ECHO SOUNDING.

BY THE PRESIDENT OF THE DIRECTING COMMITTEE.

It will be remembered that a brief Report by the Hydrographer of the U. S. Navy on Echo Sounding was published in pages 71 & 72 of the "Hydrographic Review", March 1923. Since that time several reports on this important subject have been received from a variety of sources which will now be referred to.

(1). In connection with marine invention of most descriptions it is distinctly noticeable that the majority of Nations are treating such matters as confidential; this, no doubt, is the result of the War in which it was obviously essential to keep all new inventions as secret as possible. It is thought that an additional reason for not publishing such information may be due to aversion to the publication of imperfect data; the necessity of safeguarding the commercial rights of these novel apparatus may also be a reason for with-holding information concerning their details; this secrecy appears to be especially noticeable in regard to self-recording methods for use in comparatively shoal depths.

(2). In January 1923 the Director of the French Hydrographic Service stated that a line of Echo Soundings had been run across the Mediterranean, in April 1922, from Marseilles to Philippeville on the Algerian coast; the soundings commenced about 30 miles from Marseilles and terminated in the shoal water off Philippeville; they were obtained on a line which had not been generally sounded over before but, in the few positions where previous soundings had been taken, the Echo Soundings were in fairly close agreement; the majority of soundings were in the neighbourhood of 2,800 metres in depth, in no case was 3,000 metres exceeded; this work was carried out in connection with a projected submarine cable.

The following remarks are extracted from the French report:—

(Translation from the French text).

"Professor LANGEVIN's method of soundings at sea by Hertzian waves is but one of the new systems of sounding by sound-waves, the development of which my Office is watching closely.

"In spite of the results obtained by means of the LANGEVIN apparatus we are of the opinion that this system is too complicated to be taken into general use. Besides, we are certain that we shall succeed in sounding by means of much more simple acoustic arrangements, having discovered that a light blow with a hammer on the hull of a ship transmits to the water sufficient sonorous energy to make the echo from the bottom of the sea audible in depths of 200 m. (110 fms). The Scientific Research Department of the French Navy is now engaged in the perfection of a sounding apparatus based on this principle.

"In greater depths, for the last year, we have been using an acoustic sounding instrument devised by an Officer in my Service, Monsieur MARTI, which employs the sound made by detonation. In depths up to 1,000 m. (545 fms.) an ordinary rifle, suitably shortened, is used and is fired straight into the water. Beyond this depth a small gun of 37 m/m. bore (3 pr.) firing blank, also straight into the water, is employed. This apparatus was used for the first time to obtain a section-profile from Marseilles to Philippeville. We are now using this apparatus in one of our surveys on the coasts of Algeria; it is easy to use and gives satisfactory results. We recommend it for the exploration of the depths of the oceans which, up to now, has been a difficult and lengthy matter by means of sounding by wire.

"On the other hand, I know that an American Engineer, Dr. BRAYE, has likewise developed an acoustic sounding apparatus which, according to information received, utilises a submarine sound instrument of the Fessenden type. It appears that the trials of this apparatus have been satisfactory; an American vessel seems to have crossed the Atlantic in July 1922 taking soundings at close intervals, even as we did between Marseilles and Philippeville.

"Finally, a German Engineer, Dr. BEHM, has devised an apparatus for sounding by detonation in ordinary depths. It is called the "*Anschütz-Echolot*"; we do not know whether it gives satisfactory results".

(3). In February 1923 the Italian Hydrographer requested the Bureau to supply him with a variety of information, including the fullest information on the subject of Echo Sounding, and in accordance with this request the Bureau forwarded all available material.

A considerable amount of correspondence resulted from the above, and the Italian Hydrographer called the attention of the Bureau to various matters in this connection; amongst others, he remarked on the use of small bombs, specially manufactured for the purpose, which sink with a uniform and known speed, the explosion taking place on touching the bottom; these bombs can be used from a ship moving at a moderate speed; the cost is small, but not yet sufficiently

so to make this method of sounding generally available. It is evidently more applicable to ordinary navigation than to surveying. Full particulars of this apparatus will be found in "*Die Umschau*", N° 28 of the 26th year of its publication.

(4). The Italian Hydrographer also called the attention of the Bureau to an American publication by Mr. W. H. HOBBES, entitled "Sounding the Depths of the Ocean", which had appeared in the "*Michigan Technic*", vol. 36, N° 2 of January 1923; however, this article does not give any novel information of special importance.

(5). During the correspondence between the Italian Hydrographer and the Bureau, the method of obtaining soundings by the use of a manometer had been discussed and the following remarks of the Italian Hydrographer on this subject are of interest : —

(Translation from the Italian text).

"This Office is aware of the difficulties formerly experienced in taking soundings by indications of a manometer. These difficulties may be condensed into the fact that the inflow of water into the tube which is dragging along the bottom is not constant, for this reason it is difficult to separate the increase of the pressure of the air in the tube from that caused by the vertical column of water which flows into the tube and assists to form the pressure at the end thereof.

"It is known that the difficulty has been overcome already by the German Navy by introducing special apparatus consisting of a capillary tube which has, near its open end, an air reservoir; specimens of this apparatus were found in the ships which belonged formerly to that Navy, and one of them is in possession of this Office at the present time.

"Further study of the problem has suggested another simple device, a closed pear at the end of the capillary tube, which will be tried shortly; notice of the result will be given immediately".

(6). THE BEHM DEPTH INDICATOR. — A description of this instrument is to be found in the "*Annalen der Hydrographie*", (N° 11 of 1922, vol. 50) published by the "Deutsche Seewarte".

The "*Nautical Magazine*" (British) of March 1923, also published a brief account of the instrument as follow : —

"In a popular lecture delivered recently by Mr. J. F. SIRKS, Engineer, under the auspices of the Nautical Institute and Museum at Rotterdam, the *Behm depth indicator* was described. The instrument serves to measure the depth of the sea by sound, viz., by observing the difference in time between the detonation of a sound signal and the return of the echo from the sea bottom. The whole instrument can be worked from the bridge of a vessel and consists of a rifle, loaded with a detonator signal, two micro-

phones fitted, below the waterline, to the side of the ship, and a recorder on the bridge. The rifle is fixed to the side of the ship above the waterline, and can be loaded from the bridge by a pneumatic tube and fired by electric contact. The explosion is received by the port microphone, which closes a contact of a small motor rotating a circular mirror mounted on a vertical shaft on the bridge, the maximum angle of rotation of the mirror being 90 degrees. This mirror reflects a beam of light to a scale, divided in a scale of linear measures. On the return of the echo from the bottom, same is received in the starboard microphone which, through an electric contact, engages a powerful brake, instantly stopping the rotation of the mirror. The actual depth can be immediately read off from the recorder on the bridge by noting the position of the beam of light reflected by the mirror on the scale. For great depths a photographic recorder has been patented. Experiments are now being carried out to adapt the device for measuring the height of flying machines above the land".

The Italian Hydrographer states that in March 1923 the "*Behm Echolot Gesellschaft*" (Kiel, Holsteinstrasse 31) offered to supply a complete apparatus for the sum of 1,500 American dollars, delivery to be made at Kiel; this sum included the cost of packing, but was exclusive of export duty; delivery would be made about three months after the receipt of the order; the firm places a fitter at the disposal of the purchaser free of charge.

(7). At the request of the Bureau, the Hydrographer of the U.S. Navy has forwarded a report with reference to the use of the *Sonic Depth Finder*, which was used by the U. S. S. "Stewart", (1) in June 1922 in obtaining a close line of soundings across the Atlantic from the American coast to Gibraltar, (*see* pages 71 & 72 of the "Hydrographic Review", March 1923), (2) in obtaining a line of soundings by the same vessel in July 1922 in the Mediterranean from Gibraltar to the approach to Port Said, and (3) in carrying out a survey on the West coast of the United States by the U. S. Ships "Corry" and "Hull" in November and December 1922.

The soundings obtained during the voyage in the Mediterranean are graphically shown on three sheets, copies of which are in possession of the Bureau, and which would doubtless be supplied by the U.S. Hydrographer upon request; the general direction of this line of soundings is, (a) from Gibraltar to the approach of Algiers; on this section the depths obtained are in fair agreement with those previously shown upon the chart; (b) from the approach to Algiers to a position about 5 miles off Cape Bon; the soundings obtained on this section vary, in many cases, very considerably from those given on the chart, but no satisfactory comparison can be made with them owing to the steepness

of the slope of the African coast hereabouts, a small difference in position easily accounting for any apparent discrepancies in depth; (c) from Cape Bon to Gozo the line passes over fairly shoal water and the variations are inconsiderable; (d) the line of soundings then takes a fairly direct course from Malta to about 10 miles northward of the coast of Egypt at the Damietta mouth of the River Nile; these soundings are generally in fair agreement with the existing depths shown, although the soundings now obtained indicate the existence of considerably less water, in some positions, than was previously shown.

The soundings, as a general rule throughout, were taken hourly, the average speed of the vessel being about 15 knots.

From the direction of this line, as a whole, it would appear that the soundings were taken with the object of carrying out a test of the working of the apparatus itself, rather than with a view to comparing the actual soundings obtained with those previously shown on the chart.

The report of the U.S. Hydrographer mentioned at the beginning of this paragraph is as follows : —

REPORT BY THE U. S. HYDROGRAPHIC OFFICE
17th April 1923.

SUBJECT : Sound — General information furnished by the *Bureau of Engineering*, Navy Department. Sonic Depth Finder, Type SE, 1378 — Time elapse and Angle Methods.

(A). — **Time elapse method.**

The design of the Sonic Depth Finder *(Sound Bathometer)* is based upon the theory that a sound impulse emanating from a point near the surface of a body of water will be reflected back to that point by any submerged surface within its range of propagation. This theory applies particularly to the sea bottom.

A vessel, equipped with some form of sound transmitter and receiver, passing over a sea bottom of great depth, may use this apparatus to measure the depth approximately by sending out an impulse with the transmitter and measuring with a stop watch the lapse of time before the echo of that impulse is heard in the receiver. Considering the velocity of sound to be 4800 feet or 800 fathoms, the distance the sound travels to the sea bottom and back will be equal to the number of seconds, shown on the stop watch, times 800 fathoms. The depth would be equal to one-half of that amount. The human error in starting and stopping the watch makes this method inaccurate.

Experiments have been conducted with a patented device which consisted of a constant speed mechanism which could be set in motion by the out-going impulse and,

by means of a delicate relay system, was brought to rest by the received echo, thus indicating, without the human error, the time interval desired. However, this device was found to be impractical, due to the fact that relays could not be kept in proper adjustment on shipboard, and furthermore, the device was brought to rest by various subaqueous sounds other than the echo of the sound transmitter signal.

The Navy's Sound experts then devised an indirect means of measuring the time interval which employed no sensitive relays and produced results which were correct within .005 per cent. The design of this device depends upon the principle that, if sound impulses are sent out at various known intervals, some one of these intervals will agree with the lapse of time necessary for the sound to travel to the bottom and back to the receiver.

The final design of Sonic Depth Finder, based upon the theory just stated, consists of :

(a) A continuous speed rotary converter controlled, over narrow bands of speeds, by a tuning fork.
(b) A disk of 10" radius rotated at slow speed by the motor of the rotary-converter.
(c) A shaft upon which rotating cams are mounted and which carries a friction wheel which can be adjusted to rest, at any radius (10" or less), on the rotating disk.
(d) Keys which are operated by the cam wheels for sending sound transmitter signals.
(e) Inductive coupler for connecting one phone of a head set inductively to the sound transmitter circuit.
(f) Necessary wiring to connect opposite phone of the head set to sound receiving apparatus.
(g) A divided head-telephone set of low resistance.
(h) An adjusting screw for the friction wheel, having a micrometer scale.

Operation.

Let it be presumed that the vessel, which is equipped with sonic depth measuring equipment, is passing over a bottom which is 400 fathoms deep, and that the disk of the Sonic Depth Finder is set in motion with the friction wheel in such a position that an impulse is sent out once in every one and one-half seconds. The first impulse sent out will be heard in one phone of the head-set while the key is closing the transmitter circuit and another in the same phone (or ear) when the key closes the circuit again one and one-half seconds later. In the meantime the first impulse has travelled to the bottom and back, a distance of 800 fathoms in all, and as the velocity of sound is 800 fathoms per second, it is heard in the other phone of the head-set one second after it was transmitted and one-half second before the second impulse is transmitted. The operator will at once know that the time interval to which the device is adjusted is too great and will reduce it by moving the friction wheel which operates the cams to a greater radius on the disk and, by thus increasing the speed of the cam wheel, the time interval will be decreased accordingly. As the adjustment of the friction wheel is continuously variable the time interval can be reduced until it coincides exactly with the lapse of time between the making of the impulse and the reception of its echo, which in this case will be one second.

There seems to be a general impression that the Sonic Depth Finder is a complete means in itself of measuring depth. This, however, is not the case.

For measuring depths of water greater than forty or fifty fathoms up to such depths as are encountered in mid-ocean and in the paths of ocean currents, it is necessary to use with the Sonic Range Finder a high power vibratory Sound-Transmitter. At the present time there is only one type of such transmitter on the market. Further information in regard to them may be obtained from the *Submarine Signal Company*, Boston, Mass. It is also necessary to employ some form of sound-receiver with the device, preferably one which determines direction accurately. The design of receivers used by the Navy is considered confidential. It is believed, however, that some form of receiver, satisfactory for use with the Sonic Depth Finder, will be placed on the market in the near future. Dr. H. C. HAYES, of the *Naval Engineering Research Laboratory*, Bellevue, Maryland, owns the commercial rights of the Sonic Depth Finder itself.

It is considered feasible to use the Sonic Depth Finder in conjunction with a sound-transmitter and directional sound-receiver, for measuring depth, determining the contour of the sea bottom, and in some cases, determining the distance of the sea coast.

The Sonic Depth Finder cannot determine depths less than 40 fathoms. The maximum depth depends upon the efficiency and power of the transmitter. Depths up to 3200 fathoms have been measured with this device by Naval vessels.

(B). — **Angle Method.**

The set of sound-transmitting and receiving equipment capable of measuring depths which are less than the lower limits of the time elapse method, consists of a sound-transmitter, located nearly amidships, and two lines of twelve microphones each located in the bottom tanks, one well forward and one well aft. The compensating device and the control equipment for the sound-transmitter are located in the radio room.

The compensator is a device which may be adjusted to compensate for the difference in time of arrival of a sound wave front on two different points on the microphone line. Each particular adjustment of the device may be calibrated and given a definite value in degrees of a relative angle to the microphone receiving line.

Considering that a vessel is provided with a means of determining the angle or direction from which a sound impulse approaches, it is of interest to note that the operator of the apparatus can hear the vessel's own propellor and machinery noises reflected back from the bottom. It is also possible to determine, by use of the compensator, the precise angle at which the sound impulse, received on the microphone line, is reflected. Assuming that the sea floor is level, its depth below the keel may be easily determined by triangulation once the angle of reflection has been determined. The navigator knows the distance between the center of the receiving line and the sound source, be it the ships propellors or a high pitched sound-transmitter — this distance is the base line of the triangle. The compensator gives the angle of reflection which is a duplicate of the angle of original propagation of the sound impulse. Knowing the base line and two angles, the determination of the altitude, viz., depth of water, is a simple and well known mathematical process of triangulation. It is not necessary, however, to go through this process each time it is desired to obtain a sounding.

It is a simple matter to prepare a dial for the compensator, each adjustment of which will give a direct reading in fathoms. The values written on the dial must be based on the length of the base line and the angular values of the adjustment steps of the compensator. For instance, if the distance between the transmitter and the receiving line center is 480 feet, the compensator step which has an angular value of 60 degrees will also have a value of 53.5* fathoms on the depth dial.

This theory was reduced to practice by the Navy in 1918, and has been successfully used for determining depths from five to seventy five fathoms by all vessels equipped with the necessary sound-transmitting and receiving apparatus since that time. However, up to the present time, the receiving lines have both been installed forward and the sound transmitter installed aft and errors have been made with such installations in passing over rapidly sloping sea bottom. The rules which apply to reflection of light waves, apply also to reflection of sound waves. The sea floor may be considered as a mirror and if it is sloped downward toward the ship's head at an angle of 5 degrees, the rule that the angle of reflection is equal to the angle of incidence applies, and the compensator will indicate an angle of reception which is 5 degrees** less than it would be were the bottom level. The depth indicated would be a relative amount less than it actually is. With the present installations it is not possible to check this error unless it is suspected and the vessel swings around 180 degrees and continues sounding while swinging. When the bottom slopes upward in the direction of the ship's head the case is reversed and the indicated depth will appear to be greater than is the case.

It is to eliminate this difficulty that it has been planned to install the microphone lines on survey vessels both forward and aft with the sound-transmitter interposed between them. In case it is desired to sound with this installation over a sloping bottom, the received angle of the sound wave given off by the transmitter will be greater for one line than for the other, and the actual depth will be the equivalent of the mean of the two angles.*** It will also be possible to determine the direction and angle of the slope of the bottom.

(c) With the installation of sound apparatus for both the time-elapse method and the angle method of sounding, survey vessels will be equipped to undertake work, for which they are intended, at a speed many times greater than has heretofore been possible.

(8). The U.S. Hydrographer supplied information also respecting a Bathymetric chart resulting from a survey carried out with the Sonic Depth Finder by the U.S. Ships "Corry" and "Hull" during November and December 1922 on the West coast of the United States from San Francisco to Point Descanso, Mexico; the results of this

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* Note by I.H.B. It is not understood how this figure is arrived at.

** Note by I.H.B. This statement, though correct as to principle, does not appear to be correct as to amount.

*** Note by I.H.B. This mean does not give accurate results where the slope of the bottom is great.

survey are shown on chart N° 5194 published by the U.S. Hydrographic Office: the survey was made at the special request of the Carnegie Institute of Washington.

The following are extracts from the Report furnished by the U.S. Hydrographer on this subject: —

"Dr. H.C. HAYES, Ph. D., of the *Experimental Station of the Bureau of Engineering*, Navy Department, in June 1922, completed the development of an apparatus for obtaining ocean depths by an instrument called the Sonic Depth Finder. Successful tests were made and excellent results were obtained with this apparatus by the U.S.S. "Stewart" on a voyage from Newport, R. I., to Gibraltar and from Gibraltar to Manila, P. I.

"The design of the Sonic Depth Finder is based upon the theory that a sound impulse emanating from a point near the surface of a body of water will be reflected back to that point by any submerged surface within its range of propagation. This theory applies particularly to the sea bottom. All that is necessary is to know the velocity of sound in water, and to perfect some method of accurately measuring the time from the moment the sound is produced till it is heard again reflected back. This accurate measurement of the time interval is now perfected.

"For measuring depths of water greater than fifty fathoms up to such depths as are encountered in mid-ocean, it is necessary to use with the Sonic Range Finder a high power vibratory Sound-transmitter and also a directional form of Sound-receiver.

"The soundings obtained by the U.S.S. "Stewart" with the Sonic Depth Finder showed that the contours of the ocean bottom could be charted with this device, and these important developments made it possible for the U.S. Ships "Hull" and "Corry" to obtain the depths of water necessary to construct Chart N° 5194, which data will be of great value to seismologists, geologists, and oceanographers.

"Contemporaneously with the development of the Sonic Depth Finder, Seismological Societies in the United States were making a study of the earthquakes on the West Coast of the United States. To study the earth movements in California, it is necessary to know where the zones of structural weakness are. Some of these can be plainly seen, others of them can only be found by inference from the adjacent geological structures. Knowing where the zones of weakness are located, it then becomes comparatively easy to discover both the source and the direction of the progression of underground movements.

"In connection with this study of earth movements in California, there was prepared for publication by the Seismology Society of America, with the co-operation of many different agencies, a Fault Map of the land area most liable to earthquake disturbances on the West Coast. As the observations in 1922 accumulated and the map grew, it became clear that many of these faults lead to the seashore and no doubt continued beneath the sea.

"The Carnegie Institution of Washington having learned of the Sonic Depth Finder developed by Dr. HAYES, requested the Hydrographic Office, which has charge of the Naval Surveys, to have soundings taken off the coast of California with this new apparatus. The Navy Department, desiring to be of every possible assistance in furthering this important scientific research, fitted out the U. S. Ships "Hull" and "Corry" with the Sonic Depth Finder.

"The sounding operations were commenced in November 1922, and parallel lines of soundings were run on courses 240° and 60° true from the 100 fathom curve to the 2,000 fathom curve. The lines were run ten miles apart from San Francisco to Point Conception, and five miles apart from Point Conception to Point Descanso, Mexico. The average distance between soundings on each line is one to two miles; the distance covered was 5,800 miles and the area covered 34,000 square miles. The vessel steamed at 12 knots speed and completed the survey in 38 working days, obtaining approximately 5,000 soundings.

"The observations obtained by the survey of the U.S.S. "Hull" and "Corry" has permitted the construction of a contour map of the ocean floor, by the Hydrographic Office, from the coast line to a depth of 2,000 fathoms (12,000 feet). This is the first successful contour map of a zone of deep sea soundings ever made. The chart represents the configuration of the ocean floor in the region, showing the submerged hills, valleys, cliffs, and precipices. The recent earthquake in Chile suggests that the undersea portions of coastal faults may be most active and dangerous.

"It is perfectly clear from the contour map that a number of very steep slopes or cliffs have been located, some of which may be fault scarfs of considerable elevation. The indications are that the chart also locates the so-called continental shelf, which is commonly thought of as representing the structural demarcation between a sinking ocean bed and a rising continent.

"The future study of the inaccessible ocean depths appears now to be of high precision.

"Regions in which changes occur frequently, such as the coast of Chile or the Hawaiian Island group, can be studied with great care and detail, and the direction in which future displacement may be expected can be ascertained.

"The clearness with which these contours are delineated by the sonic survey completed suggest the possibilities of a more effective study of continent building and of the general problem of isostasy than has heretofore been possible. Ancient connections, such as are supposed to have existed between South America and Africa or across the Indian Ocean, can now be worked out almost as positively as upon a land area.

"The perfection of the Sonic Depth Finder offers unlimited possibilities to tectonic geology and oceanography".

Note. — It will be observed that the above report alludes to soundings being obtained by the U.S.S. "Stewart" also from the Mediterranean to Manila, but no information as to these has been received by the Bureau.

In the "*Annalen der Hydrographie*" for August 1923 an article on the subject of the Echo Sounding voyages of the U. S. Ships "Stewart", "Corry" and "Hull" is given by Dr. GERHARD SCHOTT; he describes this method of sounding as a revolution, the voyages of very great geographical interest, and the results as a notably progressive step.

He remarks that, in depths of over 2,000 metres. Echo Sounding gives somewhat less depth than the sounding obtained by wire, and that the actual position of a wire sounding must be considered as having a possible range of several miles; the result of the investigations carried out by H. MAURER is that Echo Sounding gives a depth of about 3% less than a wire sounding, which reduction is due to the correction which should be applied to an Echo Sounding for the velocity of sound, temperature, salinity and pressure; Dr. SCHOTT considers that wire-soundings are more exact provided that, when they are taken, the conditions are favourable.

(9). In November 1922 the Danish Hydrographer reported that an Echo Sounding apparatus was being installed in a man-of-war, and results of the trials of this apparatus were promised in due course. No further information on the subject has yet been received.

(10). It is understood from unofficial sources that Spain is carrying out valuable experimental work in connection with Echo Sounding, especially for use in shoal and constricted waters.

(11). In connection with this important and interesting subject it is learnt that the American Government specially despatched to Australia the "Milwaukee", one of its latest Scout-Cruisers of 10,000 tons displacement with a speed of 35 knots, to demonstrate the Sonic Depth Finder to the Delegates of the Second Triennal Pan-Pacific Science Congress which was held in Melbourne and Sydney in August, 1923.