depths and be shown on the charts in the type of figure used for depths.

Should non-directed echo-soundings which, for some reason, have been converted on the basis of some velocity other than the standard velocity be published, the velocity employed should be published at the same time.