large scale surveys whitewash marks or flags should mark the ends of the lines, and for the back transit marks natural objects may perhaps be picked up; if not, they must be placed in the required positions. The boat is fixed by two angles, with an occasional third angle as a check; the distance between the fixes is dependent upon the scale of the chart and the rapidity with which the depth alters; the 3, 5 and 10 fathom lines should always be fixed, allowing roughly for the tidal reduction. The nature of the bottom must be taken every few casts and recorded. It is best to plot each fix on the sounding board at once, joining the fixes by straight lines and numbering them for identification. The tidal reduction being obtained, the reduced soundings are written in the field-book in red underneath each sounding as originally noted; they are then placed in their proper position on the board between the fixes. Suspicious ground should be closely examined; a small nun buoy anchored on the shoal is useful to guide the boat while trying for the least depth. Sweep­ing for a reported pinnacle rock may be resorted to when sounding fails to discover it. Local information from fishermen and others is often most valuable as to the existence of dangers. Up to depths of about 15 fathoms the hand lead-line is used from the boats, but beyond that depth the small Lucas machine for wire effects a great saving of time and labour. The deeper soundings of a survey are usually obtained from the ship, but steamboats with wire sounding machines may assist very materi­ally. By the aid of a steam winch, which by means of an endless rounding line hauls a 1oo-lb lead forward to the end of the lower boom rigged out, from which it is dropped by a slipping apparatus which acts on striking the water, soundings of 40 fathoms may be picked up from the sounding platform aft, whilst going at a speed of 41/2 knots. In deeper water it is quicker to stop the ship and sound from aft with the wire sounding machine. In running long lines of soundings on and off shore, it is very essential to be able to fix as far from the land as possible. Angles will be taken from aloft for this purpose, and a few floating beacons dropped in judiciously chosen positions will often well repay the trouble. A single fixed point on the land used in conjunc­tion with two beacons suitably placed will give an admirable fix. A line to the ship or her smoke from one or two theodolite stations on shore is often invaluable; if watches are compared, observations may be made at stated times and plotted after­wards. True bearings of a distant fixed object cutting the line of position derived from an altitude of the sun is another means of fixing a position, and after dark the true bearing of a light may be obtained by the time azimuth and angular dis­tance of a star near the prime vertical, or by the angular distance of Polaris in the northern hemisphere.

A very large percentage of the bugbears to navigation denoted by vigias@@1 on the charts eventually turn out to have no ex­istence, but before it is possible to expunge them a large area has to be examined. No-bottom soundings are but little use, but the evidence of positive soundings should be conclusive. Submarine banks rising from great depths necessarily stand on bases many square miles in area. Of recent years our knowledge of the angle of slope that may be expected to occur at different depths has been much extended. From depths of upwards of 2000 fathoms the slope is so gradual that a bank could hardly approach the surface in less than 7 m. from such a sounding; therefore anywhere within an area of at least 150 sq. m. all round a bank rising from these depths, a sounding must show some decided indications of a rise in the bottom. Under such circumstances, soundings at intervals of 7 m., and run in parallel lines 7 m. apart, enclosing areas of only 50 sq. m. between any four adjacent soundings, should effectually clear up the ground and lead to the discovery of any shoal; and in fact the soundings might even be more widely spaced. From depths of 1500 and 1000 fathoms, shoals can scarcely occur within 31/2 m. and 2 m. respectively; but as the depth decreases the angle of slope rapidly increases, and a shoal might occur within three-quarters of a mile or even half a mile of such a

sounding as 500 fathoms. A full appreciation of these facts will indicate the distance apart at which it is proper to place soundings in squares suitable to the general depth of water. Contour lines will soon show in which direction to prosecute the search if any irregularity of depth is manifested. When once a decided indication is found, it is not difficult to follow it up by paying attention to the contour lines as developed by suc­cessive soundings. Discoloured water, ripplings, fish jumping or birds hovering about may assist in locating a shoal, but the sub­marine sentry towed at a depth of 40 fathoms is here invaluable, and may save hours of hunting. Reports being more liable to errors of longitude than of latitude, a greater margin is necessary in that direction. Long parallel lines east and west are prefer­able, but the necessity of turning the ship more or less head to wind at every sounding makes it desirable to run the lines with the wind abeam, which tends to disturb the dead reckoning least. A good idea of the current may be obtained from the general direction of the ship’s head whilst sounding considered with reference to the strength and direction of the wind, and it should be allowed for in shaping the course to preserve the paral­lelism of the lines, but the less frequently the course is altered the better. A good position in the morning should be obtained by pairs of stars on opposite bearings, the lines of position of one pair cutting those of another pair nearly at right angles. The dead reckoning should be checked by lines of position from observations of the sun about every two hours throughout the day, preferably whilst a sounding is being obtained and the ship stationary. Evening twilight stars give another position.

*Tides.—*The datum for reduction of soundings is low-water ordinary springs, the level of which is referred to a permanent bench mark in order that future surveys may be reduced to the same datum level. Whilst sounding is going on the height of the water above this level is observed by a tide gauge. The time of high-water at full and change, called the “ establishment,” and the heights to which spring and neap tides respectively rise above the datum are also required. It is seldom that a sufficiently long series of observations can be obtained for their discussion by har­monic analysis, and therefore the graphical method is preferred; an abstract form provides for the projection of high and low waters, lunitidal intervals, moon’s meridian passage, declination of sun and moon, apogee and perigee, and mean time of high-water following superior transit, and of the highest tide in the twenty-four hours. A good portable automatic tide gauge suitable for all requirements is much to be desired.

*Tidal Streams and Surface Currents* are observed from the ship or boats at anchor in different positions, by means of a current log ; or the course of a buoy drifted by the current may be followed by a boat fixing at regular intervals. Tidal streams often run for some hours after high and low water by the shore ; it is important to find out whether the change of stream occurs at a regular time of the tide. *Undercurrents* are of importance from a scientific point of view. A deep-sea current meter, devised (1876) by Lieut. Pillsbury, U.S.N., has, with several modifications, been used with success on many occasions, notably by the U.S. Coast and Geodetic Survey steamer “ Blake ” in the investigation of the Gulf Stream. The instrument is first lowered to the required depth, and when ready is put into action by means of a heavy weight, or messenger, travelling down the supporting line and striking on a metal plate, thus closing the jaws of the levers and enabling the instrument to

begin working. The rudder is then free to revolve inside the framework and take up the direction of the current; the small cones can revolve on their axis and register the number of revolu­tions, while the compass needle is released and free to take up the north and south line. On the despatch of a second messenger, which strikes on top of the first and fixes the jaws of the levers open, every part of the machine is simultaneously locked. Having noted the exact time of starting each of the messengers, the time during which the instrument has been working at the required depth is known, and from this the velocity of the current can be calculated, the number of revolutions having been recorded, while thc direction is shown by the angle between the compass needle and the direction of the rudder.

The instrument is shown in fig. 12. AA are the jaws of the levers through which the first messenger passes and strikes on thc metal plate B. The force of the blow is sufficient to press B down, thus bringing the jaws as close together as possible, and putting the meter into action. The second messenger falling on the first opens the levers again and prevents their closing, thus keeping all parts of the machine locked. C is the rudder which takes up the direction of the current when the levers are unlocked. D is a set of small levers on the rudder in connexion with AA. The

@@@1 A Spanish word meaning " look-out,” used of marks on the chart signifying obstructions to navigation.