and are not attempted; astronomical observations at intervals in an extended survey prevent any serious accumulation of errors consequent upon a triangulation which is usually carried out with instruments, of which an 8-in. theodolite is the largest size used, whilst 5-in. theodolites generally suffice, and the sextant is largely employed for the minor triangulation. The scales upon which nautical surveys are plotted range from 1/2 in. to 2 or 3 in. to the sea-mile in coast surveys for the ordinary purposes of navigation, according to the requirements; for detailed surveys of harbours or anchorages a scale of from 6 to 12 in. is usually adopted, but in special cases scales as large as 60 in. to the mile are used.

The following are the principal instruments required for use in the field: *Theodolite,* 5 in., fitted with large telescope of high power, with coloured shades to the eye-piece for observing the sun for true bearings. *Sextant,* 8 in. observing, stand and artificial horizon. *Chronometers,* eight box, and two or three pocket, are usually supplied to surveying vessels. *Sounding sextants,* differing from ordinary sextants in being lighter and handier. The arc is cut only to minutes, reading' to large angles of as much as 140°, and fitted with a tube of bell shape so as to include a large field in the telescope, which is of high power. *Measuring chain* 100 ft. in length. *Ten-foot pole* for coast-lining, is a light pole carrying two oblong frames, 18 in. by 24 in., covered with canvas painted white, with a broad vertical black stripe in the centre and fixed on the pole 10 ft. apart. *Station-pointer,* an instru­ment in constant requisition either for sounding, coast-lining, or topographical plotting, which enables an observer’s position to be fixed by taking two angles between three objects suitably situated. The movable legs being set to the observed angles, and placed on the plotting sheet, the chamfered edges of the three legs are brought to pass through the points observed. The centre of the instrument then indicates the observer’s position. *Heliostats,* for reflecting the rays of the sun from distant stations to indicate their position, are invaluable. The most convenient form is Galton’s sun signal ; but an ordinary swing mirror, mounted to turn horizontally, will answer the purpose, the flash being directed from a hole in the centre of the mirror. *Pocket aneroid barometer,* required for topographical purposes. *Prismatic compass, patent logs* (taffrail and harpoon), *Lucas wire sounding machine* (large and small size), and *James's submarine sentry* are also required. For chart-room use are pro­vided a graduated brass scale, steel straight-edges and beam com­passes of different lengths, rectangular vulcanite or ivory protractors of 6-in. and 12-in. length, and semicircular brass protractors of 10-in. radius, a box of good mathematical drawing instruments, lead weights, drawing boards and mounted paper.

Every survey must have fixed objects which are first plotted on the sheet, and technically known as “ points.” A keen eye is required for natural marks of all kinds, but these must often be supplemented by whitewash marks, cairns, tripods or bushes covered with white canvas or calico, arid flags, white or black according to background. On low coasts, flagstaffs upwards of 80 ft. high must sometimes be erected in order to get the necessary range of vision, and thereby avoid the evil of small triangles, in working through which errors accumulate so rapidly. A barling spar 35 ft. in length, securely stayed and carrying as a topmast (with proper guys) a somewhat lighter spar, lengthened by a long bamboo, will give the required height. A *fixed beacon* can be erected in shallow water, 2 to 3 fathoms in depth, by constructing a tripod of spars about 45 ft. long. The heads of two of them are lashed together, and the heels kept open at a fixed distance by a plank about 27 ft. long, nailed on at about 5 ft. above the heels of the spars. These are taken out by three boats, and the third tripod leg lashed in position on the boats, the heel in the opposite direction to the other two. The first two legs, weighted, are let go together; using the third leg as a prop, the tripod is hauled into position and secured by guys to anchors, and by addi­tional weights slipped down the legs. A vertical pole with bamboo can now be added, its weighted heel being on the ground and lashed to the fork. On this a flag 14 ft. square may be hoisted. *Floating beacons* can be made by filling up flush the heads of two 27-gallon casks, connected by nailing a piece of thick plank at top and bottom. A barling spar passing through holes cut in the planks between the casks, projecting at least 20 ft. below and about to ft. above them, is toggled securely by iron pins above the upper and below the lower plank. To the upper part of the spar is lashed a bamboo, 30 to 35 ft. long carrying a black flag 12 to 16 ft. square, which will be visible from the ship 10 m. in clear weather. The ends of a span of 1/2-in. chain are secured round the spar above and below the casks with a long link travelling upon it, to which the cable is attached by a slip, the end being carried up and lightly stopped to the bamboo below the flag. A wire strop, kept open by its own stiffness, is fitted to the casks for convenience in slipping and picking up. The beacon is moored with chain and rope half as long again as the depth of water. Beacons have been moored by sounding line in as great depth as 3000 fathoms with a weight of 100 lb.

There is nothing in a nautical survey which requires more attention than the “ fix ”; a knowledge of the principles involved is essential in order to select properly situated objects. The method of fixing by two angles between three fixed points is generally known as the “two-circle method,” but there are really three circles involved. The “ station-pointer ” is the instrument used for plotting fixes. Its contruction depends upon the fact that angles subtended by the chord of a segment of a circle measured from any point in its circumference are equal. The lines joining three fixed points form the chords of segments of three circles, each of which passes through the observer’s position and two of the fixed points. the more rectangular the angle at which the circles intersect each other, and the more sensitive they are, the better will be the fix; one condition is useless without the other, A circle is “ sensitive ” when the angle between the two objects responds readily to any small movement of the observer to wards or away from the centre of the circle passing through the observer’s position and the objects. This is most markedly the case when one object is very close to the observer and the other very distant, but not so when *both* objects are distant. Speaking generally, the sensi­bility of angles depends upon the relative distance of the two objects from the observer, as well as the absolute distance of the nearer of the two. In the accompanying diagram A, B, C are the objects, and X the observer. Fig. 7 shows the circle passing through C, B and X, cutting the circle ABX at a good angle, and therefore fixing X independently of the circle CAX, which is less sensitive than either of the other two. In fig. 8 the two first circles are very sensitive, but being nearly tangential they give no cut with each other. The third circle cuts both at right angles; it is, however, far less sensitive, and for that reason if the right and left hand objects are both distant the fix must be bad. In such a case as this, because the angles CXB, BXA are both so sensitive, and the accuracy of the fix depends on the precision with which the angle CXA is measured, that angle should be observed direct, together with one of the other angles composing it. Fig. 9 represents a case where the points are badly disposed, approaching the condition known as “ on the circle,” passing through the three points. All three circles cut one another at such a fine angle as to give a very poor fix. The centre of the station-pointer could be moved considerably without materially affecting the coincidence of the legs with the three points. To avoid a bad fix the following rules are safe:—

1. Never observe objects of which the central is the furthest unless it is *very* distant relatively to the other two, in which case the fix is admis­sible, but must be used with caution.

2. Choose objects disposed as follows: (*a*) One outside object distant and the other two near, the angle between the two near