ECHO SOUNDING IN HARBOUR HYDROGRAPHY

by

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For a century, at least, the seaman-surveyor has anxiously searched amongst the unfolding principles of increasing scientific discovery for some method of vertical submarine measurement, which would solve for ever that small margin of doubt which has always surrounded the ancient use of lead and line.

The present century has seen so remarkable an increase in the maximum draught of steamships, that the Port Surveyor must now determine the greater depths with the same meticulous precision as has been demanded of him for the lesser in times past.

In approaching soundings from seaward, the need for close detail and precision was once determined by the five-fathom contour, but modern progress in Naval Architecture, taken together with the "squat" of large vessels in shoal depths at critical speeds, has increased the range for detail to at least seven fathoms below M.L.W.S. Data.

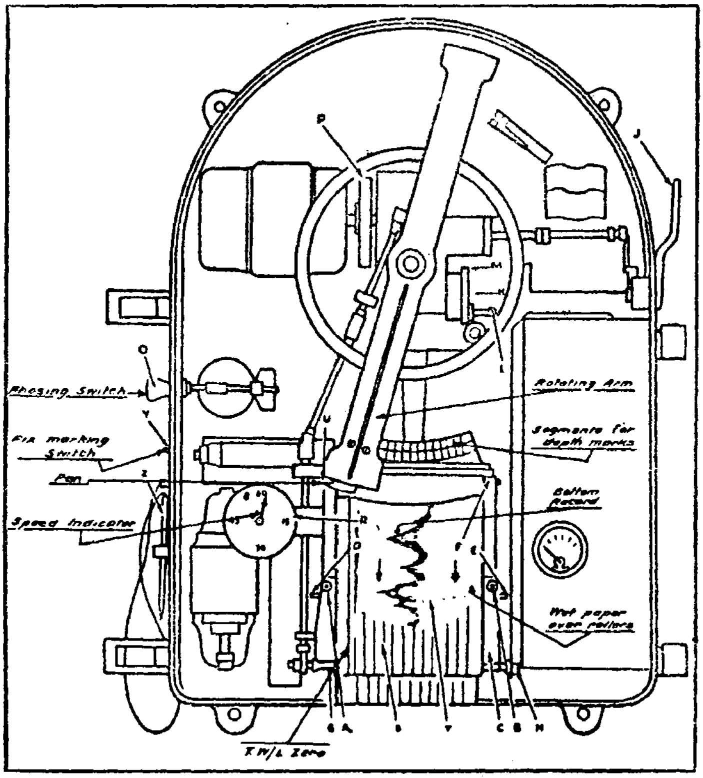

Fig. 1

It is the writer's contention that real precision at such a depth is not attainable by ordinary "lead and line" methods, for the following reasons:—

(a) The catenary of the lead-line, due to differential current layers, always causes the "calling" of excessive depths, despite the appearance to the leadsman and surveyor of a "plumb" cast. Surveys over identical sections at different states of tide have frequently given perplexing differences in proof of this, and it is, of course, an axiom amongst seamen that over-estimation of depth is fatal.

(b) The settling of the lead into soft mud and clay. This also gives an excessive depth. The contention that what is not "felt" by the lead cannot obstruct a ship, is a serious fallacy. A heavy-draught vessel requires every inch of bottom clearance at Ordinary Spring and extreme Low

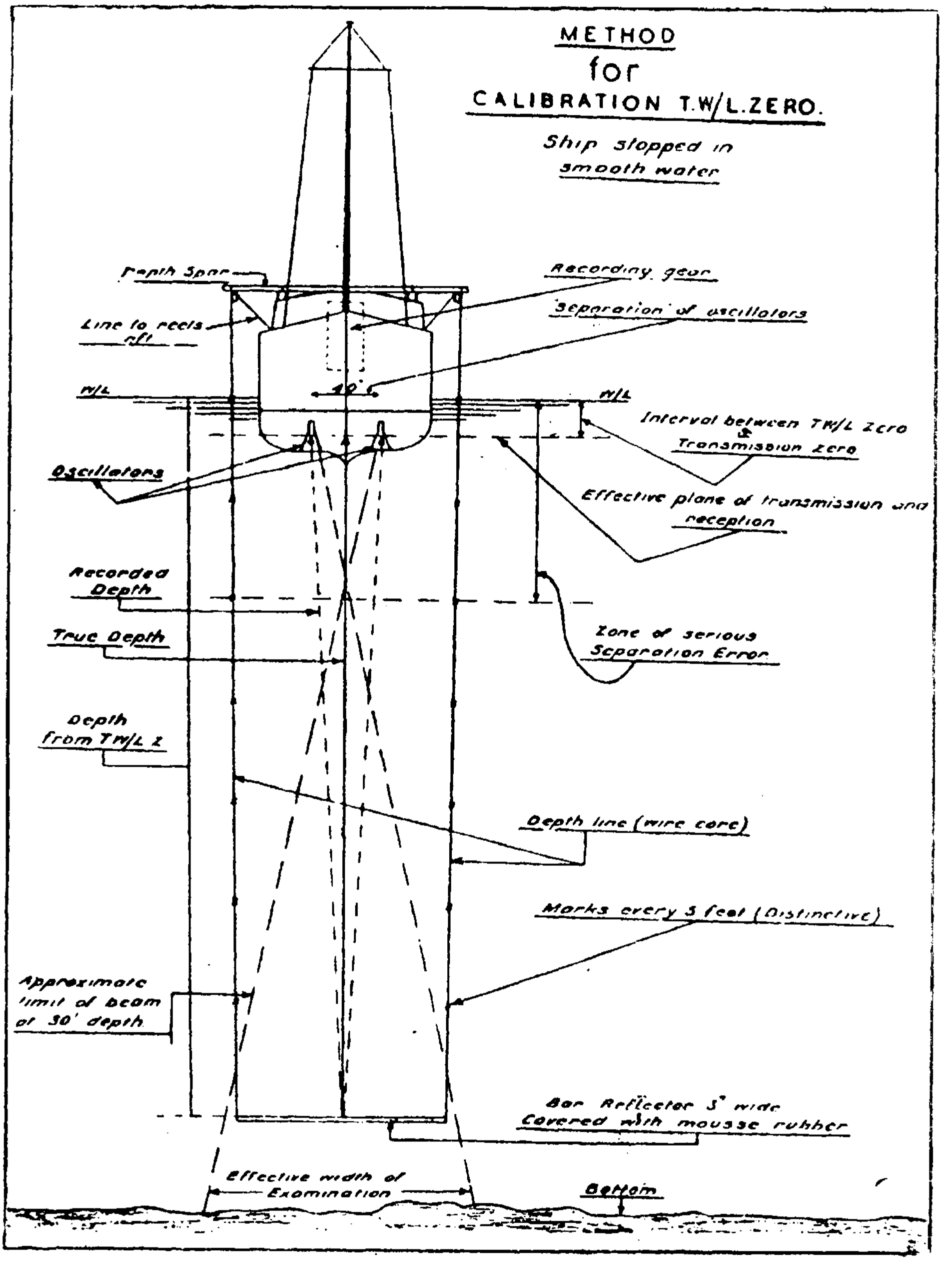

Fig. 2

Water times, in order that her screw "feed" current may be as ample as possible. Her "squat" is thus reduced, and her general handiness under helm and engines increased.

(c) The tension due to the usual leads (10 to 20 lbs.) is not great enough to ensure that the best type of lead-line (with Kelvin wire heart) is representing depths to the same degree of accuracy as when it is horizontally stretched and "taped" before and after using.

(d) The speed of the sounding boat must be quite low for the best lead work, and whilst giving all due credit to the splendid performances of first-class leadsmen, it should be remembered that the necessarily short instant of "plumbing" and "feeling" at a depth of over five fathoms from a vessel, under way, lacks that deliberation necessary for the critical accuracy which such a measurement surely demands.

When causes (a), (b) and (c) are acting in concert, it is clear that discrepancies between the Navigator and Surveyor are by no means surprising, unless the latter has been wise enough to reduce his soundings by the "full foot" method of tidal reduction, and/or reject inches in his reduced depths. If, however, he is too cautious he will be censured for unnecessarily restricting shipping—a good but irritating fault!

Fortunately, the dream of the old Surveyor Captains and Admirals has been realised and a panacea for the ills of lead sounding at last discovered.

The Magneto-Striction Radial Arm type of Echo Sounding device has solved the problem by enabling the Surveyor to take ashore a paper record giving a continuous profile of the bottom section which his sounding boat has traversed, to a definite accuracy of within 3 inches, punctuated with "fix" lines indicating the points where his instantaneous double angles for position were taken.

These consecutive numberings agree with the plotted points of the boat's track marked upon the plotting graph of position (see 7a).

The interesting point about such a record — or Echo-roll — is that it bears internal evidence of its true Zero of soundings after the "barcheck" has been carried out at definite depths.

The section is not only a continuous and accurate record of Electro-sonic soundings taken at the rate of 300 p.m. (i.e., one every 2-ft. at 6 knots), but in addition, represents a track which is not just a line, but a *strip* or *band* of "examined" area, equal in width to about one-third the depth — as the effective "cone" of sonic sensitivity is about 15° from the vertical.

Thus any pinnacle or obstruction within this zone would show a "side" echo or "shadow," and so indicate the need for a further and closer examination.

It is not the writer's intention to describe in detail the technical parts and principles of the instrument, but rather to outline its practical application to the Harbour Surveyor's requirements.

The instrument graphically measures sound intervals by respectively recording the points of transmission and reception upon specially treated starchiodine paper moving over rollers at a constant speed, which allows time intervals to be automatically recorded. (See Fig. 1).

The depth interval is therefore represented by the linear interval between the recorded point of transmission and reception — denoted respectively by the brown chemical precipitation marks — the scale calibration depending upon a standard rate of sound in water — 4.800-ft. per second.

This is mechanically achieved by a rotating arm bearing a "pen" of carefully regulated spring pressure which traverses and contacts the moist paper at a standard speed of 300 r.p.m., which speed is a function of the scale calibration. (See Fig. 1).

Continuous recording by the instrument gives such a close succession of these markings, as to show in practice a *line* of transmission, and a *line* of depth.

By pressing a button at the instant of fixing the position of the Survey Launch, a continuous line is "drawn" upon the record, and an "electric contact" pen enables the numbering of the successive "fixes" to be made without interrupting the record. (Fig. 1).

It should be noted that the scales used for measuring depths upon the record are in sine relationship to the arc traversed by the "pen."

The paper record has, of course, to be dried before plotting can be carried out, and this is accompanied by a certain amount of transverse shrinkage which affects the final scale upon which soundings are read. Fortunately, with the use of standard paper, the co-efficient of shrinkage is very constant and is allowed for in the graduation of the metal scale provided with the instrument.

In addition, as the instrument automatically marks the depths from 0-40-ft. at 5-ft. intervals upon the direct scale (i.e., on the wet paper) the dry scale can be checked for accuracy and consistency very easily. When this test is satisfied, the results can be confidently relied upon.

The scales of the instrument used by the writer are approximately 8-ft. and 16-ft. to the recorded inch, each capable by a phasing arrangement of recording a depth range of 75 % more than the single traverse of the paper width would permit (i.e., 40 and 80-ft. respectively).

As the scale (8-ft. = 1-in.) is that affording a precision of 3-in. of depth in practice, this scale will be that particularly described and illustrated in this article.

The writer accepted the M.S.X. instrument (as illustrated) upon the essential condition that an accuracy of depth within 3-in. was to be given in practice.

The tests were to be made in dry dock at high-water level, and depths compared with the readings of the inner gauge (top of block zero) and also the sill

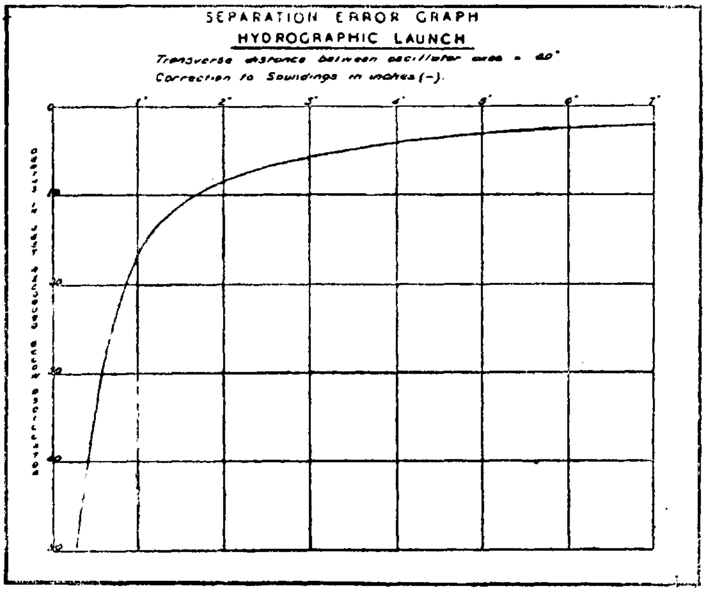

Fig. 4

level. The instrument came through with first-class honours, showing a perfect agreement between the record and dock gauge. In addition to the tops of the blocks, the dock bottom was shown; with launch moving slowly across the dock, the camber of the bottom was also clearly discernible.

Salinity and temperature affect the speed of sound in water, but within the ranges used by the Harbour Surveyor the variations are infinitesimal, and can be checked by the "bar" method described below. (See Fig. 2).

Speed error is directly proportional to "standard" speed, the performance of which can be checked by comparing a specially calibrated pointer borne upon the instrument with a good stop-watch. (Fig. 1).

In practice the writer has devised an "absolute" check upon the instrument, which avoids the necessity of applying increments due to speed variations. A 3-in. width angle bar, weighted at the ends and totalling 70 lbs. in weight, is slung from calibrated lines rove through yard-arm blocks from a spar borne in crutches and clamps athwart the boat directly above the oscillators. The lines are hemp lead-line (cable-laid) stuff (1 1/4-in. circ.) into which a Kelvin-wire "heart" has been worked. With boat stopped in smooth water, the bar is hooked on by self-mousing hooks to the port and starboard depth lines and launched over the stern.

The depth lines are then reeled out until the required marks say 35-ft. — are *on the waterline*, on each side of the boat. As these lines are continually checked as a routine by steel tape, the top of the bar is thus at the required depth, the weight of 70 lbs. overcoming differential current effects. The Echo machine is then switched on and the bar "echo" recorded.

As the sea bottom is *also* recorded, if this is hard, the line will be found to slack as soon as the bar is lowered to a position where "Bar" and "Bottom" records are in coincidence. If the bottom is soft the difference in level between the "bottom" on the record and the depth of line at the moment of "slacking" will indicate the softness of the bottom, and the penetration of the bar. It will thus be seen that the "bar-check" constitutes the criterion for the true waterline zero (T.W/L.Z.) of the record bearing it. (See Fig. 3).

Whilst the old surveyor measured his lead-line after sounding, the Echo surveyor will carry out a "bar-check" every time he uses the instrument and watch his instrument by stopwatch throughout its use.

A further small correction known as "separation error" will now be considered in conjunction with a brief outline of some of the features of installation. This correction (which is subtractive) is due to the horizontal distance between the transmitting and receiving oscillators. (See Fig. 4). The recorded depth is thus greater than the true by an amount which decreases inversely as the depth of water.

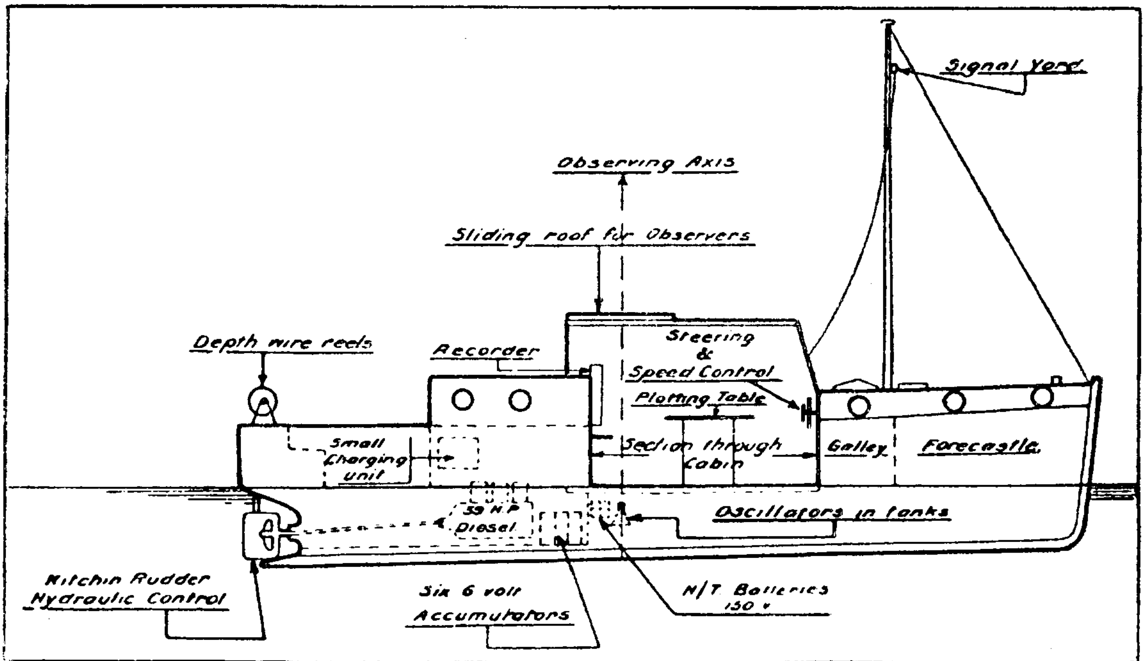

Fig. 6

The value of this correction is determined by the formula

$$C = D - \sqrt{\left(D^2 - \left(\frac{S}{2}\right)^2\right)}$$ where C = the subtractive correction to recorded depth D.

D = Recorded depth.

S = Horizontal distance between vertical axes of the oscillators.

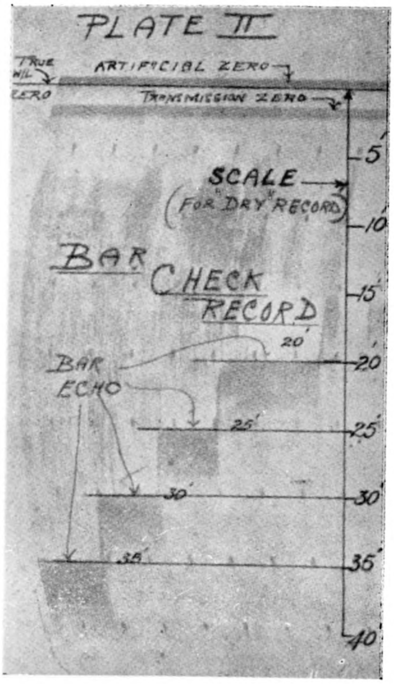
PLATE II
TRUE W/L ZERO
ARTIFICIAL ZERO
TRANSMISSION ZERO
SCALE
(FOR "DRY" RECORD)
BAR CHECK RECORD
BAR ECHO
20'
25'
30'
35'
5'
10'
15'
20
25
30
35
40

Fig. 3

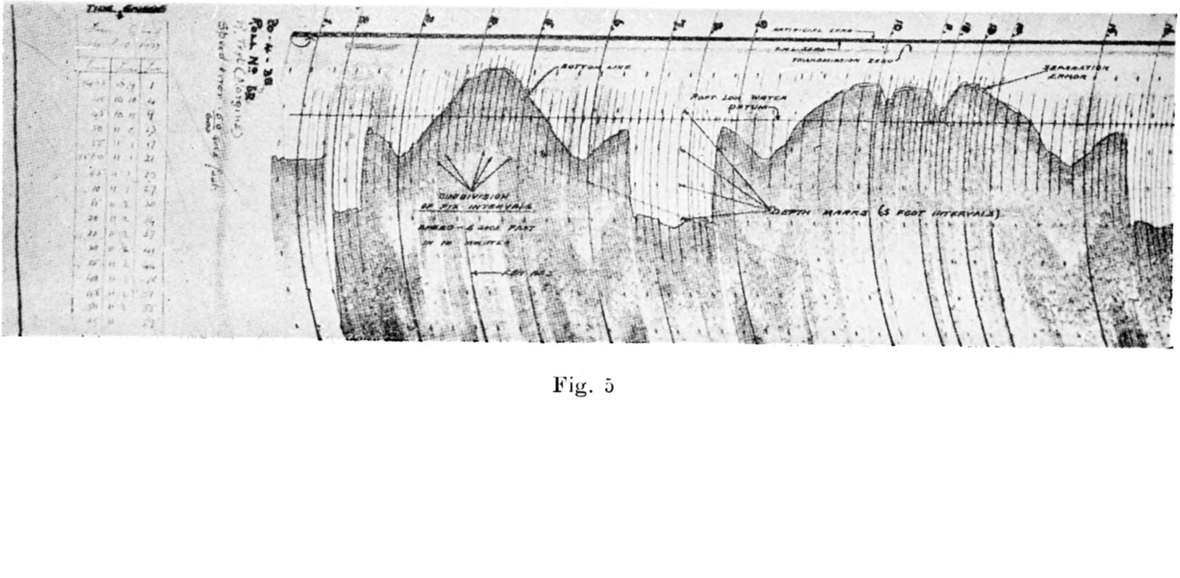
ARTIFICIAL ZERO
TRANSMISSION ZERO
BOTTOM LINE
SEPARATION ERROR
WATER DATUM
SUBDIVISION OF FIX INTERVALS
DEPTH MARKS (5 FOOT INTERVALS)

Fig. 5

For example, if the oscillators are 40-ins. apart, the recorded depth is 7 1/2-in. in excess of the true, at a depth of 2-ft. (below the oscillators); 3 1/2-in. at a depth of 5-ft., and only 1 1/2-in. at a depth of 10-ft.

In such a case, it will be sufficient, as a safe principle in practice, to pencil in the recorded "bottom" 3-in. above its "surface" when the depth is between 2-ft. and 5-ft. (See Fig. 5).

Let us examine some of the points to be considered in installing a sounding set (M.S.X.) in a small Diesel-driven launch, such as that used by the writer. (See Fig. 6).

The dimensions of the vessel were: length 35-ft., breadth 9-ft., and draughts : forward 2-ft. 6-in., aft 3-ft. 6-in. Speed 8 knots.

It was decided to fit the oscillators abreast each other and 40-in. apart on either side of the keel, at a position over which all observed angles for location were to be taken.

This position was also about the L.C.F.*, in order that small changes of trim, under way, would not affect recorded depths.

The effect of moderate rolling is counteracted by the fanshaped beam sent out by the transmitting oscillator, which is disposed approximately 15° about the vertical axis of transmission. (See Fig. 2). In shoal depths this angle is increased.

The exact vertical distance of the "effective" base of the oscillators above the keel was then taken by level on the stocks, in order that the vertical distance between waterline and "plane of transmission" could at any time be computed from mean draught and applied above the "zero of transmission" as a check upon "waterline zero" — in conjunction with any speed variations noted by stop-watch.

As the craft was a wooden one, holes had to be cut for the oscillators and compensation made. This is not necessary in steel vessels.

In the writer's view, a good shallow draught and beamy launch, of from 35-ft. to 45-ft. in length, is the most suitable for harbour survey work, for the following reasons:—

(1) "Squat" in shallow water is least felt, and thus one correction is eliminated.

(2) Variations in fuel and F.W. disposition and quantity have less effect on mean draught than is the case when the unit is fitted in large tenders.

(3) Rigging and handling of gear for "bar-check" is easy, on account of light draught and relatively small beam, and thus constant checks are simply carried out.

(4) "Separation" error is kept small.

(5) Sextant observers can observe precisely over the set of oscillators when under way.

(6) With "Kitchen Rudder" control "manœuvreability" is almost infinite.

With reference to this latter feature, the writer has found such hydraulic speed control of great value in Echo work, because speed can be adjusted to get best records with an infinite gradation to wind and sea conditions, quite unattainable by any other means.

A launch fitted as above becomes a survey instrument of mobility and accuracy, the "fixes" observed directly locating the exact positions of the soundings, which can be plotted directly upon a large-scale working sheet without those corrections for "distance from Observer to lead," which in many cases drive the surveyor to a pulling boat large-scale detail work.

An interesting point about such Echo work, is that when "wash" from passing vessels, a rough sea, or swell, causes "aeration" around the oscillators, the "bottom" record ceases for the time being until normal conditions are resumed.

This is an automatic veto upon:—

(*) Longitudinal Centre of Flotation.

(1) Sounding in narrow channels at times when shore tide gauge readings may not represent true levels where ships are passing.

(2) Sounding under weather conditions which are not conducive to good work.

It is most important to arrange a sound working drill in the Survey unit above described.

When on "Survey Stations" the following routine is advantageous:—

(a) The two Surveyors take up a position to observe angles overall immediately above the oscillator position, and prepare to plot the sounding course.

(b) One seaman is stationed to keep a look-out and act as "fix-marker" by pressing an electric switch button when the Senior Surveyor calls "stop" at the instant of fixing position.

(c) The sounding operator prepares the machine for recording, switches on when ordered, and keeps a watch on the record throughout the survey — checking and numbering the successive fixes which must correspond with the record kept by the Junior Surveyor in the "sounding book".

It is advisable that one seaman should specialise in operating and tending the machine throughout all survey work, as innumerable small annoyances (cutting of paper, etc.) are thus anticipated and avoided.

As the speed of the instrument is standard at 300 r.p.m. for the radial arm carrying the pen, the sounding operator must frequently check the speed error over 10-minute intervals.

The variation in seconds for a 10-minute "run" gives the depth error in inches at 50-ft., e.g., 3 secs. fast = 3-in. too deep.

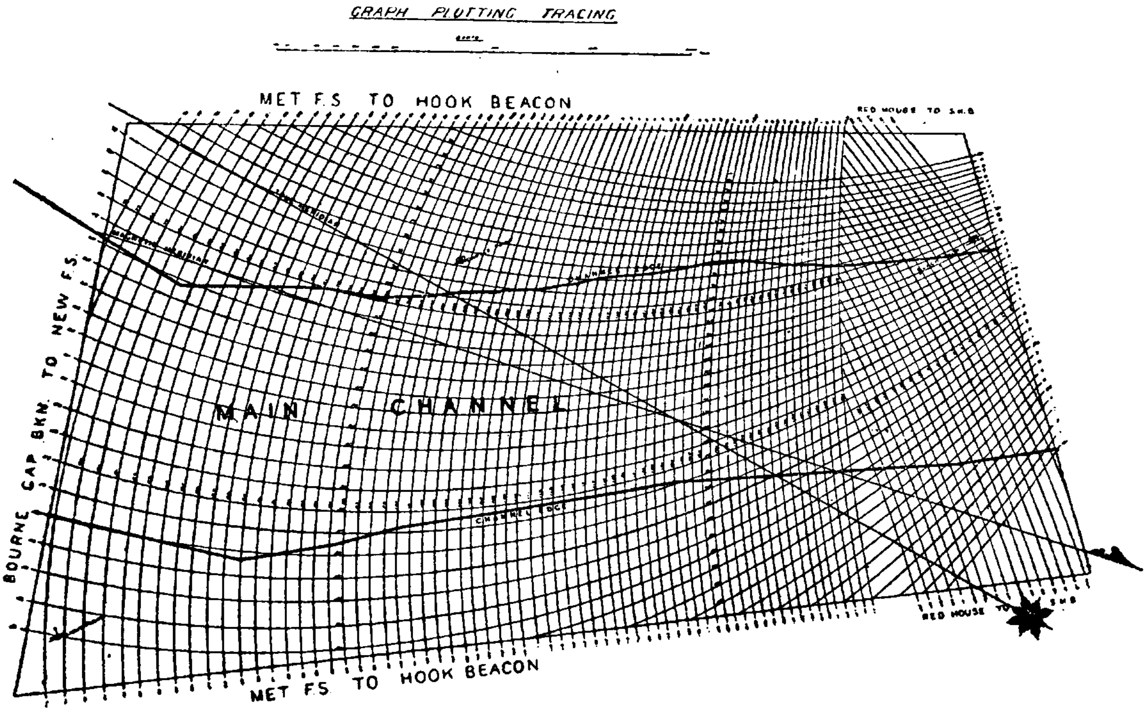

Fig. 7

The writer has rarely known this to change more than one second in a two or three-hour survey, and thus the "bar-check" described above gives a definite criterion for the true "waterline zero" which embraces all corrections.

As in other hydrographic work, all basic standards are checked as a routine. Depth wires are checked weekly by steel tape, stop-watches are timed monthly by chronometer, "phase" and primary zeros are kept in true adjustment, and the necessary spares (valves, pens, etc.) kept handy on board, in order to save delay in the case of minor breakdowns away from "home base."

The advantage over lead methods of a carefully spaced pattern of survey lines, run continuously, over a given area at 5 to 6 knots, together with a precise and continuous depth record punctuated by "fix markings," is too obvious to need dwelling upon.

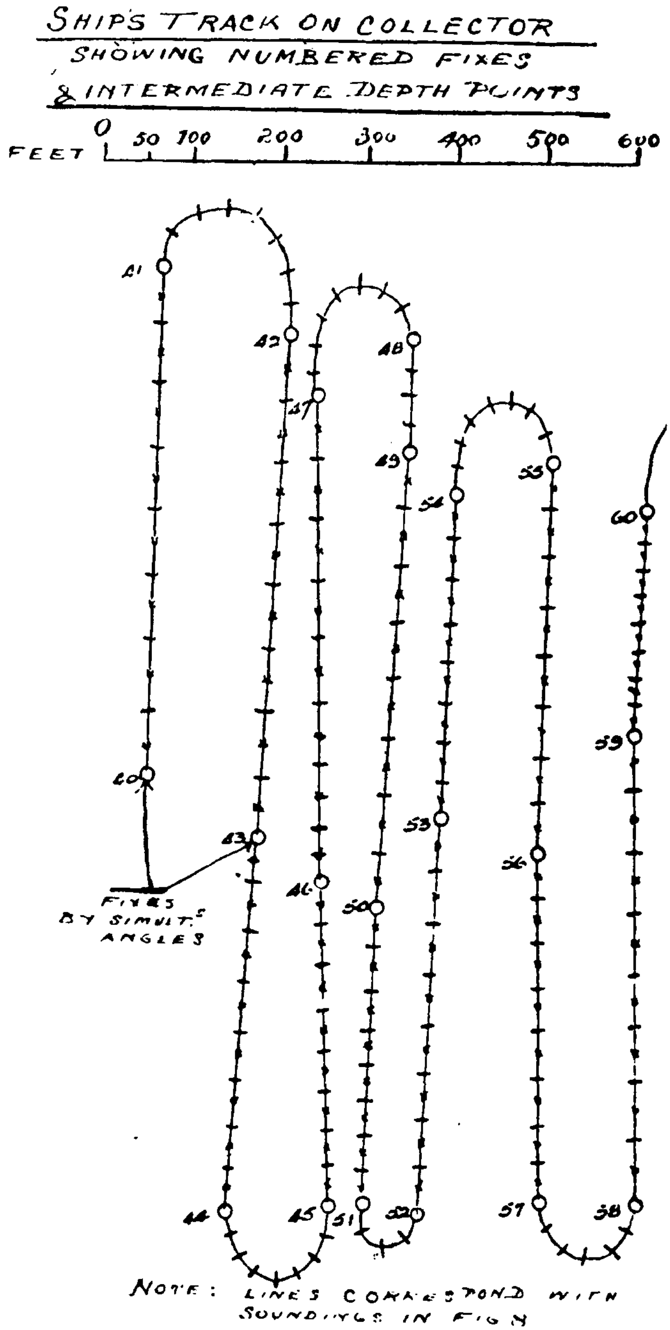

Fig. 7 a

It may be interesting to mention a further benefit.

Normally the Surveyor takes advantage of prominent natural objects in the spacing of his sounding lines for covering a given area.

The only other solution, is to steer compass courses whilst surveying, but unfortunately, if the lead is used, steerage way is necessarily so small, and wind and tide have so relatively great an effect, that such courses would be difficult to maintain in all but good-sized tenders.

The speed at which one can survey by Echo methods overcomes this difficulty, and the writer can steer courses upon an adjusted compass, in the craft mentioned above, with all necessary precision.

The magnetic effect of the Echo gear is quite small and easily compensated in practice.

A word about methods of plotting to accommodate the higher speeds of survey.

Apart from small dock wall surveys, run on transits (objects in line) using the hand lead, and wire-measured distances, the best, and even only seamanlike method of plotting the position of a survey vessel under way is by means of two simultaneous horizontal sextant angles taken upon correctly triangulated, and suitably disposed, conspicuous and fixed objects.

The "three point fix," as it is called, enables the Surveyor who is plotting to set the angles upon an instrument known as a Station Pointer, and by its means locate the point upon the "working sheet" laid out upon a plotting table carried on board.

As this routine of reading the sextant, setting the station pointer, and then using it on the plotted trig. points, takes from 20 to 40 seconds (and certainly the latter if one is as careful as one should be), it is clear that during this time the launch has traversed from 200 to 400-ft. at 6 knots.

By this time, it is necessary to fix again if one wants a detailed course. Under such circumstances the Surveyor is not sufficiently free to "conn the ship," study his contours, or check his course, unless he reduces speed — which action would, of course, annul the advantages of Echo work.

The answer to this dilemma is to be found in producing a "working sheet" bearing arcs of position so plotted that they can be used as co-ordinates, of position. (See Fig. 7).

The objects should be chosen that the resulting arcs at the required area intersect as nearly at right angles to each other as possible, and, of course, vary in radius as sensitively as desired.

This process is a new hydrographic technique in itself, and the writer has no space to deal with it here, but let it suffice to say that by its means the position of a launch, under way, can be plotted accurately within 5 seconds of the time of observing the simultaneous angles for position.

The setting of the station pointer, and the adjustment of it to the "points," are thus eliminated; high survey speed can be maintained together with fixes at close linear intervals, and easy supervision is possible throughout.

We now come to the drawing office side of the work.

Fig. 5 shows an Echo record ready for plotting, and the following points in preparing it must be attended to:—

(a) The true "waterline zero" must be drawn in throughout as deduced from the "bar-check" data contained in the record.

(b) A slip relating the fix markings to the times of gauge readings (every 5 minutes) is prepared and pasted on the record.

(c) The tide gauge readings are then plotted as requisite below the true "W/L zero" at short intervals, and a line joining them all drawn in. This is, of course, the actual Port Low Water Datum of soundings, and it will be seen that the reduced soundings are directly measured from this line.

The usual lengthly arithmetical process of reduction is thus eliminated, and yet another source of error removed.

(d) The next stage is the division of the intervals between the fix markings into a convenient number (say eight) of equidistant longitudinal intervals.

This is done by so dividing the Datum line and then transferring the points to the "bottom" record in a roller frame, which takes into account the arc traversed by the pen on the radial arm.

(e) Standard annotations for reference are finally made upon the record detailing speed variations, consequent depth error, filing number, area

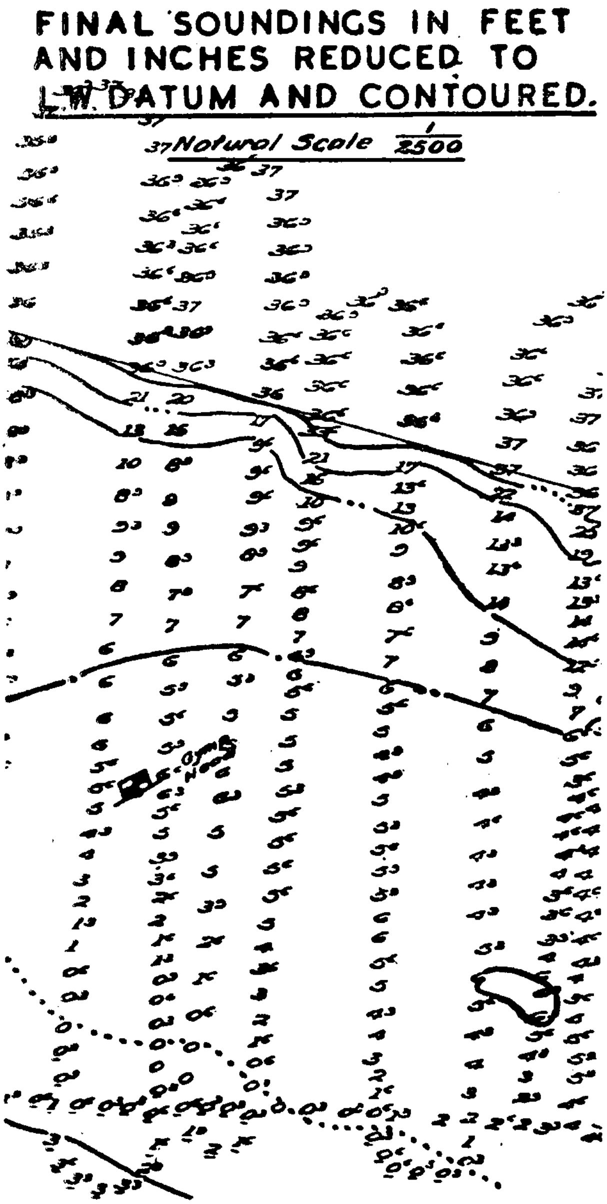

Fig. 8

sounded, sounding book referred to and dating. The record is now ready plotting, and providing this organisation is standaid and the office staff are skilled, it takes a very short time.

The preparation for final plotting upon a tracing has meanwhile been proceeding, as follows:—

(a) The "working sheet" — usually a plotting graph — is examined to check fixes and consecutive numberings.

(b) A "collector" tracing with "points" and essential details — from a metallic standard sheet — is then placed over and in relation to the working sheet graph, and the survey course and fix points transferred with numberings. This automatically compares working sheet or graph with the standard on metal, and paper distortion is incidently checked.

(c) The intervals between fixes are then sub-divided as above to correspond with the Echo record sub-division. (See Fig. 7a).

As Echo record and collector tracing are now ready, all that remains to be done is to read directly the reduced soundings by scale from the Echo record and inscribe them upon the tracing at their appropriate positions, interpolating any greater detail that may be required.

As a check can be run across the pattern of soundings during the survey, a complete check upon consistency is thereby given.

The result is then contoured, and further examination made afloat wherever the contours appear to be incomplete or bottom features and tendencies suspicious. (See Fig. 8).

Again the value of a sounding beam or "cone" giving a "lane" of closely-examined area, as against a series of points sounded by a lead, is very great indeed.

The labour and cost of identifying pinnacles or submerged piles in the past is by this means eliminated so long as sounding lines are so spaced as to arrange for "bottom areas" to overlap each other.

The writer has found no difficulty in examining dredged areas by lines run 15 to 20-ft. apart, and maintained sometimes by compass alone As one who has continuously used the instrument for the determination of dredging quantities, and final passing of dredged depths, he feels that he has given this machine a most exhaustive test, and that given a true knowledge of all factors concerned, an accuracy in final plotting to 3-in. of depth up to 70ft. is definitely attainable in practice.

In concluding these remarks upon the actual use of this instrument, the independence of tidal streams should be mentioned.

In lead survey work, it is clear that good work cannot be done in a strong tide-way, for even if "up and down" casts are *apparently* obtained, sub-surface variable currents or "slacks" will "sag" the line, unknown to the Surveyor, and give him the fatal over true depths.

In Echo work, the shortest interval to the bottom is recorded independently of the relative movement of the water past the survey vessel, and there are therefore only three factors to be satisfied if emergency requires a survey in a strong tide-way, as embodied in the following questions:—

(1) Is the visual tide gauge used well manned, near enough and so free from hydraulic obstruction as to assure the Surveyor of precise representative levels for the area of survey ?

(2) When the survey vessel is steering against the tide, will her essential speed through the water be increased above the "aeration" limit for the craft used ?

(3) Are there sufficient shore marks, and long sensitive transits available to enable the craft to make a well-spaced pattern over the area requiring examination ?

If these three questions can be answered in the affirmative, there is no reason why such a survey cannot be made in a very satisfactory manner by a seaman-surveyor.

Also, there need be no qualms about very shallow water work, providing separation error is carefully watched.

The writer has made a detailed survey of a South Coast tidal river, whose bed dried out 2-ft. at M.L.W.S., the Spring range being only 13-ft. The margins up to the points drying out 8-ft. at M.L.W.S. were included, and the results were rapid and most satisfactory.

When considering the maintenance of this instrument, one finds that £4 easily covered spares, and odds and ends for the first year.

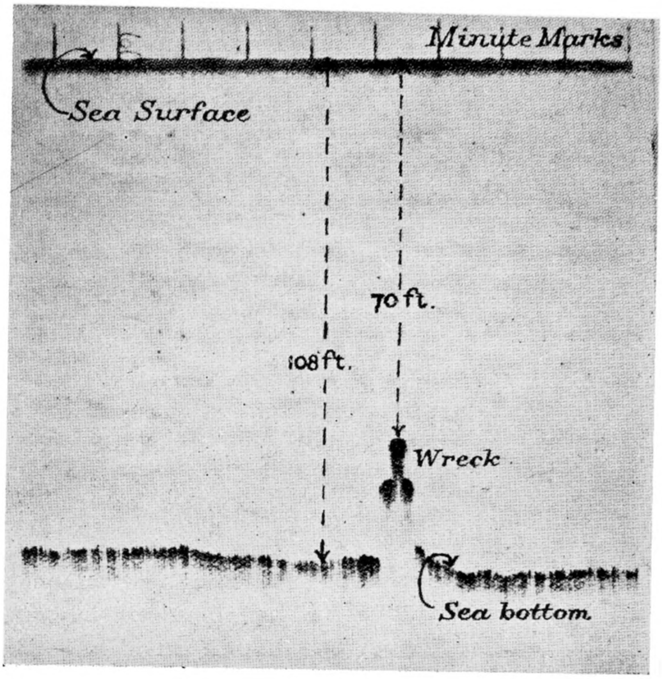

Fig. 9

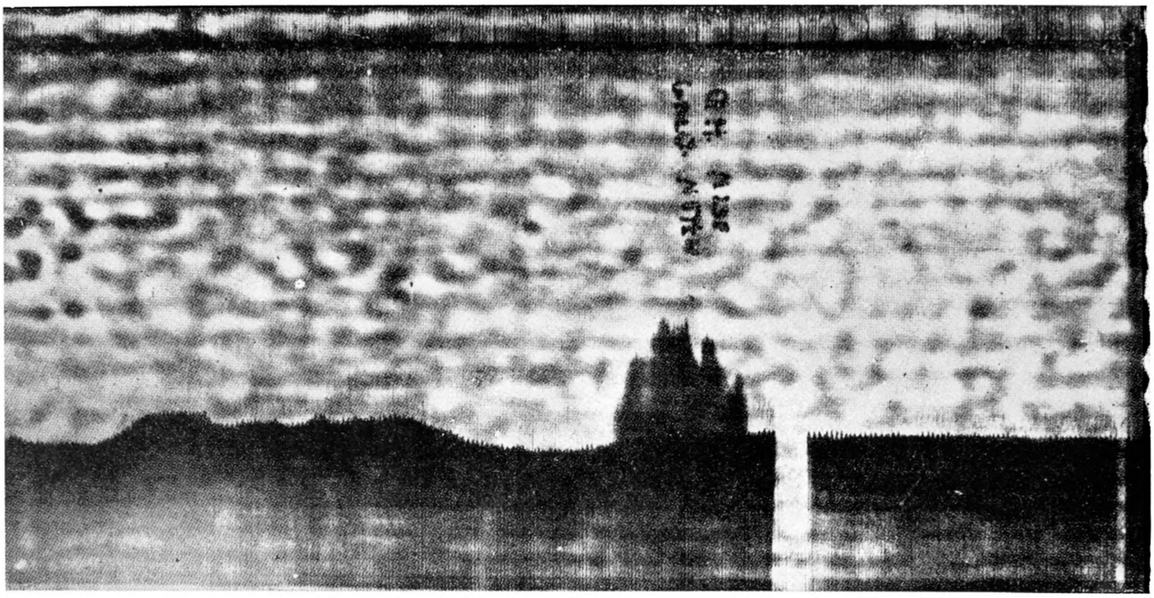

Fig. 10

The cost of Echo rolls (wet starch iodine paper) amounted to £12, but the amount of work carried out was easily four to five times that done by lead sounding.

The good weather periods were used to the full, and were sufficient to maintain a full survey programme without any "weather hindrance."

Most of the time of an Echo survey department is employed in interpreting and plotting a set of records which the drawing office sometimes, and not unnaturally, regards as a surfeit!

Efficiency, however, is well served, and the work afloat confined almost completely to ideal conditions for precise measurement without departmental slackness.

The application of Echo principles to salvage work is already proving a very great advantage to both the Port and Deep-sea Salvage Officer.

By its means, he can closely search a given area in record time, and having located a sunken vessel, can determine the least depth over it, whether it is lying upright or on its beam ends, how much of it is settled into the mud, and also by steering over it, in at most three directions, the direction it is lying on the bottom. (See Fig. 9).

If it is upright, in fairly shallow water, and he desires to make a salvage lift by camels or lighters, he can "break-down" funnel and masts by a wire sweep, and then find, by Echo sounding, the safe clearance above the hull before placing his camels in position, and heaving down for a good "lift."

In deep-sea salvage work, the name "Lusitania" is a sufficient reminder of the value of Echo "search." Fig. 10 is a reduction of an actual photograph of the record used in the location of this vessel and needs no comment.

As the M.S.X. instrument will record a bar 3-in. wide at 50-ft. quite clearly, it will not sound surprising that the writer located a lost anchor in Southampton Water after searching for 10 minutes.

The liner which had lost it during the early hours of the morning, sailed with it securely housed in the hawse-pipe the same evening.

The value of Echo work to the Harbour Officer desirous of getting about a harbour in a fog or "black-out" is immense, as the channel contours can be used by watching the Echo record and steering as requisite by compass to maintain the courses along them.

The writer knows at least one large British port where the "wreck chart" of the harbour has been much added to since Echo survey principles were instituted.

There are, however, still further applications of this instrument, one being the determination of times and places in tidal estuaries where silt in suspension is concentrated.

Not only is a light silty bottom distinguished from hard rocklike layers beneath it, but the record clouds at the points where silt in suspension — at certain concentrations — intervenes between oscillators and the bottom.

As the depth of this layer can be seen on the record, it is a simple matter to "visibly" lower a large "silt bottle" into this layer and take a sample.

Also it is possible to run lines across a certain critical section, at stated intervals, throughout, say, a 24-hour period at Spring tides and relate times in the two tidal cycles to the times of clouding, and also the depths at which this occurs.

It would appear, however, that for practical purposes the main avenue for improvement lies in the method of recording the bottom upon the wet starched iodine paper.

The makers of the instrument are, however, well alive to these problems, and research is proceeding apace.

One has no doubt, that the results will be no less complete and successful than those other achievements, so brilliantly embodied in the M.S.X. instrument.

The writer has had next to no difficulty over such minor details, and after over a year's constant use of this instrument he must, as a practical seaman and hydrographer, state it to be his considered opinion that the M.S.X. instrument is a real boon to a Harbour Surveyor and is, in his experience, the only instrument or device capable of giving an incontrovertible and readable accuracy to within 3-in. of depth over a range of 70-ft. under way.

In saying this, however, he would again reiterate that it is most necessary to such accuracy that all the factors affecting the depth record should be mastered and considered.

The resulting accuracy and increased frequency of survey cannot fail to commend themselves to the Hydrographic Surveyors responsible for the waterways of our Ports of Empire.