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Practical Nautical Surveying

Staff-Commander Thomas A. Hull R.N. ^a

^a Hydrographical Department , Admiralty

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LECTURE.

Friday, 14th June, 1872.

VICE-ADMIRAL OMMANNEY, C.B., F.R.S., in the Chair.

PRACTICAL NAUTICAL SURVEYING.

By Staff-Commander THOMAS A. HULL, R.N.,
Hydrographical Department, Admiralty.

THE object of this paper is to enable an Officer possessing the ordinary knowledge of his duties as a sailor and navigator, aided by the usual instruments found on board every man-of-war, to construct a plan of a bay or harbour, detect errors in the chart of a piece of coast line, or frame a report on a newly discovered island, rock, or shoal. Such contributions to knowledge, although standing only in the relation of sketches when compared with finished surveys, still may, in the absence of better information, be of great assistance to his fellow seamen, and qualify him for employment in a branch of the service which has been second to none in placing and maintaining the British Navy in its prominent position among the forces of civilization.

An Officer having passed his examinations for a Lieutenant may feel a desire to retain the knowledge he must have acquired in navigation, and may wish to gain some experience in nautical surveying. The first step to insure real success and self-reliance in the art, is to do what I am quite content to term *educating himself down to it*, by mastering such simplicities as every day arithmetic, since readiness in the first four rules, proportion, vulgar fractions, and decimals are of the greatest use to the practical nautical surveyor, and are in fact necessary to enable him to use logarithmic tables. Euclid's first four books, with a part of the sixth, algebra, as far as simple equations, are also required to enable him to use practical trigonometry. These studies may be lightened by practical geometry, as treated by Raper in pages 21 to 32 of his "Practice of Navigation," thereby gaining facility in handling those powerful instruments the scale and compasses. In working problems for practice in plane trigonometry, every triangle should be projected, and the problem solved by construction as well as calculation.

The ordinary problems of navigation thus handled elevate themselves

into nautical surveying. Take for instance a common day's work, in which (see Diagram 1) a vessel contending with adverse winds has made six tacks, which, corrected for variation and deviation give the following true courses, viz.: W.S.W. 16 m, S.E. by E. $\frac{1}{2}$ E. 10 m, W. by S. 11 m, S.E. 24 m, E.S.E. 10 m, and S.W. by W. 24 m. Draw the meridian line AD, and lay off from a known position at A an angle of $67^{\circ} 30'$, from south towards the west, Aa is then drawn, and made equal to 16 m, the first distance. At a , from aA , an angle of $50^{\circ} 37'$ is laid off towards the east, equal to $4\frac{1}{2}$ points, or the angle between E.N.E. and S.E. by E. $\frac{1}{2}$ E., and ab made equal to 10 m; at b an angle of $39^{\circ} 22'$ is laid off equal to $3\frac{1}{2}$ points, or the angle between N.W. by W. $\frac{1}{2}$ W. and W. by S., and bc made equal to 11 m; similarly the other angles and distances are laid off till the point C is reached, and CD is drawn at right angles to AD.

Supposing, as is often the case, no current has been experienced, a triangulation has been thrown over the water, the triangles being right angled; or the courses and distances represent the true bearings and distances taken and calculated from time to time in an ordinary survey. Assisted by the traverse table the triangles are worked out, and the position of C found trigonometrically; this is checked by comparison with the position obtained at C, by astronomical observations. The departure can be turned into diff.-long., and the sheet graduated as in the actual survey of a coast. Thus navigators become surveyors in spite of themselves, and triangulate without knowing they are doing so.

Necessary Geometry.—When in sight of land a common method of fixing a ship or boat is by observing two objects that are in transit, i.e., situated in the same line as the ship or boat, and taking an angle between them and some well known object to the right or left, taking care that the angle measured is not less than 25° . A line is then ruled through the objects in transit, any point is taken in it, and from this the angle observed is laid off in the direction of the third object; a line, ruled through that object, parallel to the line forming the angle, will intersect the line ruled through the objects in transit on the position of the ship.

Thus in Diagram 2, two points, D and L, whose positions are known, are observed to be in transit from a station P, and an angle LPD of 51° is measured between them and a third known point S; through D and L a line DLp is drawn, and at any point p in that line, an angle Dps, equal to 51° , is laid off towards S, and a line ps drawn; then through S a line SP is drawn parallel to sp, cutting DLp in P, the position required.

Diagrams Nos. 2, 3, and 4 illustrate certain questions in nautical surveying on which some time may be most profitably spent, as they represent the means whereby positions may be fixed, and are, therefore, of the greatest use to both navigator and surveyor, especially in the determination of positions afloat.

These questions are solved by means of the 20th, and the 21st, or 22nd propositions of the III, and the 5th of the IV books of Euclid.

The 20th proves that *the angle at the centre of a circle is double of the angle at the circumference upon the same base, that is, upon the same part of the circumference.*

The 21st proves that *the angles in the same segment of a circle are equal to one another.*

The 22nd proves that *the opposite angles of any quadrilateral figure inscribed in a circle are together equal to two right angles, and*

The 5th of the IV shows how to describe a circle about a given triangle.

Sailing along a coast three objects are observed—the tall chimney of a factory (C), a lighthouse (L), and the spire of a church (S), (see Diagram 2); the bearings and distances between these objects can be obtained from the chart. It is required to fix the position of the ship by angles measured from her between the points C and L, and also between L and S, the former being 15° , the latter 51° , the assistance of station pointer or tracing paper not being available.

Projecting by Circle and Line of Direction.—Join CS, and at C, on the opposite side of CS to that on which the ship is situated, make the angle SCD equal to 51° , or the angle subtended at the ship by the line SL. Similarly at S make the angle CSD equal to 15° , or the angle subtended at the ship by the line CL. The intersection of these lines gives a point D. About the triangle SDC describe the circle SDCP, and through L draw the line DLP, cutting the circle SDCP in P.

The point P will be the position required.

Join PC, PS; then DPC and DSC, being angles in the same segment, DSPC are equal; DSC was constructed equal to 15° , therefore CPL, the angle between the chimney and the lighthouse, must equal 15° . For similar reasons SPD and DCS, being angles in the same segment, DCPS are also equal, and LPS the angle between the lighthouse and the church spire, must equal 51° , and thus the position required has been found.

Projecting by Circles.—In the 3rd Diagram as one of the angles exceeds 90° another method must be followed. The angles measured in this case are 75° between C and L, and 118° between L and S.

From L and C on the same side of the line LC as that on which the ship lies, lay off the angles CLx and LCx , each equal to 15° , the complement of the angle subtended by CL; the intersection of these lines gives a point x , then with x as a centre and xL as radius describe the circle LPBC.

Subtract 90° from 118° , the angle subtended by SL, and from S and L, on the opposite side of the line SL to that on which the ship is situated lay off the angles LSy and SLy , each equal to the 28° thus obtained; the intersection of these lines gives a point y ; then with y as a centre and yL as radius describe a circle LPSD, cutting the circle LPBC in P.

The point P will be the position required.

Join PC, PL, and PS, then because y is the centre of the circle SDLP, the angle SyL at the centre standing on the same part of the

circumference SDL as LPS is therefore double of LPS . Now Sy/L , or the angle at y towards D , equals 236° , the angle at y inside the triangle Sy/L having been made equal to 124° , therefore the angle LPS equals $\frac{236^\circ}{2}$ or 118° , the angle required; and because x is the centre of the circle $LPBC$, the angle LxC at the centre standing on the same part of the circumference LC as LPC is therefore double of LPC ; now LxC by construction equals 150° , therefore LPC equals $\frac{150^\circ}{2}$ or 75° , the angle required.

A third circle may be drawn through C and S , its centre being on the opposite side of the line CS to that of the station L , having an angle at the circumference equal to 167° , or $360^\circ - (118^\circ + 75^\circ)$; this circle, by cutting either of the others more directly, determines the point P with greater exactness.

In working for practice the above examples should be solved by calculation as well as construction.

The position of a ship may always be found by the method shown in Diagram 3, or by the intersection of the circles, but in many cases with one large angle (but less than 90°), and a small angle, or with two small angles; the method shown in Diagram 2, however, will be found more convenient.

Care must be taken that the objects used in fixing a position are situated in such a manner that the centres of the circles used in the 3rd Diagram to find the point P are sufficiently remote, as otherwise the circumferences will so nearly coincide as to render it difficult accurately to determine the points of intersection; or that in the 2nd Diagram, D and L are sufficiently remote to ensure the true direction of the line DLP being accurately ruled, as if these points fall too near to each other, a small error in the observed angles will cause a large difference in the position of P ; and if the point P cannot readily be found by projection, be sure that no station-pointer or tracing-paper can more easily discover it, and an inexperienced surveyor may bring on board a chart on which the positions of shoals may be erroneously placed, owing to his trusting to three points so situated as to fully mislead him.

On the Circle.—The 4th Diagram may serve to illustrate the difficulties alluded to. It is an instance of a position in which the inexperienced occasionally find themselves known technically as “on the circle.”

This occurs when the positions of the observer and of the objects observed, lie actually or very nearly on the circumference of one and the same circle. In the 4th Diagram for instance, the circle passing through C , L , and S , passes also through P , the observer's position; the angles being 15° and 57° . The small angle LSC is therefore equal not only to LPC , but, to any angle in the segment $CPSL$. In like manner, the large angle LCS is equal not only to LPS , but to any angle in the segment $LCPS$. Laying off the angles on the opposite side of the line CS , as in the second diagram, to find point D , the triangle thus projected must coincide with the already known triangle SLC , and point D coinciding with point L , no line of direction

DLP can be drawn. If the method of the intersecting circles in the 3rd Diagram is used, the centres x and y must also coincide, because the objects and the position of the observer all lie on the circumference of the same circle.

Round the segment CPS, endless time may be wasted with station pointer or tracing paper in a fruitless endeavour to find the position of P, because, as shown above, CL and LS must subtend angles of 15° and 57° respectively, to any point taken in the segment CPS.

No other object being in sight, the only friend is the mariner's compass, as a bearing taken of one of the points, as of C, N.E., by E., can alone fix the position of the wandering angles.*

In the selection, therefore, of three points to fix a position by, the middle object should, if possible, be the nearest to the observer, or the three objects should be in or near the same straight line, or the observer's position should be within the triangle formed by the three points. But in all cases of doubtful or badly placed points, a third angle, if it can be obtained, or a simple compass bearing of one of the objects, should always be taken.

The 4th Diagram will also show the advantage of using what may be termed a danger angle. Thus, if a rock, the "Torpedo," is known to lie off a coast that has been fairly surveyed, and of which the points can be recognised with certainty, then by taking care on passing the neighbourhood not to increase the angle subtended by too well-defined points as C and S beyond a certain number of degrees, in this case 72° , it will be impossible to approach the shoal. An angle of this sort measured between the Carnero and Frayle towers would have prevented the "Agincourt" touching the Pearl rock; and had the "Lord Clyde" been kept with Pantellaria subtending four to five points, instead of being allowed to close the island until it subtended eleven points, her narrow escape from shipwreck would have been avoided.

Practice on Board Ship.—When making a passage, let every opportunity be taken of observing for time, latitude, and variation. In arriving at the results, avoid applying to the Navigating Officer for such matters as the course and distance between sights and noon, but obtain the required data from the deck log-book, and compare the position thus found, with that entered in the log-book. By night the stars should be studied, the names and positions of the principal learnt, and on moonlight nights latitudes from altitudes of stars north and south of the Zenith obtained, with frequent observations in the northern hemisphere of the Pole star.

Time should be found by observing stars just before sunrise or after sunset.

Lunars taken both east and west of the moon, form capital practice in taking angles and using the sextant in awkward positions. The working out of all the above observations affords excellent practice in figures. The dead reckoning should be carefully worked, and daily

* Where a couple of angles are taken to fix a ship running along a coast, or in a harbour, a compass bearing should always be observed at the same time.

current found by comparison of the position obtained from dead reckoning, with that determined by observation.

A track chart of the voyage is another useful piece of practice. I don't mean a chart copied from that in use, but one constructed for the purpose from the table of meridional parts, merely fixing upon it the land that has been seen during the voyage.

On leaving the land be careful to fix the ship and obtain a departure from which to begin the dead reckoning, and on making the land take the first opportunity of fixing the ship's position, thus obtaining an idea of the correctness of the landfall.

All the above work should be carefully entered in a sight-book and work-book, every day's doings in both books being fairly headed by the day of the week, month, and year. Many valuable observations have been lost through omitting to note date and place.

The results, viz.: course and distance run, latitude and longitude by dead reckoning, latitude and longitude by observation, bearing and distance of the nearest land, current experienced, should be fairly written out at the foot of each day's work.

A table of the errors and rates of the chronometers, and a deviation table should also hold places in the work-book.

It may be remarked that this is navigation and not surveying. The answer to such a remark is, that practical nautical surveying is the essence of practical navigation, and a constant attention and practice of the latter is a sure method of acquiring a true knowledge of the former.

Seamanship.—In the studies above mentioned the duties of the sailor are by no means to be neglected, and every opportunity should be taken of handling the ship, and observing how she may be conducted in or out of port. No man can expect to attain a trusted position as a nautical surveyor who is not a good sailor, or, to speak more exactly, pilot, knowing the requirements of a ship, and the room she wants to wear, stay, and anchor in. The first lessons of this art are to be learnt in boats—I don't mean mere boat sailing, racing, &c.—but the handling of boats under oars and sail, in fair weather and foul, allowing for the velocity of running water, picking up the ship under weigh, using the anchor, landing in a swell on a rocky, and beaching the boat on a sandy coast. No opportunity should be lost of acquiring this knowledge of boats.

The Sextant.—I have alluded to the power of the compasses and scale when working on paper, the instruments corresponding to these when working on the land or on the water are the sextant and lead-line. The sextant now common, but no less invaluable (whose inventor may be looked upon as one of the greatest benefactors to his race), is to the nautical surveyor what the mariner's compass and anchor are to the navigator and sailor.

It becomes necessary to speak thus of the sextant, because inexperienced men are inclined to look on the theodolite as the nautical surveyor's principal tool. The theodolite can only be used on shore, but the sextant can be used either on shore or afloat.

The nautical surveyor should therefore lose no opportunity of making himself thoroughly conversant with this useful instrument, understanding all its adjustments, peculiarities, causes of error; the size of angles to be safely measured with it, and the means of re-quick-silvering its reflectors.* With the assistance of the sextant, the lost end of the Atlantic cable was found, and without it no ocean can be properly sounded or telegraph cable fairly laid.

When in port, lying at anchor, a simple exercise in using the sextant is to take a round of angles, consisting of six or more, between distinctly seen objects lying nearly in the same horizontal plane, and see how near in addition they may be brought to 360° . Handle the sextant both ways, inverted as well as direct; many objects from being indistinct cannot be reflected from right to left, and the left hand object that can be reflected, must in such case be used. This is often the case in actual practice.

Every opportunity should be taken of fixing the ship on the chart by bearing and angle. Taking it for granted that the harbour in which the vessel is anchored is well surveyed, it is good practice to take angles to the different points, peaks, and islets, and laying the same off from the ship's position, to see if they agree with those on the chart. True bearings of objects, both right and left of the sun, should be frequently observed for practice, taking care that the angle measured between the sun and the object, is always double the altitude of the sun.

If angles are taken between two objects close to each other, care should be taken that they are on the same level, or that the angle measured is nearly horizontal; with large angles, it is of little consequence that the objects used are not on the same level, as the error caused by obliquity is in these cases small.

The Arc of Excess.—It is good practice to measure small angles off as well as on the arc; the arc of excess in most sextants is 5° . Observed masthead angles will generally be less than 5° , and angles of elevation taken to peaks on making the land will always be less than 5° . Taking the angles off and on the arc, adding them together, and dividing by 2, gives an angle free of index error. At sea, measuring the sun's semi-diameter, and comparing that obtained with that given in the Nautical Almanac, renders the observer dexterous in observing small angles with the sextant. If the object is clear and well defined, the inverting tube will be found of great assistance.

Lose no opportunity of volunteering to lay out targets by the mast-head angle, taking the angle both off and on the arc of the sextant, that being one of the methods used in nautical surveying for determining an approximate base. When the target is moored, if time permits, get a round of angles from it; these plotted on the plan of the harbour will afford an opportunity of testing the accuracy of the base obtained from the mast head angle, taking care to fix the ship's position for the way in which she may be swung, either on leaving or returning on board. The distance of the target may also be checked by using the length of the ship, or a line drawn from her knight-heads to her taffrail as a base

* See Sir E. Baker's treatise on Nautical Surveying, page 10.

line. The great length of the modern ironclads presents the advantage of a large base in this direction. Two points, one at each end of the ship are taken as far apart as possible, from which two observers can easily see each other; these points should be carefully marked, and the distance between them known and noted for reference. Angles between moderately distant objects and observers standing at these points, can be taken simultaneously from each end of this base, and from these, the required distance may be obtained. This subject of "Base by ship," with useful tables, has been fully treated of by Admiral Ryder in his book, "On Ascertaining Distances from Ships at Sea," a useful little work for the practical nautical surveyor, and which is supplied to every ship.

Practice of Sounding in Boats.—The lines pulled in laying out the target may be also sounded, the lead line being measured on leaving and returning to the ship. The time must in this case be noted, so that the soundings may be reduced to low-water spring-tides, as those on the chart are all given for that state of the tide. To ensure the line thus sounded being a straight line, the ship should either be kept in transit with some object beyond her, or two points that are in transit in the direction towards which the target is to be laid, should be selected before leaving the ship. The soundings obtained, compared with those marked on the chart, will give evidence of the correctness of the work.

This performance will also show that some little practice and method is required on the part of the man heaving the lead from the boat, and also on the part of the Officer, to determine, first when an "up and down" cast can be obtained without lying on the oars, and secondly, when it may be necessary to stop the boat altogether. In the boat, as in the ship, the end of the lead-line should always be secured before beginning to sound, and care should be taken that "a boat's lead" is taken from the ship for this work, with the necessary tallow for arming, as the nature of the bottom should always be noted.

Measuring Distances by Sound.—The morning and evening gun fired at most ports will afford an opportunity of practising measuring base by sound. The ship being fixed, her distance may be measured on the chart from the fort where the gun is fired, and compared with the result obtained by noting the interval of time between the flash and report of the gun. (See page 729.)

The Standard Compass.—No opportunity should be lost of being present when the ship is being swung for local deviation. The practical rules for ascertaining and applying the deviations of the compass caused by the iron in a ship should be carefully studied, the Officer thereby acquiring a thorough knowledge of the use of that heart of a ship, her standard compass. This instrument is of the greatest assistance in examining a portion of a coast, making a rough sketch of a bay or harbour, or sounding round islands and shoals that may require examination in the course of a voyage.

Artificial Horizon.—In using the artificial horizon care must be taken in pouring out the quicksilver. Sir Edward Becher, at page 8 of his "Nautical Surveying," gives the following useful hints:—"Place the finger over the orifice of the bottle, and give it a shake in an inverted position, holding it over the trough previously cleaned. Ease the finger, and allow the mercury to flow gently, keeping the bottle inverted, and taking care to stop the opening of the bottle before the last portion with the dross flows. This will produce a clear brilliant surface."

In pointing the horizon towards the sun, see that the shadow is thrown directly behind it, and not on either side. The spot chosen for making these observations should be sheltered from the wind, and, to be free from vibration, removed from traffic. The roof of the artificial horizon should be so placed that the same part is always towards the observer. A mark may be made on the glass or on the frame work to insure this precaution being carried out.

Observations at Night.—Obtaining latitudes at night with the artificial horizon requires some practice; see that it is placed in the true meridian before the observations are commenced. A handy man should be trained to hold the dark lanthorn, by which the observations must be first noted by the watch, and then read from the sextant, in such a manner that, while the assistant who is taking time can see the watch, no light is thrown in the direction of the artificial horizon. On the time being secured, the light is taken to the observer with the sextant. Practice is required both in holding the lanthorn and in reading off.

Astronomical Observations.—Every opportunity should be taken to practise the rating of chronometers by equal altitudes, failing that, by a.m. or p.m. sights, taking care to work a.m. with a.m. and p.m. with p.m. In making these observations, the eye-piece of the inverting tube should, if possible, be used instead of the shades of the sextant; if shades are used, endeavour always to use the same. The meridian altitude of the sun should be taken with the eye-piece, as the latitude obtained from it can then be measured more satisfactorily with those determined by the stars.

To obtain latitudes from sun and stars, circum-meridional altitudes are generally used, taken from 20 minutes before; to 15 minutes after, the meridian passage, working them out by the method given in Inman's Tables, Introduction, page IX. The approximate mean times of the meridian passages of sun or star should be calculated from the "Nautical Almanac," the error on mean time of the watch in use should then be applied to them; these times of the meridian passage of sun or star, as shown by the watch in use, should be entered in the sight book as a guide to the observer. When at sea, stars of the first magnitude are generally taken; but on shore those of the second magnitude may be advantageously used. The study of the position of the stars at sea, before advocated, will now be found of the greatest assistance.

In the northern hemisphere, several sets of observations of the Pole-

Star may be taken to work against latitudes from meridian altitudes of stars south of the zenith. In the southern hemisphere, stars both north and south of the zenith must be taken, and the latitude determined from their mean result.

The watch used on these occasions should for the day be carried in a box, and not kept in the pocket, care being taken to compare it with the standard chronometer on leaving and returning to the ship both in the forenoon and afternoon.

Drawing is a useful accomplishment to a surveyor, but the mistake must not be made that a draughtsman is a surveyor. Sir Edward Belcher has remarked that "any draughtsman can make a neat showy plan, but it is useless if it cannot stand the seaman's test." If the Officer has a natural talent for drawing, let him by all means encourage it, copying plans of ports from published surveys, and practising the signs and abbreviations adopted in the Admiralty charts and used by the Admiralty draughtsmen, in all cases confining his abilities to the bare facts before him. Few mistakes are more mischievous in a survey than those committed by the accomplished draughtsman who allows his fertile fingers to wander from his facts, and to produce a *pretty* plan instead of a *trustworthy* survey.

Sketches of headlands should be made on leaving and making the land, taking care that magnetic bearings of well-defined peaks and points are always obtained and inserted on the sketch. Sketches of leading and clearing marks are also most valuable, the magnetic bearings being written against them. In harbour, panoramas from the ship should be drawn, the surveyor confining the work to the land only, and avoiding sketches of boats, or shipping, remembering that the object in view is not a picture, but a ground plan or survey of the port.

When sailing along a coast, it is good practice to observe how the points, peaks, and prominent features of the land change their aspect with a change of bearing. To know a place as the same when the bearing has changed some eight points, is a difficult matter to beginners, but is of great value in nautical surveying. This knowledge may be acquired by vigilantly watching the prominent points and observing the gradual change. Although mistakes will frequently be made, and the most promising points turn out failures, becoming lost and undistinguishable, yet those that are recognised will fully repay the trouble bestowed upon them.

Equipment of Boat.—It is supposed that a boat has been granted for the purpose. Care should be taken in her equipment. Dockyard rigs are the best, and all fancy rigs should be avoided. A spare hand should be asked for when sounding is to be undertaken. The following list of gear will be found useful:—

Two leads and lines, the latter marked to feet as far as 5 fathoms, one line being 40 fathoms long; the leads, one to weigh 14 lbs., and the other 7 lbs.; a spare lead of 7 lbs.
Anchor, with cable of 30 fathoms.

Yoke lines sufficiently long to allow of the boat being steered by the feet.

Bag of lime, whitewash-brush, bucket, and bailer. Slow-match. Matches. Strand of junk for stops. Old canvas or old black bags to make marks on the shore. Tallow for arming.

Two slung 56 lbs. pigs of ballast for mooring-buoy. An axe and crowbar.

Boat's compass, pocket compass, sextant; patent log fitted, so that the box part may be lashed on to the gunwale of the boat, a longer fly line being required; note book, sketch book, drawing instruments, small board, tracing paper, penknife, india-rubber, haversack, telescope or binoculars, watch, pocket sextant, slings for sextant box, and a station-pointer if it can be obtained.

Two barécas, one with water and one fitted as a buoy.

Practical Hints.—As there is generally a little climbing to be done in nautical surveying, and as there may be difficulties in landing, it is advisable to have the sextant case, glass, &c., fitted with slings to put over the shoulder, the note book, &c., should be kept in a haversack to be carried by the Officer. This ensures the hands being free in climbing, landing, and embarking. If instruments are being carried in the boat, they should be placed on the gratings at the bottom of the boat, and not on the thwarts, thereby avoiding the risk of injury from falling. Cushions and all dandy gear should be left on board the ship, as they will only be found in the way. The men should be in clean working dress, with blanket frocks in the tropics, and trained to be handy in taking off their shoes, not to be afraid of wetting their feet if necessary in landing or embarking, the Officer setting the example, being as ready to risk his comfort in surveying as he would be in shooting. Gun, powder, and shot had better be left on board the ship, the gun complaint being very dangerous to the real success of the nautical surveyor.

The Boat's Crew.—It will be of great assistance to an Officer thus training for practical surveying, to study the men who compose his boat's crew.

Let him make himself acquainted with how far they can fairly pull in a day's sounding, exercise them in lowering and hoisting the sail, tacking, and wearing, getting the mast up and down, as smartness in these matters will often give them a spell from the oars, and enable the Officer readily to find the position of a shoal cast, obtained in a line of soundings.

Without descending to what is called philanthropy, courting popularity, interfering too much with their domestic arrangements, or in any way departing from the necessary discipline of the service, let him interest himself in their habits of comfortably getting their breakfast before leaving, and their supper on returning to the ship. As taking their dinners already cooked away in the boat greatly facilitates the work, let him at first see they get their gear into the boat for this purpose, so as not to find when three miles to leeward of the ship that the rum, biscuit, or water has been left behind.

The boat's crew will soon learn to look after these matters, and although it will always be the Officer's especial business to see there is fresh water in the boat, the men themselves must be made to answer for such articles as rum or biscuit. In arranging the work for the day, if opportunity offers, and the nature of the coast permits, let him foresee where they may be landed during the dinner hour, as such a change forms a pleasant break, and taking a pot away, driftwood may be found, and the dinner warmed up.

The coxswain will probably soon be able to assist the Officer in noting, one of the crew will quickly learn to watch the tide pole, others will pick up the method of measuring the base-line and prove sharp in pointing out transits that are coming on or stations that there may be a difficulty in discerning.

Thus interest begets interest, and the Officer will soon find himself surrounded by hands and eyes ever ready to assist him.

In Nautical surveying, as in all other arts, it is attention to small matters that mainly secures success. No work or duty should be despised because it is small or trivial. A glance at nature will show that nothing is beneath the notice of the Great Surveyor of the Universe, the microscope proving that the mechanism of the spider and the bee are as well ordered and as exquisitely finished, as the mechanism of man.

Having thus shown some of the preparatory studies and exercises necessary to qualify an Officer to undertake a small survey, an attempt will now be made at a plan.

The Triangulation of Plymouth Sound.—Plymouth Sound has been selected as a model harbour on which the principles of triangulation and sounding may be explained. The breakwater will be supposed to be a natural instead of an artificial creation and formed of sand instead of stone; its position, sandy beach, &c., causes the surveyor to use it as an "Observatory island" where he can get his sights, put up his tide pole, and measure his base. The first day may be devoted in pulling or sailing if possible round the Sound, erecting stations on the prominent points, and acquiring a general knowledge of the locality that will be found very useful in the course of the work.

Stations may be erected by whitewashing points of rocks, and building cairns of stones, which must be always whitewashed. Driftwood will often be found of which good marks may be made. An old hammock lashed at the head and foot to cross-pieces of wood and these lashed on to an upright about the length of a boat's mast, the heel secured by a pile of stones or by driftwood, or an old bag stuffed with leaves and lashed to the pole, the whole being whitewashed on the sea face, form marks easily seen and recognized. Advantage should be taken of buildings erected in prominent positions which may be made stations of.* As a rule, round buildings will show out better than square ones,

* In the Syrian survey the Nebys or small Mahomedan tombs built on the hills and along the sea shore being generally dome-shaped and whitewashed, proved of the greatest service.

and in erecting stations, care should be taken not to place them in positions where they are likely to be shaded from the sun.

In carrying on the survey, work as much as possible with the sun at your back; thus, in the Sound, the angles should be obtained on the eastern shore in the forenoon and on the western in the afternoon.

The result of the first day's work has been to fix upon the following prominent points on which stations have been erected where the position is not sufficiently marked by natural or artificial means (see Plymouth Sound triangulated):—

The Mewstone, the Shagstone, the rifle-butt on Staddon Heights, Mount Batten, Drake's Island, the Hoe, Devil's Point, Ravenness Point, Picklecomb Point, Maker Church, Cawsand, Penlee Point, Folly Hill, Rame Chapel. The Breakwater Lighthouse, will be named as the Observatory Station and the Beacon the east base; the supposed beach between these two stations on Observatory Island affording at low water an eligible flat on which to measure the base.

Surveying a port where the names are unknown, points, islands, bluffs, &c., taken as stations, should all be named, and the practice of lettering or numbering be avoided; naming each station after some incident connected with it or its character, as Cliff Station, Beach Station, Bay Island, Leading Hill, Bald Mound, or Dead-tree Bluff; this precaution will be found of great assistance to the memory in the course of the work.

Observing the Angles.—Starting as early as possible from the ship for the Mewstone, so as to work on that side of the Sound in the forenoon, the soundings between the East base and the Shagstone give indications of shoal water in that channel. Arrived at the Mewstone and the summit gained, a true and magnetic bearing of some low but prominent station as the Observatory, is the first thing to be obtained. The rifle butt on Staddon Heights is then evidently the best object to reflect round and use as a zero or initial point of the angles to be measured, taking care not to reflect it to objects at the water-line that are within 20° ; such, for instance, as East base, as in that case the obliquity of the angle may introduce an error.

Angles are then measured to Drake's Island, Devil and Wilderness Points, which will make as entrances to Hamoaze. Ravenness Point, which will probably show out black against the trees behind it; Picklecombe Point, distinguished by its fort; the Observatory Station; the Shagstone, Maker Church, Cawsand, Folly Hill, and Penlee Tower (which two last will be nearly in line), Penlee Point, and Rame Chapel: East base will then be reflected to the Observatory, thus completing the angles to stations from the Mewstone.

Angles will next be taken between the Observatory and the tangents* under Staddon: thus Reny Point will be reflected to the Observatory, then each side of the island off it, then Staddon Point, which will be probably seen over Reny Point, the words "seen over" being written in the angle book. The nearest part of Wembury Point, the bight

* Tangent is a term used in surveying describing a line drawn from the eye to touch the points of the coast, or the edges of reefs or shoals; an angle being measured between that line and one drawn to a station or fixed point.

between it and Reny Point; the bight of Bovisand Bay also "seen over," and the east tangent of Observatory Island. The rifle butt may now be used and taken to prominent points on the Cawsand Bay shore, such as bluffs, cliffs, patches of sand, conspicuous houses, extremes of beaches, and anything that there may be a probability of again recognizing. The coast guard under Lower Hams, the rocks at Pier Cove, will probably show out. The cliff at Amory Bight, the neck of Rame Head and its outer tangent will complete this part of the work. A few angles should then be taken to the prominent hills and their shoulders, the run of the valley behind Cawsand, and the fall of the hills over Ravenness, so as to give some idea of the topography. A rough plan should be sketched of the Mewstone and its vicinity with the rocks off it, lines being taken to the little Mewstone.

The Shagstone will next be visited and a few angles taken to ensure giving some idea of the adjacent coast. From the Shagstone, pull as close along the shore as possible, sounding, noting the courses steered, the distances run, and sketching the nature of the shore. Arriving at Staddon Point, the heights must be ascended, and angles taken from the rifle butt on the same system as that pursued at the Mewstone; taking care to stand as nearly as possible in the position or against the same part of the butt, to which, and from which, the angles taken at the Mewstone were reflected. In visiting the other stations similar care must be taken, as it is of the greatest importance that the angles should be measured from the exact point to which they were taken; Mount Batten will here form a good object to reflect as far as Penlee Point, after which Penlee Point itself should be used to get the angles round to the Mewstone. In thus shifting the object reflected, care must be taken that such objects are always connected; in this case, for instance, the angle between Mount Batten and Penlee must be carefully measured.

Angles are then taken to the bight of Jenny-cliff Bay, the high and low tangents of Drake's Island, with the cliffs, bluffs, houses, and conspicuous points taken from Mewstone. From the rifle butt a panoramic sketch of the Sound should be made to the best of the Officer's ability; never mind how rough may be the production, it will often serve to remind him of points in the work and prove most useful to him in projecting the survey.

Mount Batten will next be visited, the coast between Staddon and Mount Batten being pulled along and sketched in as before. Maker Church will here form a good point to reflect, taking care to use the Observatory when observing to points, &c., under the Church, and also to observe from that part of Mount Batten to which the angles were taken.

Thus each station will in turn be visited, the angles obtained, and the coast pulled along and sketched in between.

True and magnetic bearings should if possible be observed from one of the stations in the afternoon, to check those obtained from the Mewstone in the morning.

It should be arranged, if possible, that the angles from one of the stations visited in the day should be taken at low water, when, what is

called low-water tangents, or lines from the station to the low-water extremes of the coast with its rocky or sandy points and beaches, should be obtained.

If in the port during spring tides, the greatest trouble should be taken to obtain these necessary lines from at least three prominent positions.

Getting out the Triangles.—Supposing that all the stations have been visited and the angles obtained, the next process is to get out the triangles it is intended to use, commencing with one of the largest, in the following manner:—

TRIANGULATION OF PLYMOUTH SOUND.

No. of triangle.	Stations.	Angles observed.	No. of triangle.	Stations.	Angles observed.
1	Mewstone	59 55	7 ..	Rifle butt	38 00
	Penlee Point.....	40 45		Penlee Point.....	55 20
	Rifle butt	79 20		Maker Church†....	86 40
		180 00			180 00
2	Mewstone	46 40	8 ..	Drake's Island	63 30
	Penlee Point.....	68 50		Rifle butt	51 35
	Drake's Island	64 35		Observatory	62 00
		180 05			180 05
3	Penlee Point.....	28 05	9 ..	Drake's Island	115 55
	Rifle butt	66 15		Mount Batten	36 50
	Drake's Island	85 40		Observatory	27 15
		180 00			180 00
4	Drake's Island	52 26	10 ..	Drake's Island	80 15
	Rifle butt	44 45		Mount Batten	62 45
	Mount Batten	82 45		East base	37 00
		179 56			180 00
5*....	Drake's Island	138 00	11 ..	Observatory	83 40
	Penlee Point.....	10 46		East base	60 35
	Mount Batten	31 15		Drake's Island	35 40
		180 01			179 55
6	Mewstone	27 00	12 ..	Observatory	21 55
	Penlee Point.....	96 00		East base	130 35
	Maker Church† ..	57 00		Rifle butt	27 30
		180 00			180 00

And so on for the minor stations.

* Ill-conditioned triangle.

† Calculated angle.

As some points in a survey, although they may be prominent positions in the plan, are likely to be inaccessible, trees or other causes preventing the angles being observed from them, triangles which have one of these stations at their angles are said to possess a calculated angle, as such angles can only be obtained by that method; greater care is therefore used when taking an angle to a place that cannot be visited. In this survey Maker Church and the Folly Hill are fixed by calculated angles. In tabulating the triangles, such angles should be written in red ink.

It is evident that if the angles have been correctly taken at the several stations that the sum of these angles will be for each triangle 180° . Instrumental error, obliquity, personal error, and other imperfections generally prevent this happy result, and the Officer may be content if his sums are not less than $179^\circ 55'$ or more than $180^\circ 5'$.

The method of getting out the angles of these triangles is as follows:—In triangle (2) at the Mewstone, Staddon rifle butt was taken to Drake's Island, the angle being $13^\circ 15'$, and then to Penlee Point; the angle being $59^\circ 55'$, from which $13^\circ 15'$ being taken, leaves $46^\circ 40'$, the angle required. This process may be termed the reduction of the angles. But it may be asked, why was not Drake's Island taken at once to Penlee? Because Drake's Island, having the buildings of Plymouth behind it, was a bad object to reflect and the rifle butt was a good object to reflect; also it was not advisable to shift the zero.

At Drake's Island we have Penlee Point taken to the Mewstone, Penlee being a good object to reflect, and at Penlee we have Mewstone taken to Drake's Island for similar reasons.

In some of the triangles the angles will be found at once in the angle book, and from most of the stations used in the triangulation the angles required will easily be obtained by simple reduction. If these calculations are made at the main stations in the course of the work, much after-trouble and vexation will be prevented. For instance, if in getting the angles at Penlee, having already observed the angles at the Mewstone, the rifle butt, and Drake's Island, the triangles Nos. 1, 2 and 3 are proved on the spot, the angles at Penlee are at least certain of being taken correctly, and any error will be known as not to have been made at that station. At the same time the numerous small sums required to be worked will show the necessity—remarked upon in the commencement of this paper,—for the would-be nautical surveyor educating himself downwards, and mastering such simplicities as every-day arithmetic; thus the roots of his work, like those of the oak, penetrating the soil more deeply than those of other trees, ensure to his labours a solidity and durability similar to that attained by the monarch of the forest.

All the angles of the triangles having been sorted in the above manner, any error in the observation will be readily detected and such triangle scored as faulty; the angle wherein the error lies may possibly be detected in the course of the work. Triangles having an angle in them of less than 25° are to be looked on as ill-conditioned, and more than usual care should be taken in laying off and ruling a line likely to cut another at a less angle than 25° .

Projecting the Triangulation.—The work taken from the ground, or

the angles and observations obtained by the above system, has now to be projected or placed upon paper. Drawing-paper of the size required may be stretched in readiness. This process is well described by Heather in his *Treatise on Mathematical Instruments*, page 64 of the seventh edition.* It is a good plan to first form some idea of the bay or harbour by a rough plan projected on a sheet of common cartridge paper.

A prick made on the lower right hand corner will represent the Mewstone, through which draw a long straight line parallel to the perpendicular edge of the paper to represent the true meridian, and another line at an angle of $21^{\circ} 25'$ to the left for the magnetic meridian. The true bearing of the rifle butt, N. $19^{\circ} 15'$ W., obtained by reduction, or its magnetic bearing, N. $2^{\circ} 10'$ E., if no true bearing has been obtained, is next laid off. An estimated distance of the rifle butt from the Mewstone has been formed by its being about as far from the Mewstone as the ship, which latter distance (Mewstone to ship) was determined by mast-head angle. Using this as an approximate base, the rifle butt is taken at $2\frac{1}{4}$ miles from the Mewstone, which at 6 inches to the mile equals $13\frac{1}{2}$ inches; a prick is therefore made on the line drawn to the rifle butt from the Mewstone at that distance to represent the rifle butt.

At the Mewstone an angle of $59^{\circ} 55'$ is next laid off from the line to the rifle butt, in the direction of Penlee Point. At the rifle butt an angle of $79^{\circ} 20'$ is next laid off from the line to the Mewstone in the direction of Penlee Point; the intersection of these lines if carefully drawn will be Penlee Point; on this intersection the protractor should next be laid and the angle measured on the paper between the Mewstone and the rifle butt; if this is $40^{\circ} 45'$ the work is right, a prick should be made in the paper to represent Penlee Point, and the projection may be proceeded with, but do not leave Penlee Point without feeling sure that the angle between the Mewstone and rifle butt measures, as nearly as the protractor will show, $40^{\circ} 45'$, which was the angle observed there.

From the Mewstone and Penlee Point the angles $46^{\circ} 40'$ and $68^{\circ} 50'$ are next respectively laid off and the converging lines drawn, their point of intersection will be Drake's Island; here repeat the operation of testing the angle at Drake's Island, being sure it contains the proper number of degrees, viz., $64^{\circ} 35'$. Four points, the Mewstone, the rifle butt, Penlee Point, and Drake's Island, now appear on the paper. The work is further tried by another test on the following plan:—At Drake's Island the angle measured between Penlee and the rifle butt was found to be $85^{\circ} 40'$; $85^{\circ} 40'$ is accordingly laid off at Drake's Island from the line to Penlee Point and a line drawn to the rifle butt; if this line does not fairly pass through the prick in the paper representing the rifle butt some error has been made, and the work must be carefully gone over again to discover the mistake. Should it pass fairly through the rifle butt the work may be proceeded with, but woe to the tyro who fails to insure the accuracy of his first four points.

Maker Church, Mount Batten, the Observatory, and East Base are

* A useful work to the practical nautical surveyor, published at 1s. by Virtue Brothers and Co., 1, Amen Corner, Paternoster Row.

next fixed on similar principles, and then the minor stations, until the whole network of the triangles is laid down, remembering that no station can be considered as fixed before it has been fairly cut in from three or more well-determined stations.

Caution.—This is main triangulation, and if this is carefully and honestly projected, the rest of the work will fall into its place with ease, and that important part of the survey, the soundings, will be readily laid down; but no words can express the confusion worse confounded, the chaotic mixture of right and wrong, the untold annoyance, vexation, loss of temper, and temptation to fudge that will assuredly arise, if in these apparently minor and simple details, the greatest care is not taken, and every effort used to insure accuracy, in thus laying the foundation of the work.

Straight Lines.—I dwell forcibly on these common place matters, apparently adapted to the simple capacity of the industrious, from observing the difficulty most beginners find in drawing a straight line. To draw a long straight line requires all the attention of the practised surveyor. Heather, in his treatise on mathematical instruments, at page 66, gives some excellent rules on drawing lines. Rulers must be tested to see that they are straight, and surveying vessels are supplied with a plain steel ruler, known as a straight edge, used solely for the purpose of drawing straight lines.

To ascertain that a Ruler is Straight.—Carefully draw on a flat table between two points marked on the paper a line nearly as long as the ruler, first with the edge of the ruler turned towards you, and then with the edge of it turned from you. If the ruler is true the lines will coincide, but if not they will enclose a space.

Detail.—From the fixed stations the angles taken to conspicuous houses, trees, peaks, and cliffs, with the tangents of the points and islands, and the lines to the bights of bays and extremities of beaches are laid off, cutting the objects in, if possible, from three stations, the islands being drawn within the limits enclosed by the tangents, as in the case of Drake's Island and the Mewstone; such secondary points fixed, the coast line sketched in the boat while pulling round the sound from station to station, will be easily laid down. The fixed peaks, with the panoramas sketched from two or more points will permit of some idea of the topography being given, and thus the detail of the work will be completed.

Sounding.—We now come to the most important part of a nautical surveyor's duty, on which his character mainly depends, viz., the soundings. Without these figures the work before described is of little service to the sailor. A plan of a port without soundings may be compared to a pretty purse with no coin in it, useful only to him who knows how to fill it.

The importance of sounding is not sufficiently considered by young surveyors. They have a superstition that any fellow can sound, and

Officers wishing to obtain an insight into nautical surveying have been disgusted at being sent to learn to sound. But while the land work may be done by the soldier or civil engineer, the sounding is the sailor's portion, requiring all the ready wit and tact of his profession. In sounding the sailor has to manage air and water, the rise and fall of the tides, the velocity of currents, and to fit in his work to suit wind and weather; these forces becoming firm allies to the man who studies them, and foes only to him who knows not how to use them.

The Lead Line, by means of which the soundings are obtained, should be looked upon and treated as a valuable instrument, and, therefore, to be used for no other purpose but sounding, except in the absence of a chain for measuring a base line, or ascertaining the height of a cliff.

A good plan is to take for this purpose a ship's line that has been some little time in use, and is therefore well stretched, marking it to feet as far as five fathoms, on the same principle that the ordinary line is marked to fathoms, with 2 knots at 20 feet, and a bit of leather at $\frac{1}{4}$ fathoms, or 24 feet.

The line should be always measured on leaving and returning to the ship. If obliged to use a new line, and shoal water is found, the line should be remeasured in the boat, on the boat-hook marked to feet*. Men should be accustomed to heave the lead from the boats, and should be narrowly watched when fresh at the work, in order to ensure their giving the correct soundings. The foremost awning-stanchion shipped forms a good support to the leadman's breast rope. The end of the lead line is to be secured before beginning to sound, and care should be taken that all hands take a fair turn at the lead.

Noting.—The soundings should be noted at equal intervals and distances. If a patent log cannot be obtained, this must be done by the judgment of the Officer, by time or strokes of the oars. Under five fathoms the lead should be hove continuously, and the boat's position fixed near the three and five-fathom line at low water on approaching and leaving the land.

A space must be left underneath the figures of the soundings in the angle book in which they may be reduced to low water by a table derived from observations made on the tides, to be presently treated upon. The reduced soundings should be noted in red ink.

The time should be noted whenever angles to fix the boat's position are taken, or at least every half hour. In the absence of a watch, if working within sight of the ship, permission should be obtained for the signal man to hoist a numeral flag every hour, showing the number of the bells struck, keeping the same flying for five minutes, and hoisting the dinner pendant at noon.

Attention in the notation of the time is not only a great assistance to the memory when plotting the soundings, but without it that most delicate and important part of a survey, the reduction of the soundings to low water, cannot be honestly carried out.

* The line should always be marked from the heel of the lead.

The nature of the bottom should be frequently noted, especially marking any changes that may occur, such changes often giving warning of neighbouring shoals.

Selection of Points.—The diagrams treated on in the early part of this paper explain the means whereby the soundings are fixed, as by them has been shown what points may be considered as good, indifferent, or useless. The angles should be taken either to stations or to points fixed in the survey. When ill-conditioned angles are unavoidably used, *i.e.*, if the objects taken lie in any way near the circumference of the circle that passes also through the position of the boat, or when there is any doubt regarding either of the points, a third angle or compass bearing should be obtained as a check. In fixing the boat's position, the angles should be taken as nearly as possible at the same time and in the same place; the points to be used being looked for before reaching the position to be fixed. Sounding in a tide way, or with points difficult to distinguish, it may be necessary to anchor to obtain the fix.

Lines to be Run Parallel.—The lines of soundings should, if circumstances permit, be run parallel to each other, the distance apart being determined by the locality, the nature of the bottom, and the scale on which the plan is being made. In Plymouth Sound, for instance, the outer lines are three cables apart, the inner lines two cables apart.

To ensure these lines being pulled or sailed as straight lines, before starting from a station or fixed point, some well marked object should be found on the shore in line or transit with the point or mark for which it is intended to steer, this second mark lying sufficiently far behind the point steered for to show any deviation from the straight line required. If pulling or sailing to seaward, the same should be looked for astern; such objects kept in transit *must* insure a straight line being followed; on nearing the shore a good look out should be kept for a third object in the same line, in case of the second mark used, dipping behind the foreland. Keeping the boat on known straight lines is the only sure method of sounding in a tide way, often enabling the surveyor to fix his position by one angle only, and is of great assistance to him when there is any difficulty with regard to the objects used.

As there is some difficulty in steering by stern marks, the use of them should be made a point for practice. In all cases the compass-bearing of the points steered for or from, should be noted.

In sounding under sail five fathoms may be obtained without lowering the sail, but if the water is deeper, the sail should be lowered if running free, or the sheet eased off when sailing near the wind, to insure getting an "up and down cast."

Baréca for Beacon.—In the list of boat's gear two barecas have been enumerated, one of which should be fitted as a buoy, with a buoy-rope of about ten fathoms made of lead-line.

This buoy is to be used as a beacon when it is required to examine shoal patches lying some distance from the shore, as the Tinker Shoal. The lead-line is bent on to the pig of ballast before alluded to, which will be found sufficient to moor the baréca.

Boat's Anchor.—In using the boat's anchor in surveying, where the boat may frequently be anchored on rocky ground, it is advisable to bend the cable like a buoy-rope to the crown of the anchor, stopping it with spun-yarn to the ring; then if the flukes jamb in the rock the stop will carry away, and the anchor may be weighed with ease. This precaution has saved many a boat's anchor, prevented a return to the ship, and the disarrangement of a well contemplated scheme.

Gaining Local Information.—If the bay or coast to be surveyed is inhabited, take pains to gain the friendship of the fishermen, as these men making their living by their knowledge of localities useful to themselves, but dangerous to shipping, are often able to point out the positions of rocks or foul ground. Boats or canoes fishing should be piously avoided by a vessel coasting or entering a strange port or roadstead, as they are liable to be working in the vicinity of rocks or shoals.

Plotting the Soundings.—By laying another sheet of cartridge paper underneath the rough plan, the points obtained by triangulation may be pricked through, the names written against them, and any lines of soundings already obtained should be ruled on this second rough plan to prevent the work being done twice over.

This sheet may be fixed to a board by tracing-pins and taken away in the boat, so that the lines of soundings may be laid down as obtained by station-pointer, tracing-paper, or projection. If in the absence of station-pointer or tracing-paper the work has to be done by projection, three or four stations should be selected as points liable to be used in fixing, the lines joining them ruled, bisected, and perpendiculars drawn from the point of bisection; the centres of the projecting circles would then be readily found by laying off the complement of the angle taken, from one of the points, the intersection of that line with the perpendicular giving the required centre. Thus perpendiculars might be raised upon lines joining Mewstone and Observatory, rifle butt and Observatory, Observatory and Penlee, and Observatory and Maker Church.

In the first day's preliminary examination of the sound, soundings were obtained in pulling from point to point. On returning from the Mewstone, not wanting to pass over work already done, a line was run in the direction of Penlee Point until the Shagstone coming in line with the tangent of Mount Batten, gave a good opportunity to fix the position of the boat; the next line was run to the northward by keeping the East base in line with a mark on the land; on shoaling the water three feet to the north-west of the Shagstone, that rock was observed to be in line with the north tangent of the Mewstone, on deepening to six fathoms, angles were taken, and from the East base the boat returned to the ship. (See Plymouth Sound sounded.)

The lines of soundings should all be drawn on the rough plan, to prevent the work being done twice, and all work such as main

triangulation, and especially soundings, should be plotted on return to the ship, if possible before sleeping, while the memory is green. It will then be seen where further examination is required, and how the work is progressing.

It may here be remarked that if time or opportunity does not admit of making a survey of a harbour, an idea of its form, extent, and depth of water may be arrived at by simply running lines of soundings from the ship anchored near the centre, to the prominent points, noting at these points the masthead angle and bearing of the ship; thus, in the Sound, a line of soundings might be run from ship to Observatory, masthead angle observed and bearing taken, not only of the ship but of Picklecombe, then a line run from Observatory on the bearing to Picklecombe, on reaching that point, bearing of ship and masthead angle again to be taken and a line run back to ship; leaving ship again for Drake's Island, lines on the same principle could be run, returning to ship from Mount Batten, and so on till the Sound be completed.

Method of Sounding.—It is next required to fairly commence the sounding. Fine weather, with a pleasant breeze from the south-west, suggests the advisability of a day's work outside the Observatory Island to examine the entrance of the Sound. Starting from the ship for the west end of Observatory Island, the leadsmen begins to sound on passing the Observatory, the boat pulling S.W. $\frac{1}{2}$ S. on a line dead to windward; on this line the water suddenly shoals six feet, the position is fixed, but the examination is deferred to another time, the shoal lying near the ship and it being desirable not to lose the present good opportunity of running the long outside lines. A quarter of a mile farther on, the water again shoals 12 feet, deepening 15 in less than a cable. Another fix* is obtained, and as the ebb tide is running the mast is got up and sail made for the Mewstone, a reef being taken in to prevent the boat running too fast for the soundings. A course is shaped to keep the gap in the little Mewstone open (S.E. $\frac{1}{2}$ E.) with the forts on Maker Heights in line astern; after a run of about a mile the water shoals a fathom, the bottom being rock; ship swung to the ebb is observed to be in line with Drake's Island, and the position is fixed,† and the next cast gives an increase of a fathom, making the last cast suspicious. On reaching the Mewstone the shoal to the south-west seen from the summit, when the angles were taken, is examined and the extreme fixed.

A long line is now run, N.W. by W. $\frac{3}{4}$ W., for Rame Head, keeping the tangent of the head in line with some mark on the land beyond. In the deep water to be found in this line, the sail must be lowered to get the soundings, which should be obtained at least every five minutes, and the boat fixed when favourable transits occur, such as the East

* Position (a) on "Plymouth Sound" sounded—

East base and Observatory Station	45° 10' }	fms.
Observatory Station and Maker Church	55° 20' }	6½ rock.

† Position (b)—

Mewstone and rifle butt	86° 40' }	fms.
Rifle butt and Penlee Point	120° 50' }	8 rock.

base in line with the Hoe obelisk and also with Mount Batten, the Observatory in line with Mount Batten. Arrived off Rame Head, the boat is fixed in three fathoms.

Penlee Point is then sailed for, E. $\frac{1}{4}$ S., keeping it in line with a mark found on the land near Audern Point. Under Penlee Point the fix may not be a good one, but a position will be taken up directly the Sound opens and objects can be seen. A mark on the land beyond the Mewstone having been found in line with the north tangent of the Mewstone, it is steered for, haulyards in hand, ready to lower to get the fix before spoken of; a sudden shoaling of 8 or 9 feet gives warning of a rock. Angles are taken and buoy put over and the mast got down, and the shoal starved by a method that will be presently described. The line is then continued S.E. by E. $\frac{1}{2}$ E. for the Mewstone, lowering the sail as before to get the sounding, the transits being noted and used as in the first line. The East base coming in line with the Hoe obelisk, the position is fixed and the boat run up, N. by E. $\frac{1}{2}$ E., on that line for about three cables, until Folly Hill coming in line with a gully under it, bearing N.W. by W. $\frac{1}{4}$ W., offers a good mark to stand back upon.

Just after the East base comes in line with Mount Batten the water shoals a fathom, a fix is taken, and the angles are found to be nearly the same as those taken in the rocky ground met with in standing towards the Mewstone in the morning. This ground must therefore be examined on return. Fixing under Penlee Tower the forts on Maker Heights are steered for; and after running about a quarter of a mile, the boat is fixed, and the Shagstone touching Wembury Point, bearing S.E. by E., offers a good mark to stand back upon; it being necessary to examine the neighbourhood of the two shoal and rocky casts before mentioned. A shoal cast is obtained when abreast of Observatory, giving warning of the tail of the shoal pulled over in the morning when starting, and when near the suspected locality, with Mount Batten in line with East base, 23 feet is reported.

Starring a Shoal.—It being just low water, a fine opportunity offers to examine this shoal, sail is lowered, mast got down, and a line pulled N.E. by N. for the East base. 15 feet being found, the buoy is put over and the line continued until a depth of 6 fathoms is obtained, a line is then pulled S. by E. until the boat is in 5 fathoms, back to buoy and beyond to 7 fathoms, then S.W. by S. crossing a patch of 18 feet, then back to buoy, and so on until the patch is fairly sounded out, the least water found, and its extremes determined.

The course is then continued for the Shagstone till the East base comes in line with the Hoe obelisk. Running up on this line another shoal of 4½ fathoms is struck, making this entrance to the Sound appear suspiciously foul, angles are taken, and Cawsand Chapel in line with a mark on the hill behind affording a good mark for running west, sail is made, and a line run for those marks. Crossing the suspected ground S.W. of the Observatory Station, several shoals casts are obtained, showing the necessity of further examination of that locality.

The soundings inside the Observatory Island will be obtained on similar principles, the lines being run nearer to each other and pulled instead of sailed. Sounding round Drake's Island and the entrance of Hamoaze will give some idea of river work, the bridge representing the bar; in sounding the bridge, great care should be taken to discover a mark to lead over in the deepest water, the breadth of the channel, and the states of wind and tide in which it should be avoided.

If prevented by weather from using the board, and plotting the soundings in the boat, it is a good plan to rule the proposed lines on the plan and note in the sounding book the courses and distances it is intended to follow and the positions from which the lines should be run. Thus for sounding inside the Observatory the first line is to be run from ship W.N.W. for a mark to the southward of the redoubts over Cawsand, until the tangents of Redding and Mount Batten Points were in line; to the N.E. on that course for three cables until the rifle butt came in line with a battery beneath it, bearing E.N.E. From under the rifle butt run up two cables for Mount Batten, and then run back W.N.W. for the highest cliffs of Redding Point, heading up again two cables for Drake's Island, and so on till the lines required are all laid down. An occasional pair of angles might also be taken off the plan and inserted in the sounding book to ensure taking up the positions and running the lines proposed.

In plotting the soundings with tracing-paper, the paper may be economised and confusion of lines prevented by laying off as many angles as possible from the same point on the paper, that one point being made to take the position of the centre of the station pointer, marking each set or pair of angles laid off with some distinguishing symbol, the second set being known by a line ($\sim$), the third by a triangle (Δ), the fourth by a circle ($\bigcirc$), the fifth by a square ($\square$). Thus one sheet of tracing-paper may be used to lay down a considerable quantity of work.

In plotting the reduced soundings count the number of soundings obtained between two fixed positions on the line, and divide that part of the line between those stations into as many parts as there are soundings, so as to enter them evenly on the plan; in the absence of proportional compasses, the sector will assist in this performance.

When the soundings are all laid down, what are called contour lines are drawn round the coasts through the points where three and five fathoms were obtained. Draw similar lines round all the shoals, inking them in as shown in the signs and abbreviations adopted in the charts issued by the Hydrographic Office.

Although the soundings taken under five fathoms are all noted in feet, yet in plotting them on the paper they should be marked in fathoms and quarter fathoms, unless the whole of the soundings are marked in feet. Inside five fathoms the soundings should be entered on the plan to the nearest quarter fathom, outside five and inside ten fathoms, to the nearest half fathom, and outside ten to the nearest fathom.

Elevations.—From stations that are near the level of the sea, angles of elevation might be taken of objects such as Maker Church, Mount

Batten, the rifle butt, the hills over Penlee, and the redoubts over Cawsand. Seated at high-water mark, the observer may frequently detect the high-water mark directly under the objects of which he wishes to know the approximate height, and the vertical angle taken off and on the arc will give him a much better result than he can obtain by mere estimation. If the high-water mark cannot be detected, an angle taken at the water line bringing the object down to the water line will answer the purpose. The height above high water of all rocks and islets, such as the Shagstone and Observatory Island, should always be noted against them. Cliffs can often be measured by the lead line.

Astronomical Observations.—The first fine clear day after arrival should be devoted to sights, and the entire day and part of the night spent on Observatory Island. Sights for equal altitudes, latitude, true bearing, and variation of the compass should be obtained. The Officer's practice during the voyage having made him an expert observer, little difficulty is met with. Rates are obtained from observations taken from five to ten days apart, meaned with those taken at the port last sailed from, and supposing its position to be well known, a meridian distance determined in the following manner:—

MERIDIAN DISTANCE BETWEEN BEIRUT AND SIDON.

Numbers of chronometers.	Dent, 1,793. Standard.	McCabe, 187.	Frodsham, 2,714.
	h. m. s.	h. m. s.	h. m. s.
Standard fast on Beirut mean time, } June 17th, 1861	7 15 00·79	7 15 00·79	7 15 00·79
Comparisons (standard being fast on chrs.) }	—	9 11 15·60	9 35 15·60
Chronometers fast on Beirut mean } time, June 17th, 1861.....	7 15 00·79	10 03 45·79	9 39 45·79
Ditto Ditto, June 11th, 1861 ..	7 15 11·68	10 03 43·68	9 39 41·68
Rate in six days	10·89	2·11	4·11
Daily rate*	— 1·81	+ ·35	+ ·68
Sidon rates in June.....	— 1·91	+ ·18	+ ·59
Beirut-Sidon rate.....	— 1·86	+ ·26	+ ·63
Chronometers fast on Beirut mean } time, June 17th, 1861.....	7 15 00·78	10 03 45·79	9 39 45·79
Rate in three days by Beirut-Sidon rate }	— 5·58	+ ·78	+ 1·89
Chronometers fast on Beirut mean } time, June 20th	7 14 55·21	10 03 46·57	9 39 47·68
Chronometers fast on Sidon mean } time, June 20th	7 15 25·91	10 04 16·91	9 40 18·41
Meridian distance, Beirut and Sidon ..	30·70	30·34	30·73

* Losing rates are marked — ; gaining rates marked + .

s.		
30.70	Long. of Beirut..	35° 29' 04" E.
30.34		— 7 39
30.73		<hr/>
<hr/>	Long. of Sidon..	35° 21' 25" E.
177		
<hr/>		
30.59 = 7' 39"		

Latitude of Sidon from five observations of	} 33° 34' 11" N.
stars south of the Zenith	
Ditto by five observations of the Pole-Star..	33 34 39 N.
	<hr/>
Mean Latitude....	33 34 25 N.

N.B.—The Sidon Observatory was at the southern end of el Jezireh.

The chronometer or watch to be used for observations should be placed in a box and carried with care. Especially avoid giving it a circular motion. The watch should be compared with the standard on leaving and returning to the ship, and all the chronometers should be compared at noon on sight days. For further information on the management of chronometers, and the measurement of meridian distances, see Shadwell on Chronometers.

Tide Pole.—A sheltered corner is found, in which the tide pole may be erected. A broken oar is driven into the sand, and supported by guys of spun yarn, or secured by stones or shot among the rocks, the place chosen being in about 2 feet water at low water, protected as much as possible, and yet with the sea having free access to it. To this oar a painted batten is lashed, conspicuously marked, the alternate feet being painted black and white, the figures 6 inches long, painted black on the white ground, and *v.z.*; such a batten can be read from some distance with a telescope. The time is noted for the rise and fall of every 3 inches, or the state of the pole marked every half hour, great care being taken to determine as near as possible the times of high and low water, by taking a mean of the times at which the water was at equal heights before and after high or low water, on the same principle that apparent noon is found by adding the times of the equal altitudes of the sun together, and dividing by 2. The state of the wind should be always noted.

If in port at the time of the full and change, it is advisable to especially observe the high and low water on that day, remembering also that the greatest rise and fall occur from the third to the fifth tide after the full or change.

On the days that are not spent on Observatory Island, if the tide pole is not near enough to be noted from the ship (which may often be done by means of a telescope), supposing the ship to be moored, and the nature of the bottom at the anchorage level, a good idea of the daily rise and fall may be obtained by noting the depth alongside every

half hour with a lead-line marked to feet, taking care, as before, to obtain as nearly as possible the times of high and low water.

From one or other of these methods of observations, a daily tide table may be made, showing for every hour of the day the number of feet to be subtracted from the soundings taken to reduce them to low-water springs.

The soundings should be reduced very shortly after the return to the ship, and not entered even on the rough before they have been so reduced.

If the ship's stay is not long enough to get the times of high water at the full and change, that fact should be noted on the survey, and the rise and fall termed approximate.

A study of the Admiralty tide tables, and a comparison of the times and heights obtained, with those of some of the ports there given that at the same age of the moon have a similar rise and fall, will enable an observer to form a tolerably correct idea of the necessary amount of reduction.

To determine the rise and fall of the tide, and to reduce the soundings accurately, require very considerable fact, judgment, experience, and patience; and these must not be given grudgingly, as the knowledge of the rise and fall of a foot is often of invaluable service to a sailor in difficulties.

Measuring a Base.—To get a scale for a plan it is necessary to measure a base line. There are several methods by which this may be obtained, which, in the absence of actual measurement by chain or line, may serve to determine a scale sufficiently near for the general purposes of navigation, viz., mast-head angle already treated upon, sound, patent-log, and pacing. The last method, allowing $2\frac{1}{2}$ feet to the step, is a rough method, but infinitely better than putting no scale at all, or one by estimation on the chart.

Circumstances often prevent the base being measured by chain or line, owing to absence of level ground, or even if that is found, its position with regard to the triangulation preventing its being used, in which case one of the other methods must be fallen back on. In all cases the objects or stations erected at both ends of the base must be securely fixed, and connected with the main triangulation. In the case before us, the breakwater or Observatory Island is remarkably well suited for the purpose; rarely, I fear, will a more obliging island be found.

Possessing no chain, some old well stretched lead-line, 200 feet long, is carefully marked when wet to feet, with knots at the tens, half-knots at the fives, and bunting at the fifties, an eye being spliced in each end. When it is to be used, this line must always be wetted. Ten iron pins, made like stout priming wires, should also be procured; they can be made by the blacksmith. At low water, the beach being then dry between the Observatory Station and East base, one hand (Jones) having a flag made fast to the long boat hook, is told to walk from the station in the direction of the East base for nearly a quarter of a mile, keeping a look out on Observatory Station for orders.

On being told to halt, he is beckoned to move a little either to the right or left until he stands to the Officer at Observatory Station directly in line with the East base. The boat hook is then stuck firmly in the sand, and he returns. Jones is next provided with the ten pins and one end of the line, and told to run it out in the direction of East base, by keeping the flag in line with that station. The line run out, he turns round, and is directed to shift his position, if necessary, a little either to the right or left, so as to place him directly in line with the East base; the line is then shaken, to see that it lies straight along the sand, with one end touching the centre of the Observatory Station. He is then ordered to put his pin in the sand at the bare end of the line, and to proceed in the direction of the flag and East base, drawing the line after him, and followed now by a second hand (Smith) who carries the other end of the line, walking at a pace sufficient to keep the line taut, and accompanied by the Officer with note-book. The pin reached, a halt is made; Jones turns round, and gets Smith immediately in line with Observatory, while Smith sees that Jones is in line with the East base. The line is shaken up, the bare end placed against the pin. Jones puts the second pin into the sand, while Smith takes out the first pin, and is ordered to retain it until he can muster ten pins. Meanwhile the Officer enters a stroke thus (/) in his note-book, and orders Jones to proceed as before. The second pin reached, the operation is repeated, Jones putting in a pin, Smith taking up a pin, and the Officer entering a second mark in his book. When the fifth pin is taken out, the mark is made thus (///).

On Jones arriving at the eleventh length, he naturally calls out for more pins. Smith, having ten, gives them to the Officer, who, finding they correspond with the tally ~~///~~ ~~///~~ in his book, knows the work is so far correct, and that 2,000 feet have been measured. The Officer then carries the pins to Jones, and they proceed as before.

In the example before us, the shift of pins occurs twice, and if the work is correctly done, Jones will find himself at the East base, 10 feet beyond the position of the fifth pin of the third batch. The distance between this pin and the centre of the east base is most carefully measured. Smith, taking out the last pin, returns five to the Officer, Jones having the remaining five. The score in the book stands thus:—

Observatory to East base ~~///~~ ~~///~~ ~~///~~ ~~///~~ ~~///~~ and 10, or 5010 feet.

The operation is then repeated, measuring from East base to Observatory, and should agree within two or three feet.

By Mast-head Angle.—If the mast-head angle is used, care must be taken (the ship being a floating and moving object) to obtain the horizontal angles from the same mast of which the angle of elevation is being taken. These horizontal angles are taken between the station on the shore from which the mast-head angle is being measured, and two other stations, one right, the other left of it, every angle of the two triangles being above 25°. These angles should be taken as nearly as possible at the time when the observer on shore is taking the mast-head angle. Meanwhile the observer on shore measures the angle between

the mast used and the two stations taken from that mast on board the ship. A flag or black ball should be hoisted close up to the truck of the mast to be used.

The station on shore from which the mast-head angle is taken should be one near the water line, so that the lower angle at the ship should be as nearly as possible a right angle.

By Sound.—The base may also be measured by sound, in which case as long a distance as possible should be used, and if guns are fired from only one end, the base should be measured on a calm day, or when there is not much wind.

The best method of getting base by sound is first to ascertain the number of times that the watch to be used beats in a minute of time. Most pocket chronometers beat 5 times in 2 seconds, or 150 beats to a minute; common watches vary. The number of beats of the watch ascertained, it is easy to find the number of feet that sound travels in that beat. That number of feet multiplied by the number of beats observed, corrected for temperature (heat accelerating the velocity with which sound travels), will give the distance required.*

To measure base by sound, a little pre-arrangement is necessary. In this case it is understood that the ship will fire three guns to the observer at the Mewstone. On the Officer's reaching the Mewstone, and being quite prepared, a flag is shown; that flag is answered by the ship hoisting the preparative, dipping it when the gun is ready. When the flag at the Mewstone has also been dipped, the flag at the ship is slowly hoisted, and the gun fired on its reaching the truck.

The flag re-hoisted at the Mewstone shows that the Officer is again ready, and the operation is repeated.

A simple method of counting the beats is by binding the watch close to the ear by means of a pocket-handkerchief; this leaves hands and eye free to use glass and note-book. The observer, comfortably placed with his eye on the ship, begins to count on seeing the *flash*, finishing with the *report* of the gun.

As in the former case, angles are taken at the same time at both ship and Mewstone to connect the base with the triangulation. The gun fired should have extreme elevation given to it; and, if possible, guns should be fired from each end of the base.

The patent-log base should, of course, be run at slack water, running the base three or four times to insure accuracy. The error of this instrument may be found by previous experiment in well surveyed ports.

An opportunity to test the patent-logs occurs when ships are running the measured mile.

The base obtained, the next step is to work out the sides of the triangles, checking the work as it is proceeded with by finding an occasional side from two adjacent triangles, remembering that the sum of the angles not being in all cases equal to 180° , the sides found will not quite agree. When one of the longest sides is found, as Penlee Point to the rifle butt, it may be compared with the number of inches

* At a temperature of 32° Fahr., sound travels 1090 feet in a second; acceleration for temperature, 1.19 feet to 1° of Fahr. At 60° Fahr. therefore, sound travels 418 feet in one beat of a chronometer beating 150 times in one minute.

found between those stations on the plan, and the scale of the chart deduced therefrom.

Shoals out of sight of Land.—If a shoal is fallen in with out of sight of land, or if a ship is sent to search for and examine a danger so placed, the vessel should, on finding the shoal water, if possible, anchor, mooring if convenient. Four boats might then be sent away to sound on north, east, south, and west lines from the ship for three miles, hoisting a flag every half hour, and taking a mast-head angle of the foremast, at which truck a black ball should be shown; an observer at the ship at the same time taking a bearing of the boat. (See Diagram 5.) At the end of the three miles distance, to be determined by mast-head angle, the boats will pull respectively E.S.E., S.S.W., W.N.W., and N.N.E. for $2\frac{1}{2}$ miles, fixing their position by mast-head angle, and hoisting their flags to allow the ship to obtain bearings of them. They will then return to the ship on S.W., N.W., N.E., and S.E. courses, sounding and hoisting their flags as before.

If shoaler water be found, requiring further or more extended examination, the launch, with her gun, should be sent in the direction of the foul ground to anchor on a given bearing at a distance of not over three miles from the ship; three guns will then be fired from both ship and launch to determine the distance. Ship will then weigh and take up a second position as convenient not more than three miles from the launch, when another base will be measured by sound, the ship beginning to fire when she has anchored. Launch will return to ship sounding, and the three remaining boats sound round the ship as before.

Coast Survey for Practice.—Sailing along a coast of which there are reliable charts, it is good practice to take angles, bearings, and true bearings, whenever observations are obtained, thus acquiring experience in examining a coast of which the charts are faulty.

Thus a true bearing from amplitude may be obtained at sunrise, with angles to conspicuous objects, noting the direction of the ship's head, the course to be steered, the patent log if in use, and the time. Another set of angles to the points taken at sunrise, and true bearing from azimuth, may be taken when the forenoon observations are obtained, other objects ahead being selected to continue the work by; a third set may be taken at noon, and the observations continued on similar principles in the afternoon and evening. Bearings of all objects in transit should be taken, and the direction of the ship's head and her courses carefully noted. If no current has been experienced, the courses steered and distances run, will form bases from which an attempt at projection may be made; or from the true positions determined by observation, the bearings and angles may be laid off, thus seeing how nearly conspicuous points could be recognized, and compared with the same points as marked on the chart.

Night Survey.—A knowledge of the system of sounding will enable an Officer under cover of the night, with the judicious use of masked

lanthorns, to examine an enemy's coast, the charts of which may not be trustworthy, with a view of effecting a landing, of bombarding, or of otherwise giving him trouble.

In Diagram No. 6 a squadron of five vessels, viz., the "Argo," carrying the broad pendant of the Commodore, the "Tiphys," the "Palinurus," the "Pelorus," and the "Archimedes," are supposed to have anchored about four miles distant from the coast, on the following bearings and distances from the flag-ship:—the "Tiphys" east 10 cables, the "Palinurus" N.N.E. $7\frac{1}{2}$ cables, the "Pelorus" S.S.W. $7\frac{1}{2}$ cables, and the "Archimedes" S.E. 10 cables.

Immediately on anchoring, observations are made to determine the state of the tide, its velocity, time of turning, &c. The distance of the shore is found by observing angles from the "Pelorus," "Palinurus," and flag-ship, to well-defined objects on the shore, the distances the outer vessels are from each other affording a base, the same base to be measured by sound or mast head angles.*

As soon as it is dark, three boats will leave the squadron with muffled oars and other cat-like and cautious contrivances, one from the flag-ship, the two others from the "Palinurus" and "Pelorus." Each boat will be provided with the red bow-light of her steam launch,† a patent-log (the box part being lashed to the gunwale of the boat to allow of the hands being seen, the fly line being lengthened if necessary), watch, compass, lead-line, and sextant. The boat of the "Palinurus" will pull in N.W. $2\frac{3}{4}$ miles *over the ground*, keeping the lights of the "Palinurus" and "Tiphys" in transit, sounding continually, and allowing in her distance for the tide that may be running, the distance actually to be pulled being approximately determined on board the ship before leaving; the Officer in charge being required to exercise his judgment in the matter, as he will know approximately by the angle with her course, on which the boat has to be steered, to ensure her keeping the lights in line, the velocity with which the tide may be running.

On reaching her station, the boat will exhibit the light towards the flag-ship, carefully masked from the shore by jackets and other appliances, remaining in this station no longer than ten minutes.

While in this position the Officer in the boat will take bearings of the flag-ship and the "Pelorus," and if possible obtain the angle by sextant between the latter ship and the "Palinurus," avoiding the danger of reading off by stowing the sextant away with the arc firmly clamped, noting the time of arriving and leaving with care, keeping the boat in position by watching the lead.

The boat will then pull three-quarters of a mile S.S.W., or until the "Archimedes" comes in line with the flag-ship bearing S.E., when she will come back on that line sounding all the way. When sounding

* As this base may be considered small, the "Tiphys" and "Archimedes" might at first take up positions of respectively N.E. by N., and S. by W., distant two miles from the flag-ship, observers from the flag-ship visiting each vessel to obtain angles to objects previously determined upon; that done, and the bases measured, the ships would take up the positions originally assigned to them.

† Here, perhaps, Captain Colomb's inventions may be turned to useful account.

in-shore it may be advisable to stop the boats to sound, thereby avoiding the splash of the lead.

The boat of the "Pelorus" will pull in west $2\frac{3}{4}$ miles on similar principles, keeping the "Archimedes" and "Pelorus" in line; arrived at her station she will exhibit her light, obtain bearings of the flag-ship and "Palinurus," measuring the angle between the "Pelorus" and the latter ship, remain in station ten minutes, noting time of arrival and leaving with care. She will then pull N.N.E. three-quarters of a mile, or until the flag-ship comes in line with the "Tiphys," bearing east, when she will pull to the flag-ship on that line, sounding the whole way.

The flag-ship's boat will pull in W.N.W. $2\frac{3}{4}$ miles, keeping the "Argo" as near as possible exactly between the "Tiphys" and "Archimedes," arrived at her station she will exhibit her light and obtain angles on the same plan as the other boats, she will then pull half a mile N.N.E., and then S.E. by E. for the "Archimedes," keeping that ship just open southward of the "Argo" until close to the flag-ship, sounding the whole way.

Meanwhile the ships on the departure of the boats will, on a signal from the flag-ship, all hoist position lights, as if in communication with friends in the offing. A sharp look-out will be kept from the "Palinurus" for the boat of "Pelorus" showing her light, and *vice versa*. Directly the lights are seen a bearing will be taken, and, if possible, angles measured between the boats and the flag-ship. A second look-out will be kept for the light of the flag-ship's boat, and also for that of their own boat; angles and bearings taken, and the time in all cases particularly noted.

These angles and bearings will at once be sent to the flag-ship, from which ship angles and bearings will be taken to the boats on similar principles.

Taking it for granted that this manœuvre is successfully executed, the following information will be obtained:—That the 5 fathoms line lies about three-quarters of a mile from the shore west of the "Pelorus," and $1\frac{1}{2}$ mile from the shore north-west of the "Palinurus;" that there is a distance of about one-third of a mile between the 3- and 5-fathom lines; that a shoal distant $1\frac{1}{2}$ mile from the shore lies 2 miles W.N.W. of the flag-ship, on which as little as 18 feet was found, while the northern boat found a ridge of 10 feet little over one mile from the shore. The general result of the examination has shown that foul ground lies to the northward, but that the southern part of the coast appears to be clear.

The squadron might then weigh, and taking a new position to the southward, in a similar manner renew the examination.

It may be remarked that this work could be done without the risk of exhibiting lights from the boats. The answer is the uncertainty of even practised men being able with any tide running to take their allotted positions; the difficulty of getting angles and bearings from the boats; while the bearings from the ships ensure a greater amount of accuracy in the work. Masked lights have been used with success and may be so again.

Advantage may be taken in the day time to observe from the ships the nature of the country, angles may be taken which, combined with others obtained immediately on landing, will serve to fix any elevated points, forts, or bridges. Angles of elevation to any heights may be taken and worked out, and thus some knowledge of the prominent features may be put upon paper, and prove of great assistance to the Officer in command.

For many of the practical hints contained in this paper I have been indebted to the kindness of Captain Shortland and other friends whom I have consulted on the subject, and I am free to confess that I have thereby added considerably to my own knowledge of "Practical Nautical Surveying." Admiral Ryder has also suggested the following ideas relating to the survey of an enemy's coast by night.

Steam launches may be used to run the lines of soundings, and with great advantage, owing to the speed with which they can run in, return, and escape if chased; the assumed difficulty of keeping the lead-line clear of the screws may be overcome by having a metal open framework fitted in front of, and on each side of the screw, or towing a boat alongside, from which the casts of the lead should be made.

Electric Light.—The power of throwing a beam of light, sufficiently brilliant to light up fully a ship two miles off, can, it is said, be obtained by means of the electric light. This may evidently be made very useful in aiding a night survey. Small fast steam vessels sent in on the flanks could frequently illuminate the beach and water near it, passing the beams slowly or quickly as may be thought advisable; this would draw the attention of the enemy from the surveying boats which would be pushed on in the dark space between the flank ships and between beams of light thrown by those ships on the beach.

Marking Extreme Positions.—Each boat should drop an anchor and beacon-buoy at her extreme position, which should be fixed by cross-bearings from the ships immediately after daylight, before the enemy has time to remove it.

Exercise in making Night Surveys.—The only way to ensure our being able to make useful night surveys in war time, is to practise in peace time, first by day, and then by night. The boats from ships at Spithead could be usefully exercised at making a night survey of the anchorage off Southsea Beach and the Isle of Wight, and from ships in the Sound, of Drake's Island and the beach under Mount Edgecumbe.

Signals.—The flashing signals should be used when necessary, but very sparingly, from the boats. Each boat should have a general and a special pass word.

The Colour of the Boats.—This should be light grey, to be as little distinguishable as possible.

I would remark in conclusion that although nautical surveying, from its simplicity, may seem suited to the meanest capacity, still, if real success be looked for, there is no profession that requires more straightforward perseverance and steady application. It is adapted not so much to "men of genius" as to those who possess the rare gift of industry

in one particular direction, or what Carlyle calls a capacity for taking trouble, with conscientious labour, shirking and evading no difficulty, completeness of work in all its divisions, and incessant practice when opportunities offer.

I have thus, Sir, in as full a manner as the time at my disposal permitted, endeavoured to embody in my lecture the programme of the Committee of this Institution on "Practical Nautical Surveying." To fulfil the wishes expressed in the last clause of this instruction, viz., "To ensure at some future time our having on board every ship of war "one or more Officers capable at an instant's notice of undertaking a "rough marine survey," is, however, beyond my powers; with the active co-operation of the State it may nevertheless be accomplished.

We possess gunnery establishments and go to vast trouble and expense in raising a body of Officers cunning in the manipulation of the huge artillery of the day, but unable, from pressure in one direction, to give much attention to the art of navigating the wondrous platforms that carry that artillery.

The science of naval gunnery, however perfect, cannot be turned to account, without the assistance of navigation, to guide our floating batteries with confidence and security.

This fact strongly points to the necessity of extending to navigation and nautical surveying a care and encouragement similar to that which naval gunnery has so long enjoyed.

If this could be done, and a system established by which the subjects briefly treated upon in this paper could be fairly and practically taught, it would in a few years "ensure our having on board every man of war "one or more Officers capable, at an instant's notice," not only "of "undertaking a rough marine survey," but qualified to perform in their various branches the responsible duties of the pilots of the Fleet; able, as of old, to place an element of success at the disposal of the fortunate Admiral or Captain under whom they might have the honour to serve.