intersection, or if there is only one lighthouse on that sector of coast? The answer to the first part of the question is that he takes a bearing on the first light to come over the horizon, converts it to a back bearing and lays it off on the chart. With a bearing and range on the light, he has a fix, see Fig 48; in this drawing I have omitted the compass roses for the sake of clarity, and have only shown the

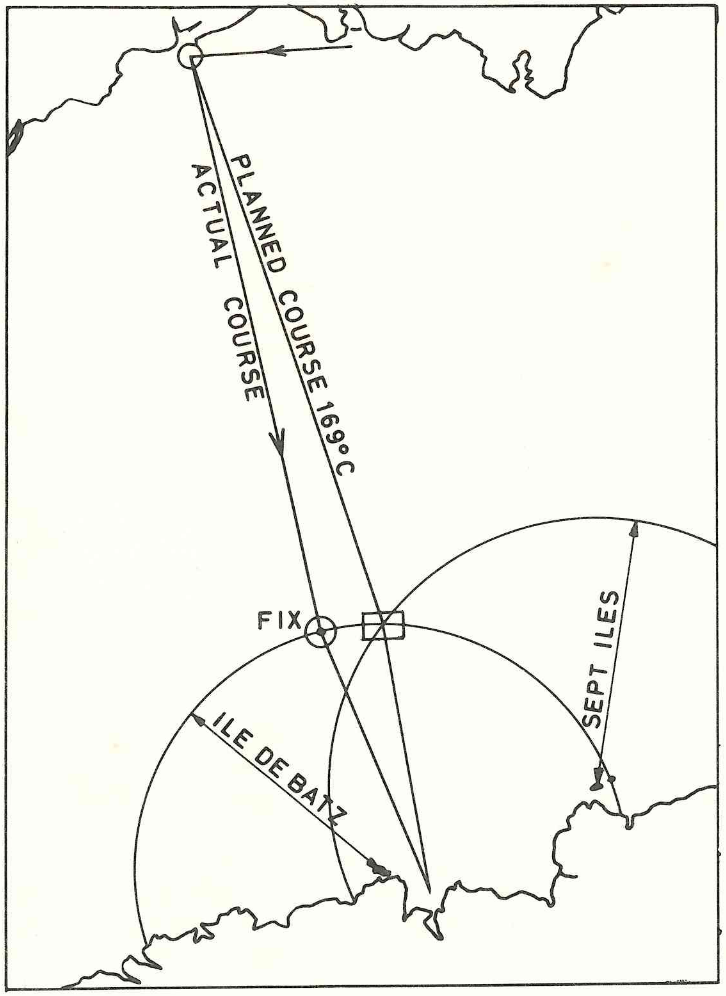


Fig 48

arcs of maximum range of visibility. He now knows where he is, and can plan accordingly. The answer to the second question is the same; he takes a bearing on the light, converts it into a back bearing and lays it off. The point at which the back-bearing line cuts the arc is his position. All this conversion to back bearings and laying off on the chart shows how the drawing of compass roses round all major features and lights pays off in time saved.

The reason I chose the passage from Plymouth to Morlaix is because it just so happens that the point of intersection is exactly on the safe course into Morlaix River. It must be realised that lighthouse characteristics may change and should be checked annually. I bring out this point here because it helps to illustrate the importance of one of the navigator's jobs: that of keeping all his charts up to date through the Admiralty Notices to Mariners. These apply not only to lights, but to the positions of all types of navigation marks and their characteristics, radio beacons and all other navigation information contained on charts which can be subject to alteration. Even soundings can alter. It is not necessary to take the weekly copies of Notices to Mariners – the Hydrographic Department publish special small craft editions, while the *Practical Boat Owner*, amongst other publications, publishes a list of those alterations which are likely to affect yachts, or are of interest to yachtsmen generally. The French charts published by Éditions Cartographiques Maritimes are also subject to alterations, and lists of these can be obtained from the publishers for the cost of the postage from France to the UK.

The principles of navigation remain the same whether it be day or night, but the methods differ. In daylight, providing that visibility remains good, one has the advantage of being able to see unlit marks such as the Whittaker Beacon near the mouth of the River Crouch. This, whilst it requires good eyesight and binoculars, means that keeping on track is simplified. Also, one can see where water shoals or whether there are rocks close to the surface. Consequently it is possible to cut a corner here and there if conditions allow, and to sail much closer to a sandbank than would be prudent at night, especially if one is having to beat to windward along a channel between two banks. By day it is possible to obtain fixes from many different types of topographical feature, and buoys whose positions are shown on the chart. In strong weather when visibility is badly reduced by rain or blown spume, whether it be lit or unlit the next mark ahead can be very hard to find. In a narrow channel when one wants to be able to see the next mark and the one astern, things can be very trying. It is then that good course plotting pays off, and the navigator earns his corn. Taken all in all, daylight passage making, coastwise or offshore, is easier than at night. In the dark one only has lighted marks to go by, and in tricky waters such as the Thames Estuary or the Wash, the navigator *must* know, at any given moment, where he is to within a cable. If not, the boat can be ashore before he knows what has happened. It is for this reason that, until a navigator has gained experience, I always recommend daylight passages coastwise. Until that experience has been gained, one should think very carefully indeed before undertaking a night passage, and under no circumstances whatever try it if the weather forecast is bad. There is no sense in saying 'I've got to be back in the office on Monday without fail' if you are not going to live to see that Monday morning because the boat got into serious trouble through heavy weather, or you ran ashore on to rocks because you did not know exactly where you were. It is not much good relying on the philosophy 'it can't happen to me'. It happens round our coasts all too often every year.

Night navigation calls for care and precision. One must pinpoint every light by its characteristics, and make certain of each and every fix. The skilful use of compass, chart, lead line and watch is very elegant navigation, and a joy to watch. It is also sound practice not to try a tricky passage for the first time at night; one can get into enough bother in daylight, so why add to your difficulties! Night navigation involves using every lighted mark available, getting a bearing on it and if necessary taking a running fix from it. If two or more lights are visible then one can get cross bearings and so obtain a fix that way. Coastwise navigation at night is made fairly easy by lighthouses and lightships. There are not many areas round the coasts of these islands when one cannot see the loom of at least one or the other, and even this can give some idea of the boat's position. Also, don't forget the light cast into the night sky by towns; even such a tenuous source can help to establish a fairly accurate position.

I hate fog and so, I think, do all sailing men and women. As with night navigation, so with fog. Care and precision, and because fog can come down by day or night without warning this is one very

good reason for keeping an accurate plot going on the chart at all times. Again, a reliable and accurate watch earns its cost in just one thick fog. Unless the boat is equipped with RDF, and in this chapter we are assuming that she is not, the only instruments of any value are a good log, an accurate compass and a reliable watch. Hold a course for a stated time, check the distance run on the log, change course and repeat. This is where using a lead line in conjunction with a large-scale chart pays off. Keep sailing timed courses, use the lead line and keep the plot going on the large-scale chart, and you will arrive safely at your destination, or the fog will clear so that you can establish your exact position.

If you find yourself in a shipping lane in fog, GET OUT OF IT AS QUICKLY AS POSSIBLE. One of the busiest areas is the mouth of the River Thames, which is also an area very prone to fog. When I used to sail in that area, if fog came down suddenly I would plot a course to the nearest buoy marking the channel. Sailing by lead line and compass, I would stand on until I found the buoy, or until the lead line told me that I was out of the channel. The lead line, in default of an echo sounder, is an essential aboard any boat and can frequently be used to help the navigator if he has lost his way, or is overtaken by darkness or fog. When I was quite sure that I was out of the deep water channel and therefore safe from being run down, I would sail along parallel to the edge of the channel, but well outside the line of the channel buoys, using the lead line all the time. One can sail from buoy to buoy, and it is surprising how, with practice, one can go buoy jumping in fog and meet each one as it is due to come up. If I have to cross a busy channel, I find the narrowest convenient part and then dash across at right angles, using the engine if necessary, although this tends to blank out any noise made by other shipping.

Fog has a nasty habit of disorientating people and of disguising the direction from which a ship is approaching. However, there is a method of getting an approximate idea of the direction of a ship's approach with the aid of a pencil. A boat's hull acts as a sounding box and if you press one end of a pencil against this, and press your ear hard against its other end, you will hear the propeller – and often the engine beats. The ship is coming from the direction where the sound is loudest. This method is sometimes successful in finding a buoy – the sound of water swirling past it can be picked up.

When navigating in fog there is one essential to be borne in mind: the compass, the most important instrument aboard, *must* be trusted. If it serves well in clear weather, it will serve just as well in fog. I have known experienced yachtsmen suspect the accuracy of a perfectly good compass in thick weather, such is the disorientating effect of loss of visibility. The same can apply to the navigation watch; it becomes suspect if a buoy fails to come up on time. In fog, without electronic navigation aids, the navigator must put his trust in those items of equipment which he has at his disposal and which have proved their reliability. Failure to do so can end in disaster. As I have already said, I hate fog, and I dread its coming down when I am in unknown waters, or those which have a mass of dangers, such as the Chenal du Four. But years of experience have taught me to keep my head, use my ears and trust my instruments. Hearing can be a great help, especially when it is used in conjunction with other aids. It is sound practice to have a reliable hand right up forward just listening and reporting anything he hears. I have found that youngsters between the ages of thirteen and sixteen are reliable for this job. They have not learnt to imagine dangers which may or may not exist, and so give fairly accurate reports. Above all, as skipper/navigator never let the crew know that you are worried or frightened, as you may well be; nothing spreads faster than fear, and imagination begins to play tricks on all and sundry.

Approaching an unknown coast can be a worrying time for a navigator. There is, as a result, a tendency to see what one wants or hopes to see, with the not infrequent result that, without warning, the realisation dawns that features are not what they were thought to be, and that one is lost. A way to prevent this is to decide on a particular offshore mark as the landfall point, *and find it* — its name will be painted on it. For instance, there is a port hand, International Association of Lighthouse Authorities (IALA), lateral system buoy at the entrance to Morlaix River called Stolvezen. Coming to the North Brittany coast in daylight, this buoy or the Pot de Feu nearby makes a very good aiming point. Alternatively, approaching the port of Ijmuiden in Holland there is a red and white landfall mark with a red spherical top mark, which is about 5 miles west of the harbour entrance. I always try, if I am to approach a coast in daylight, to make for a very positive landfall mark of this type, and this is a further reason for keeping

an accurate plot going. It is dangerous to have a slipshod attitude to navigation at any time, but out of sight of land, when one relies on picking up an actual mark at sea – which may be difficult enough to find in any case according to the conditions – it is nothing short of foolhardy.

As has happened to many people when approaching the coast with bad visibility, the mark may not be found. When this happens, there are two courses of action to take. Firstly one can obtain as true an Estimated Position as possible from the plot, using compass, log, watch and lead line, then sail in the direction of the mark using all four aids. It is extraordinary how often, after taking one or two stabs at it, one usually finds the missing mark. Never expect the mark to come up first time, right on time. There are too many imponderables in navigation for this to happen often, though when it does, the navigator does get a truly wonderful feeling! I usually allow at least five minutes beyond the expected time of appearance of the mark, and then search all round the horizon very carefully. If the mark doesn't show up I refer back to the plot to see if I have made a bad mistake. If I cannot find one, I try a fresh approach beginning from the plot at the end of the last run. If this fails, I try sailing carefully a mile or two inshore, still keeping up a careful all-round search, and then listen for breakers. When these are heard, it is safe to sail up or down the coast using the lead line. Sooner or later something will turn up, even if it is only a fishing boat coming out of, or entering, harbour. Whatever it is, once recognised on the chart it gives the required information for getting into harbour. But *for goodness' sake don't try this in bad weather, or on a rock-bound coast.* In both cases the best action is to sail up and down until the fog clears, or anchor if possible – out of any shipping lane. When the fog clears, approach the coast; using chart and pilot's guide, establish your position from as far offshore as possible and then make for the harbour entrance.

Approaching a coast at night is in many ways simpler than in daylight. There are lighthouses whose loom can be seen over 10 miles before the light itself comes over the horizon, so that recognition of individual lighthouses can be made while still a long way off. I have in front of me a small-scale chart of the English Channel, and on the French coast there are seven lighthouses with light ranges of more than 20 miles between Cap

Gris Nez and Dieppe, and another six between La Pointe de Barfleur and the Casquets. On the English coast between Dungeness and St Catherine's Point there are three lighthouses, two Lanbys and the Nab Tower. Between Portland Bill and the Lizard there are six more. Since, as I have explained earlier, only one light is needed for a positive fix, both the English and French shores are well served.

Approaching a coast at night in fog is a very different kettle of fish. Under these conditions, stand well offshore, out of the shipping lanes, and wait for the fog to clear – or for daylight, since fog often disperses with the sun. On those occasions when it is necessary to go inshore to get out of a shipping lane, there can be problems, but they are reduced to a minimum aboard a well-ordered boat where the navigator knows his job. The best policy is to cut inshore at right angles to the flow of traffic and, when soundings show between 7 and 10 metres (3 to 5 fathoms), anchor. Using the lead line continually, it is possible to follow the 5-metre contour as far as the entrance to the harbour or river. This is a cold and wet business, so the leadsman should be given a spell after about half an hour. Following a particular line of soundings is a very good way of finding one's way in fog providing that a keen watch is kept on the chart for any outlying dangers. Following a depth contour and noting any change of direction is one way of maintaining a reasonably accurate plot. If a sudden deepening of the water is encountered which can be recognised on the chart, this can be as good as a fix. If there is a buoy along the route, then so much the better – and even if it is slightly offshore, there is no harm in making a short excursion to find it. I have done this more than once and been rewarded for my trouble. Any action at all, however small, which will help to give a fix in fog is worth trying. Contour sailing is not only simple, it helps to give a sense of security which, in fog, is so vital for navigator and crew. Never say that you know where you are if you don't; just say 'I'm going to find out where we are'. It is when sailing single-handed that fear of, and in, fog is at its worst, and it is then that contour sailing comes into its own, because one at least knows how much water is under the keel. It is not easy, but with practice one finds a rhythm of casting lead, reading compass, casting lead again and so on. A confident navigator works well; one who has either lost confidence or is frightened will make mistakes. Therefore, do anything which will

maintain confidence, providing that it assists navigation and safety.

A great deal has been written about horizontal sextant angles as a means of obtaining a fix. Using this method from the bridge of a merchant ship or warship has a great deal to recommend it for speed and accuracy; from the deck of a small sailing cruiser it does not find very much favour with me owing to the difficulty of using a sextant on a platform which is probably bouncing about like a demented grasshopper. Getting a sun sight from the deck of a small boat is difficult enough, but taking a round of horizontal angles is often impossible. Nonetheless the method is worth looking at. I do not recommend an expensive sextant for a small boat; a light plastic one, such as the Davis series, is quite good enough and is surprisingly accurate considering its price. One other device is needed when taking a round of angles; this is an angle pointer, and though it appears similar to a woodworker's bevel is of a different construction – as shown in Fig 49. An angle is taken between two objects A and B, see Fig 50, and is set up on the angle pointer, using a compass rose for convenience. Remember

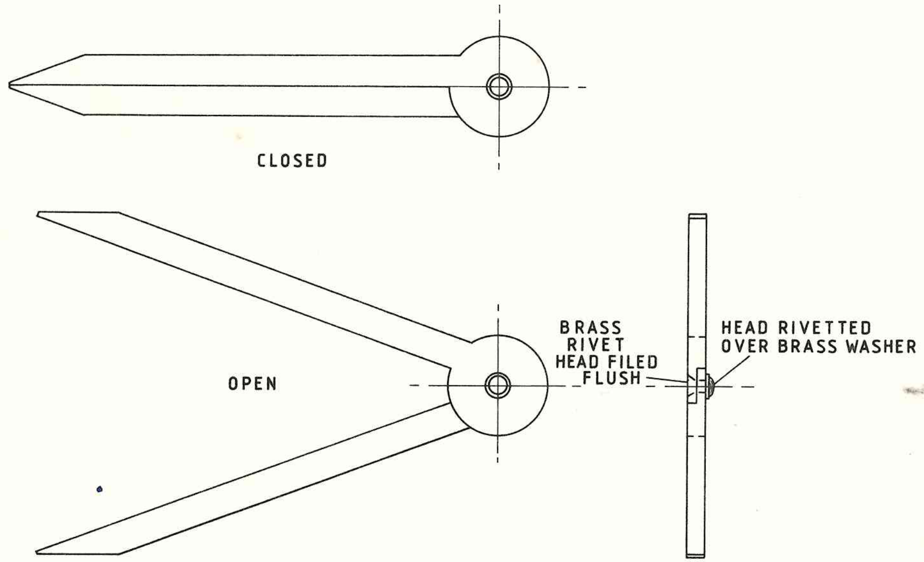


Fig 49

that this angle has no reference to the compass, and is therefore true. Let us say that this angle AOB (O being the observer) is 64°. This value is set on the pointer, one arm is placed on the chart so as to pass through A, and the other to pass through B. Since O is the observer's position, there is only one condition where the arms of the pointer can pass through A and B.

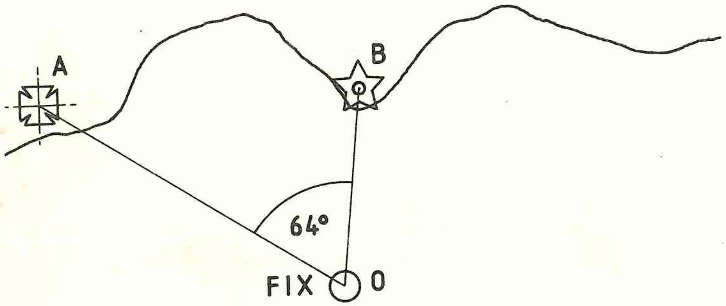


Fig 50

Another method of obtaining a fix is by measuring the angle subtended by an object of known height. The nautical almanacs give tables of distance off by vertical angle. For example, a lighthouse is shown on the chart as being 138ft 0in (42m) above the height of Least Astronomical Tide (LAT). After making the necessary adjustments for the height of tide and the height of eye of the observer, the vertical angle is measured by sextant. This angle is taken from the *top* of the *light* to sea level, as shown in Fig 51. Any necessary corrections are made for index error to give an included angle which, we will say, is 2° 36′. For a height of 138ft 0in we find that the distance off is 0.5 n miles. A bearing taken at the same time as the sextant angle will provide a bearing and range fix.

These then are the main methods of obtaining a sextant fix but, as I have said, a small boat is not an ideal platform from which to obtain accurate vertical or horizontal angles.

If, after all the care and attention to detail taken by a navigator in maintaining his Estimated Course and Positions, a mark fails to appear on schedule, there is one immediate course of action to

be taken. The whole plot must be checked through for any mistakes. No mistakes must mean that there is a difference between the actual tidal stream and tidal atlas, or the mark has been moved, and this is not as unlikely as it might seem. Therefore check the tide tables and atlas for anything which may have been missed. Failing this, and being certain that the last EP was correct, alter course by 90° either way and sail for a mile on that course keeping up a constant search for the missing mark, *and keep the plot going*. If after a mile no mark appears, alter course 180° and try in the opposite direction for double the distance sailed on the last leg. If still nothing appears, carefully check the latest Notices to Mariners. Failing information from this source, the only possible step is to approach the coast with the greatest care, pick up any easily identifiable feature and fix the boat's position from it. When you are sure, and only when, set course for your destination.

Some coastlines, however, do not lend themselves to this method since they are flat and featureless, and these usually have shallow water extending for some distance offshore. In this case, sail as close in as possible, and sail along a contour until you either meet a navigation mark, or a prominent feature ashore is

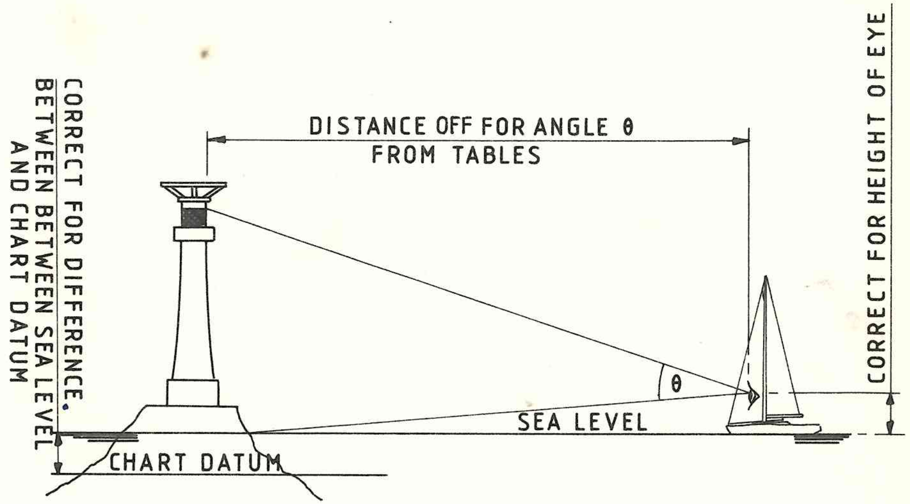


Fig 51

recognised from the chart and a fix obtained. But remember, *do not succumb to wishful thinking*; because you are hoping for a particular feature, and something like it appears, do not take it as proof that it is what you are looking for. Many boats have gone ashore through such a mistake. A careful use of compass, chart, watch and lead line, nautical almanac and pilot's guide will eventually provide proof, one way or another.

5
Electronic Equipment

It is considered by some that electronic equipment of any kind is an unnecessary luxury aboard a small boat. My opinion, backed by a number of years' experience, is that – providing that the pocket can stand the initial expense – some items, whilst not vital, can be of great help to the navigator. There are aids which it would be nice to have, but which are either too expensive or require too great a battery capacity to be practicable; radar is an example. There are makes of yacht radar which it would be quite possible to fit aboard a small cruiser, but their demand is something of the order of 50 watts which, from a normal small boat battery, would resemble a current demand of approximately 4·2 amps at 12 volts and this using a 75 ampere/hour battery and ignoring all other electrical demands, would last eighteen hours at the most without the battery receiving any charge. Using a wind- or water-driven generator with a maximum rated output of 4·5 amps, the actual input into the battery would rarely exceed 3 amps. The answer would appear to be a larger-capacity battery, but since space is at a premium aboard mini-cruisers and weight an important factor, a larger battery could present problems of its own. If, however, questions of pocket and space do not arise, I would recommend the small boat owner to fit radar. Apart from the safety aspect and the confidence it would bring, the navigator would benefit enormously. It gives an entirely different dimension to finding one's way in the dark or fog. With intelligent interpretation of the radar 'picture' a navigator can see his position and obtain a good fix either by cross bearings or by bearing and range. The modern small boat radar has an accuracy on maximum range of under 2 per cent, and this must give a navigator enormous confidence.

Whilst on the subject of radar, I feel it to be a good idea to examine the relationship between a small yacht and a merchant ship. It must first be realised that the sensitivity of the normal big ship radar is such that, whilst it will show a response from even quite small steel hulls, it can fail (as mentioned earlier) to show a recognisable or continuous response to a yacht's radar reflector. This is not due to the failure of the radar, but to the small echo produced by the reflector, too many of which are deliberately kept small to reduce windage. Also, a heeling yacht can dip her reflector below the radar 'lobe', see Fig 28 (ii), p 62, and radar aerials and reflectors are not always rigged in the optimum position and attitude. Consequently the response as shown on the screen could well be mistaken for wave clutter which, unless the set is fitted with an anti-clutter device, could well blank out a radar-reflector response. It must also be realised that some ships have quite large blind areas forward because the lobe is cut off, or just does not reach sea level soon enough, Fig 28 (i). Another factor in the recognition of yachts on big ship radars is that the set is not usually continuously manned except aboard naval vessels. Consequently the officer of the watch, taking his periodic look at the PPI Tube, may well not recognise a small 'break' as anything but local clutter, or he may miss it completely. I have never, even aboard quite big boats, relied upon being 'seen', and have made decisions on that basis. Even the best radar reflectors, such as the Firdell, cannot, through no fault of the equipment, be relied upon to make a big ship realise that there is another vessel in the vicinity. This is as a result of some or all of the factors mentioned above.

Fortunately it is possible to use another ship's radar emissions to give reasonably accurate information as to whether risk of collision exists or not. There are radar detectors on the market which will give a bearing on the origin of a radar signal. Because it is impossible for a radar detector to measure the time taken for a signal to reach the yacht from its point of origin, it cannot tell how far away that point is, but it is possible to tell from which point of the compass it is coming. If the angle remains more or less constant a risk of collision exists; if it changes by a measurable amount, one has to judge by the rate of change whether or not the ship will pass with a good margin of safety. If there is the least doubt, assume that a risk of collision exists and alter course accordingly. I am assuming that conditions of fog or low visibility exist. If a navigator finds himself approaching a shipping lane, particularly one of high density, he must keep out if possible, and

keep using the radar detector; there may be a rogue about.

The way to use most radar detectors is as follows (two people are better than one for this, one to operate the detector and one to log the readings). It is easiest to assume that your own boat is stationary for plotting purposes, and to use a plotting sheet, as shown in Fig 52. Hold the detector in the upright position to check if there are any radar signals to receive. If there are, change the detector to the horizontal position, and rotate it in a clockwise direction. As each signal comes up, call out its bearing to the plotter who enters it with a prefix letter and number on the plotting sheet, as in Fig 53. The radar detector I used had a compass attachment which, although it behaved consistently, may not have been a very good idea. I see no objection to taking bearings from the ship's head since all bearings are relative to the boat. Consequently, if one takes a set of bearings relative to the ship's head, a change of bearing or a continuous one will show.

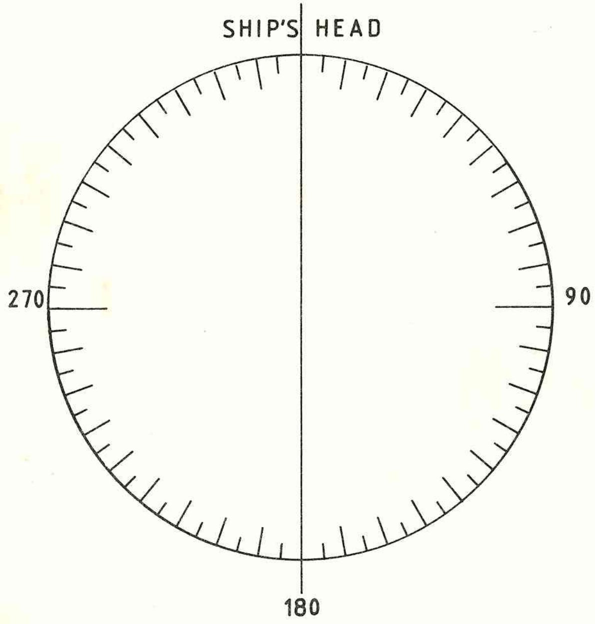
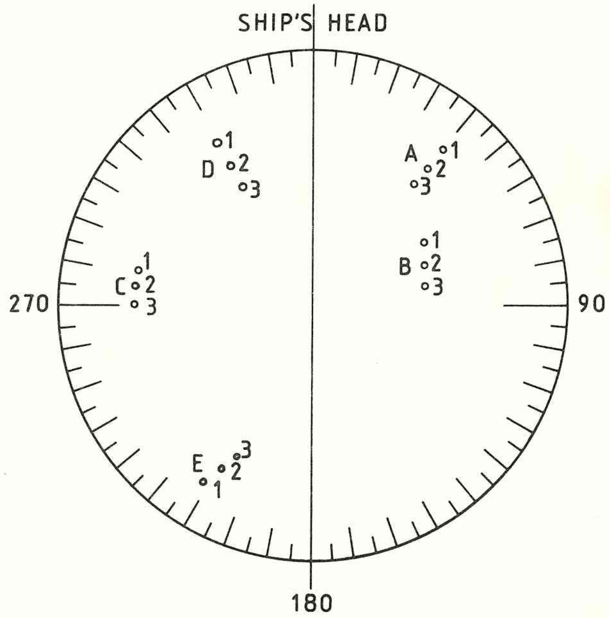


Fig 52

Therefore, for use with the latest radar detectors, which have no compass fitted, I have designed a form of Pelorus with the ship's head as 0°. It is simply a Perspex disc with a fore-and-aft line (0° and 180°). The athwartships line (90° and 270°) is also marked. The edge is graduated in 10° and 5° angles as shown in Fig 54. A hole is drilled through the centre of the disc through which is mounted a carriage for the detector which is free to rotate, and an arm with a pointer is attached to it which must be parallel to the antenna of the set. The underside of the Perspex is painted white to make the graduations show up clearly. The whole system is firmly mounted in a position where it can be read easily. As the set rotates, a signal is received and its bearing recorded. Whilst this is in progress the helmsman must maintain as steady a course as possible, and call out any variation over 2° so that a correction can be made on the plotting sheet. Any variation anti-clockwise should be called out as *plus* so that the recorder can add the



RADAR DETECTOR SHEET

Fig 53

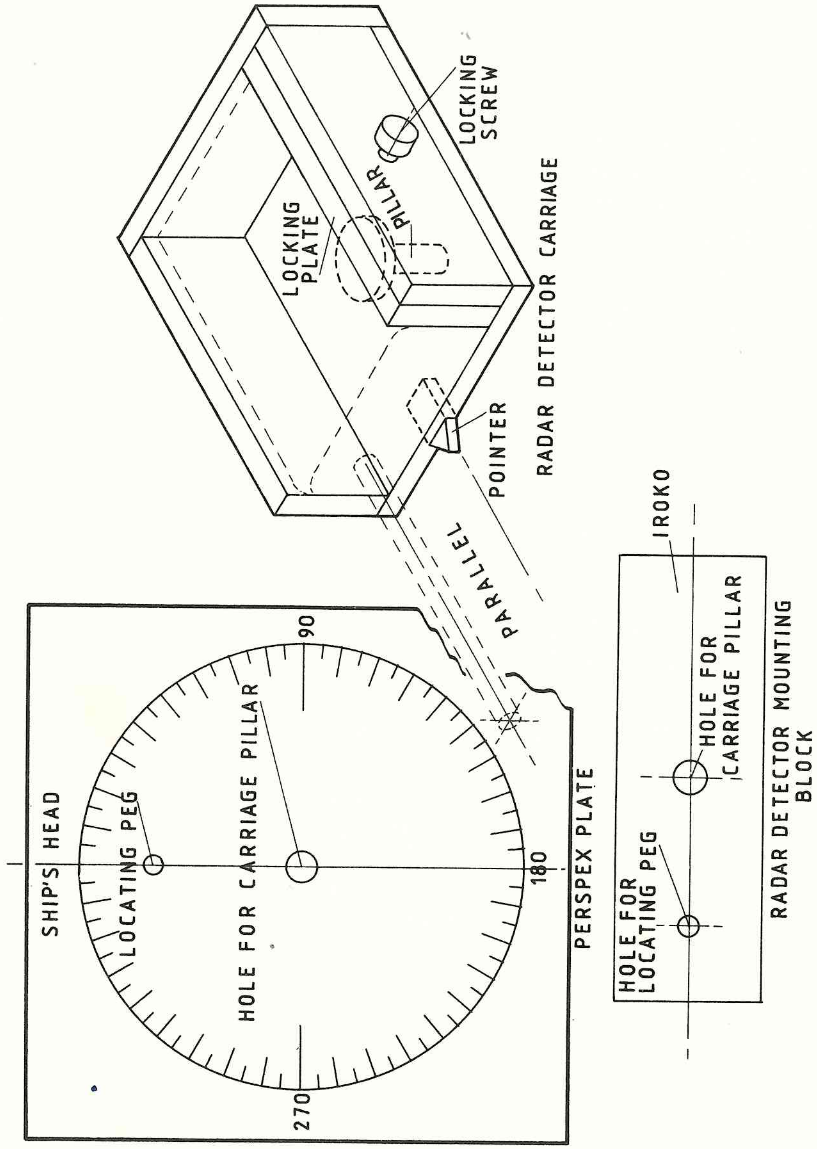
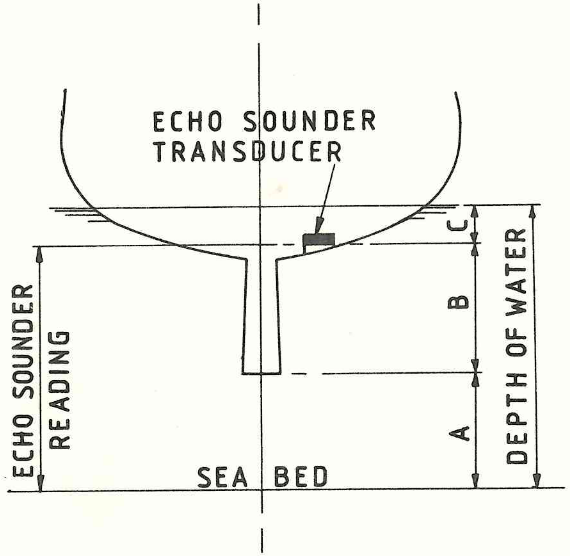


Fig 54

correction. Likewise any clockwise variation should be called out as *minus*. This method may seem complicated, but with very little practice it becomes simple, and a reasonably accurate angular location of radar signal will be obtained. Even though consecutive signals would seem to indicate that the ship will clear the yacht, it should continue to be logged on the recording sheet just in case it changes course. There are no range rings on the plotting sheet; the displacements shown in Fig 53 are to differentiate between successive plots. If no signals are received after a careful scan, the detector can be put away for ten minutes because even a ship travelling at 30 knots (unlikely in fog) will have made only 5 miles and her radar signal would probably be received in excess of this. One final point: even though a radar detector is carried and used, the normal procedures for sailing in fog should still be employed because it is quite possible that a ship's radar is out of action. Radar detectors are not all that expensive, and will repay their cost in the added peace of mind they will give.



A DEPTH TO UNDER SIDE OF KEEL
B FACE OF TRANSDUCER TO UNDER SIDE OF KEEL
C FACE OF TRANSDUCER TO SEA LEVEL

Fig 55

Taking an all-round look at the electronic equipment available to yachtsmen, price should not be the only consideration, although it will obviously be of great importance. My opinion is that function is the prime factor after which cost has to be considered. Cruising area and type of cruising ground are additional considerations. For the man whose cruising is limited to estuaries with occasional hops along the coast I would recommend an echo sounder as first choice, and the question to be answered is 'which is the best one I can afford?' Since most mini-cruisers sail in comparatively shallow water, I would suggest that the simplest type obtainable is quite adequate. The second question is whether to have the instrument calibrated in feet/fathoms or metres. Since practically all new editions of charts are being published with soundings in metres, my choice would be for the metric calibration with an alarm facility.

To use an echo sounder to its fullest potential requires practice, but most important is to install it correctly in exact accordance with the manufacturer's instructions. The best electronic instruments, of whatever type or make, will not perform with perfection unless correctly installed. After fitting an echo sounder, go out for a sail, switch it on and watch how the depth of water changes as shown on the display. But always remember that the recorded depth is that from the transducer to the bottom, NOT from the waterline or from the deepest part of the keel, see Fig 55. It is possible to check the exactness of the instrument by using an accurately marked lead line in still water and comparing the results, not forgetting to make allowance for the distance between the face of the transducer and the waterline. Any small differences can be corrected by the calibration knob on the set. The makers of most echo sounders give an accuracy figure of about plus or minus 2 per cent so, if, in making adjustments to the calibration, it is found to be more than this, the set should be returned to the manufacturer. However, it is very rare indeed that this is found to be necessary.

Having satisfied yourself that the equipment is working correctly, take a local large-scale chart and go to an area where there are a number of significantly different soundings, and watch how these are shown up on the display. If the sounder is fitted with a shallow water alarm, sail inshore with the alarm set at 2 feet (0.6 metres) over draught of the boat, again measured from the face of the transducer allowing for the distance to the underside of the keel. As you move into shallower water you will see the depth getting less until indicator and alarm spots correspond when the alarm will sound.

Once you have got used to the changing depths on the indicator, and have gained some experience in the behaviour of the sea-bed, it is time to move on to the more subtle use of the echo sounder. One element of this is contour sailing which I mentioned in the previous chapter. With practice this can prove to be one of the most useful ways in which to use an echo sounder. Contour sailing consists of sailing through water at constant depth. This can be, with the aid of a chart, an accurate and safe system of finding one's way into an estuary in bad visibility or at night. There are two methods of contour sailing: one can, from the chart, choose a depth which will keep one clear of outlying dangers, or one can follow a chart contour line such as the 5-metre or 5-fathom lines. Using the first method, a depth is chosen which gives plenty of water under the keel and which, by checking on the chart, keeps the boat clear of all dangers. Suppose that we choose to have 3 metres under the keel; we have to add the depth of the keel below the transducer, which we will assume to be just under 1 metre. Therefore we aim to sail keeping the depth indicator at 4 metres. The advantage of using this method is that we don't have to make any calculations to allow for the height of the tide. The disadvantage is that an accurate plot has to be maintained on the chart, so that the actual position of the boat over the ground, Estimated Position, actual course sailed and Estimated Course shall be as close as possible to each other. A fair check can be made by calculating the actual depth of water, allowing for the state of the tide, at an EP. If the calculated depth corresponds fairly closely with the depth on the indicator, this can be accepted as a reasonably accurate check. Following a contour line on the chart is possibly easier to do, but it calls for hourly checks on actual depth in relation to the height of the tide. By taking advantage of sudden changes in the direction of a contour line, it is possible to get a fix for position.

When contour sailing, the bias, if any, should always be towards the deeper water, thus giving a slight advantage should something unforeseen happen. A man I know, while contour sailing, once ran full tilt into an unlit and uncharted buoy, fortunately without

doing any damage. As he so very rightly remarked later, 'That'll teach me to keep a proper look-out'. Do not, because you are sailing on an echo sounder, neglect the dictates of good seamanship. This, as with all electronic instruments, is an aid to navigation only. All the requirements of seamanship and good navigation must continue.

Contour sailing can also be used for finding one's way along a channel in a river or estuary that is badly buoyed. I always recommend newcomers to the ownership of an echo sounder to practise this, and to try sailing in different depths of water. When one has had plenty of practice in the general method try sailing with half a metre or less under the keel. My reason for recommending this is that ability to sail in shallow water, without running on and off the bottom, means that, in fog, one can sail in shallow water out of the main channel, thereby reducing the chances of a collision.

The last, but by no means least important, method of using an echo sounder is profile sailing. Anyone who has learnt map reading on land will know how to produce the profile of a line across country. The same can be done with a chart to produce a profile of the sea-bed. By this means it is possible to check whether an Estimated Course is actually being sailed. I am not going to pretend that the method is simple, or that it can be done quickly. It requires time, patience and a small amount of drawing ability. There are two methods: one can prepare the profile for a planned course and compare this with what actually unfolds, or a profile can be prepared from a set of previous echo-sounder readings as entered in the navigation log, and compared with the chart until one finds a line which corresponds. In either case one really has to draw two profiles on the same piece of paper initially, but with experience it is possible to tell whether or not the drawn profile agrees with the sounding figures on the chart.

Profiles produced from echo-sounder readings have to be reduced to Chart Datum Sea Level, otherwise they will be false, because while the boat sails through the water this will be growing shallower or deeper according to the changing state of the tide. When an appreciable difference between two profiles is noticed, it is possible to tell which way to turn to get back on course through the change in the style of the profile; perhaps it starts to drop suddenly when it should have been going up slowly, or vice versa.

This should show on the chart, and the necessary course correction be made.

The way to draw a profile is simply a matter of common sense allied to an ability to draw a graph; there is only one difference – the zero line is at the top of the paper because the horizontal datum line represents sea level to Chart Datum, and it is depths below this level which are recorded. The vertical scale is chosen to cover the entire range of depths to be encountered on the course

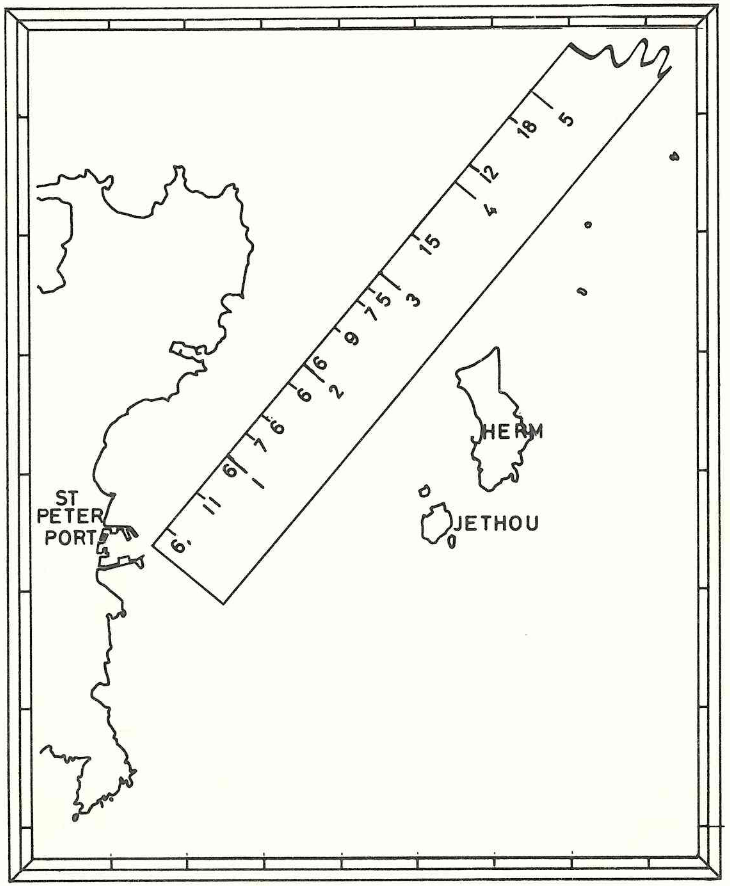


Fig 56

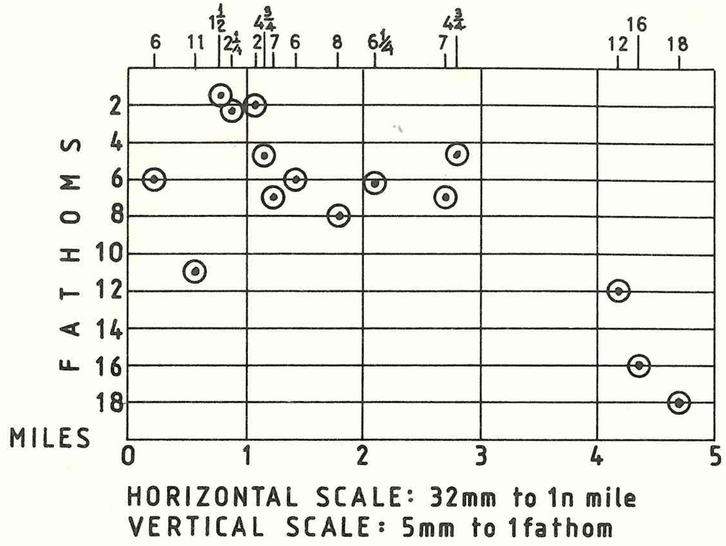


Fig 57

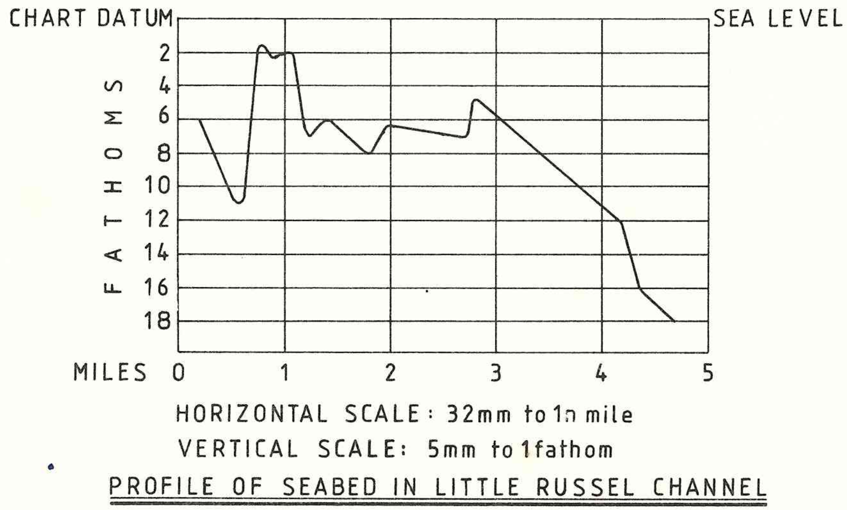
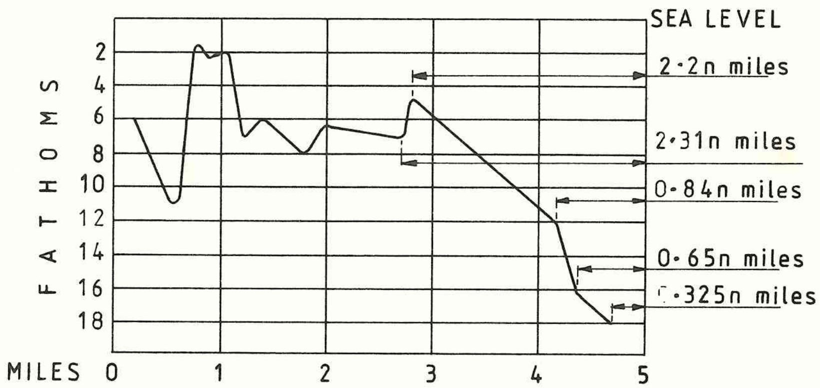


Fig 58

sailed, and should be as small as is practicable to show clearly the alterations in depth. The horizontal scale along the top of the sheet must be that of the chart in use, and for this reason there is little or no point in using small-scale charts. A natural scale of about 1:50,000 is about the smallest; anything smaller would not give much of a profile. Having chosen a suitable vertical scale, the horizontal one being that of the chart in use, a reference point, such as the last positive fix, is chosen. The edge of the paper is laid along the proposed course and the distances and depths of all soundings are marked along it, see Fig 56. The soundings are marked in *below* the horizontal datum line as in Fig 57; a dot with a ring round it is the best way of doing this. When the required distance has been covered and the dots are joined up, a profile of the sea-bed, exaggerated because of the vertical scale, has been obtained, see Fig 58. Remember that all soundings taken from the chart are below chart datum, which on the newer British charts is the Lowest Astronomical Tide (LAT), and on older charts Mean Low Water Springs (MLWS). It is as well, therefore, to check the chart in use and to remember that, since new tide tables are based on LAT, there will be a small difference if the chart datum is MLWS. This will result in the calculated depth being slightly



HORIZONTAL SCALE: 32mm to 1n mile
VERTICAL SCALE: 5mm to 1 fathom
PROFILE OF SEABED IN LITTLE RUSSEL CHANNEL

Fig 59

greater than that shown on the echo sounder. To compare the plotted profile with that over which one is sailing, the echo-sounder readings will have to have two corrections: one for the height difference between waterline and transducer, and the other the difference between actual and charted depth. The latter correction, based upon the state of the tide, can be calculated by using the 'Rule of Twelfths', which is a good general approximation, and suitable for this purpose. The Rule states that the tide rises or falls:

One-twelfth of its range during the first hour
Two-twelfths of its range during the second hour (1/6)
Three-twelfths of its range during the third hour (1/4)
Three-twelfths of its range during the fourth hour (1/4)
Two-twelfths of its range during the fifth hour (1/6)
One-twelfth of its range during the sixth hour.

If one wants to be really accurate, one uses the tidal curves, a description of which is rather too lengthy for this little book. A very good explanation is to be found in the *Macmillan Silk Cut Nautical Almanac*. As the boat sails along, readings are taken from the echo sounder at intervals which correspond with the distances apart of the points on the profile drawing, see Fig 59. I have not given all the distances, for the sake of clarity, but the drawing does illustrate the principle. Thus, one person keeps an eye on the log and, when the required distance comes up, the sounding is read off; then, after making the two necessary corrections, it is transferred to the drawing. If the boat is on course, the profile and recorded soundings should be very similar. It is unlikely that they will coincide exactly because the actual depth of water and that which is calculated are very rarely the same, mainly because of wind effect but also because of the boat's position on a wave at the moment of recording the sounding. With light winds and small waves there should be very little difference; what there is will probably be due to the fact that the tides do not always behave as predicted.

With stronger winds and bigger waves, differences could be over a metre. The wind affects the tides. A strong wind against tide will tend to hold the water back, whereas wind and tide together could mean that the tides in some areas will be higher or lower than predicted, see Fig 60. The time may come when a large discrepancy shows up on the profile sheet, and the navigator has to decide which side of his planned course the boat has gone. Since he may be sailing in conditions of visibility which either prevent him from seeing the coast, or prevent him from seeing it clearly enough to obtain a fix, he has but one resort: the chart. With one to a reasonably large scale he might be able to pinpoint the cause of the discrepancy, because of an odd sounding or a steeply shelving bank which has turned up sooner or later than expected – this is shown at point X in Fig 61. By the time he is within half a mile of the harbour entrance, he is about $1\frac{1}{2}$ cables to the south of his course, and must alter accordingly. If there is no actual indication from the chart the navigator has to make an intelligent guess as to the right course to take, and this is where experience tells. But, if he is approaching a coast, he would do better to change over to contour sailing.

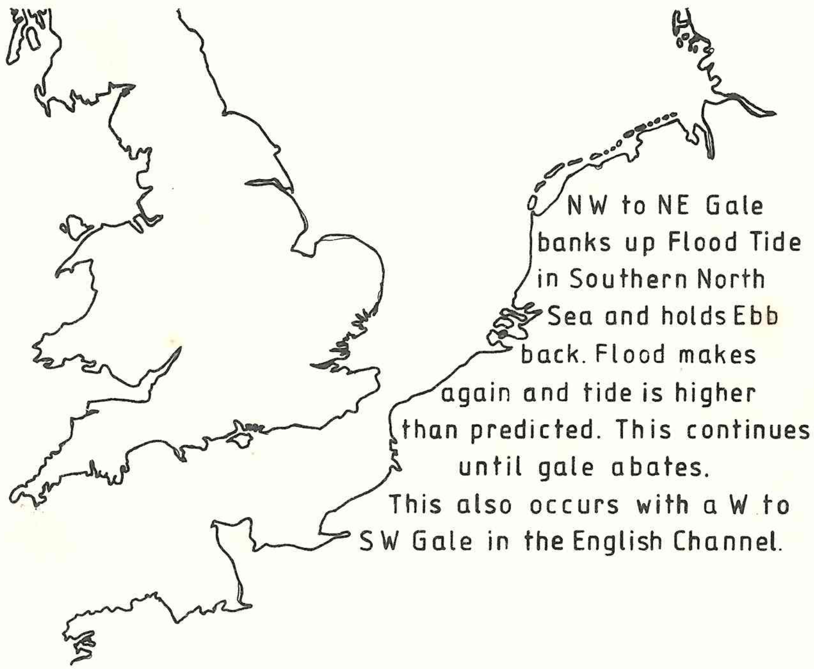


Fig 60

The second method of profile sailing is used when the navigator does not know where he is when approaching a coast. If he has maintained echo-sounder readings in his navigation log – which, when approaching a coast, he should do anyway – the profile which these produce, corrected to chart datum, can be compared with the chart and an approximation of position obtained when chart and profile correspond. This is not a method I like, and I hardly ever use it.

A more expensive type of echo sounder records soundings continuously on paper from a roll, and this saves time in having to draw a profile. Where the speed of recording is adjustable, it is possible with considerable practice to produce a profile to chart scale.

Next to an echo sounder, in order of priority, I would place a Radio Direction Finding (RDF) set. Day or night, clear or fog, an RDF set is a boon to the navigator. But be warned; any RDF set, cheap or expensive, if not used intelligently or correctly can be a menace because more reliance will be placed on it than is warranted. But in good hands it will give as good results as can be

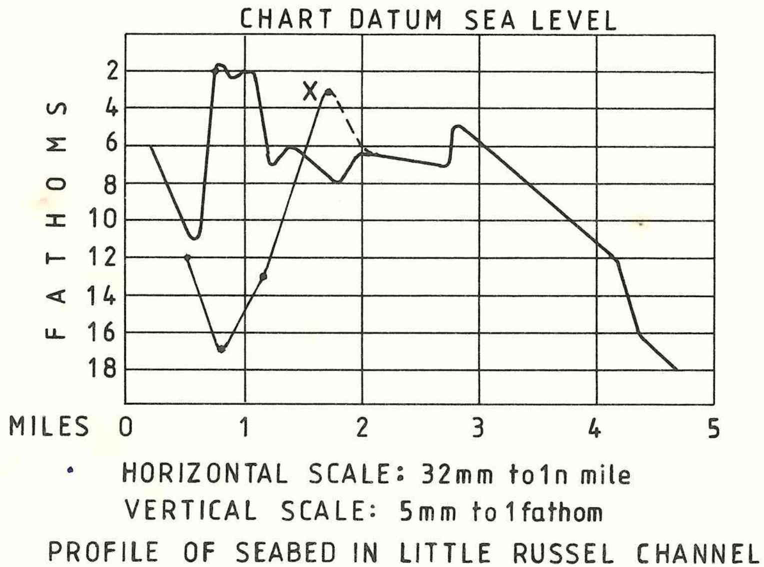


Fig 61

asked for. The system is perfectly simple, calling only for the set itself, a reliable watch and the identification signal, mode and timing of the beacon being sought. All this information is obtainable from the nautical almanacs, and any alterations are published in the Notices to Mariners, and repeated in some yachting journals. There are two important requirements for the RDF-set operator: the first is positive aural recognition of the Morse Code, and the second is practice in the use of the set. It must be obvious that without the former an RDF set is useless, and that for the latter all that is needed is time and patience in getting to know the set and how to use it. No specialised teaching is required; just follow the instructions in the manual and you can teach yourself. Aural recognition of the Morse Code requires practice. When learning the Code it is, in my experience, useless to learn the letters by dot and dash; learn them by saying 'dit' for the dots and 'dah' for the dashes so that the sound of each letter is learnt. When the time comes to put it into practice, the recognition of individual letters is much easier. An example of what I mean is shown in Fig 62 (see also p138). Having learnt the Code, try to get hold of a key-operated electric buzzer (cheap to buy or make) and enlist the help of a friend, preferably one who knows Morse Code, to send the letters. The friend will probably need a bit of practice, will learn the Code if he doesn't already know it, and help you to perfect your recognition of it. When you can receive the Morse Code at about fifteen letters a minute you will be able to recognise the identification signals of radio

LETTER	MORSECODE	SOUND
A	• —	DIT DAH
C	— • — •	DAH DIT DAH DIT
F	• • — •	DIT DIT DAH DIT
M	— —	DAH DAH
Q	— — • —	DAH DAH DIT DAH
V	• • • —	DIT DIT DIT DAH

Fig 62

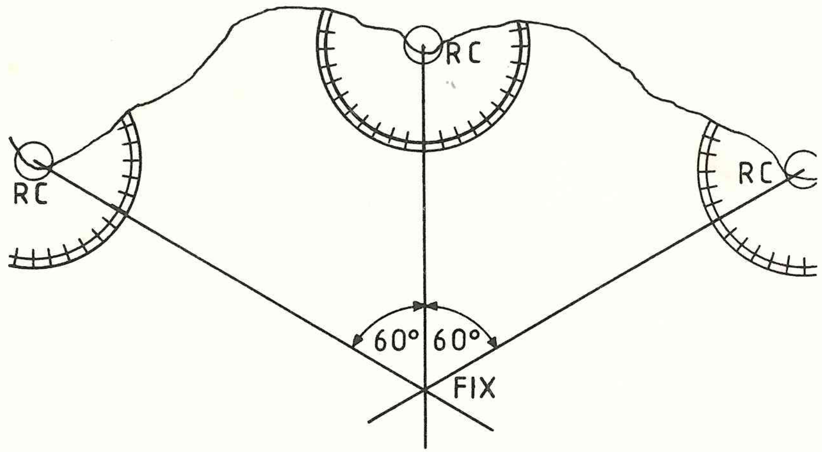


Fig 63

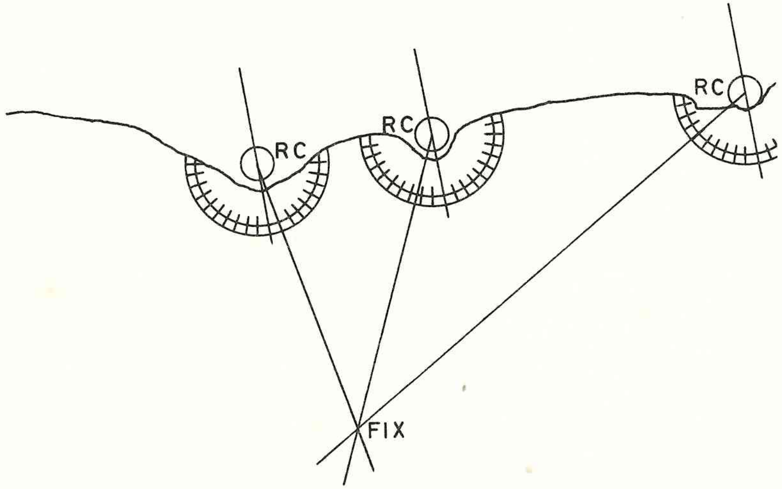


Fig 64

beacons without difficulty. Learning the Morse Code is a good winter evening occupation; an alternative way of learning to self-teaching is to attend those evening classes which give instruction to amateur wireless enthusiasts who have to be able to send and receive Morse by key in order to obtain their operating licences.

Once the Morse Code has been learnt, the RDF set can be used. The best way to get plenty of practice is to take the set every time you go sailing, and use it to obtain bearings either on radio beacons, aero radio beacons or even on normal broadcasting stations which cover your area. As I said before, the method is quite simple. Write down the names of the nearest beacons with their frequency, identification signals, modes and timing sequence. All these are obtainable from the nautical almanacs. Choose one of these, tune to its frequency, and at the time it is due to transmit you will hear its signal. If you don't hear it, turn the tuning dial slightly either way and you should pick it up. This of course does not apply to those sets equipped with push-button tuning. When the identification signal stops it will be followed by a long dash. The set is rotated until a minimum signal or 'nul' is received, when the bearing is noted. The same procedure is carried out for at least two other beacons. The ideal cut between any two stations is 60°, see Fig 63. However, this is not always possible, but whatever the bearing the navigator, taking each beacon in turn, converts it into a back bearing which is laid off on the chart using the compass rose drawn on the chart round the beacon. This is done for each beacon in turn, and ideally the point where the three lines cross is the boat's position, see Fig 64. It is seldom, however, that the three lines make a perfect cross; the more usual result is a small triangle, the famous 'cocked hat'. The size of the cocked hat gives some idea of the accuracy of the bearings obtained. Obviously a large triangle must be treated with reservation, a small one accepted – the boat's position being at the centre of the triangle. If the triangle is large, the bearings should be checked again and, if there was a measurable interval between obtaining each one (anything over five minutes), a correction must be made for the change of position of the yacht. If after this correction the triangle is still large, take a fresh round of angles and start again. By using the Mark V chart board and A3 size charts, duly modified, the time taken in producing the yacht's position is very much reduced when comparing the same function using a folded

chart on the knees. After many years' experience of using RDF sets held in the hand, I still get cocked hats, and in fact very seldom get a perfect cross; like a good many experienced navigators I tend to be suspicious of one, and then render thanks to Neptune, Poseidon and all the nautical deities I can think of. So, if after considerable practice you still haven't obtained that much-sought-after cross, don't be downhearted.

A great many factors can affect the quality of RDF bearings, not least of which are atmospheric conditions. These can bend a beam sufficiently for the bearing to be well off on occasions. Also, a bearing taken over land where the line to the beacon is not at right angles to the coast will be refracted and give a false reading. Other factors are whether or not it was taken near the limit of range of the beacon, or whether the set was used an hour before or after sunrise or sunset. Using a small hand-held RDF set, I would not employ a beacon at more than 75 per cent of its range. For instance, the Round Island Beacon in the Isles of Scilly has a published range of up to 200 miles; I would not use it at a greater range than 150 miles, and would certainly never use it if I had closed the beacon with the Land's End peninsula. The beacon at St Catherine's Point on the Isle of Wight can be trusted practically all the way across the Channel to the Cherbourg peninsula because there is no land for it to cross, and the signal seems reasonably accurate up to 40 miles. If only two beacons appear to be within decent range, one can take two bearings to obtain a preliminary fix, and then take a running fix on one or the other – preferably the one furthest along the course being sailed.

Obtaining any kind of bearing aboard a small boat in a seaway will not be as accurate as the plus or minus half a degree of which a small hand-held RDF set is capable. Under some circumstances one will be very lucky to get within plus or minus three degrees!

There arises the question of discrepancies between an Estimated Position obtained by careful plotting of the course being sailed by log and compass, and an RDF fix. A good navigator will compare a series of the two taken over a period of at least some hours to see if the difference continues. Finally, after weighing up all the evidence at his disposal, he has to make a decision as to which of the two is the most likely to be correct. A great deal depends upon beacon range and atmospheric conditions, particularly if there are thunderstorms about. Under reasonable conditions I prefer to trust my RDF fixes, but I make sure that I calculate my next EP from the last one, and also from the next EP from the last RDF fix. From the results I can usually tell which of the two I can rely on. In Fig 65, the navigator has plotted his Estimated Course through EP1 to EP2 and EP3. He maintained this course to windward and up tide of his planned course into the mouth of the estuary. He made, in my opinion, two errors; fortunately neither of them very large. The first was that he did not make a sufficient allowance for tide. Since wind (Force 4) and tide were together, the rate of tidal flow would be more than shown in the tidal atlas, and surface drift should have been allowed for. The second mistake came in not trusting his RDF set enough. His first two fixes should have shown him that he was to leeward of both his Planned and Estimated Courses, and he should have altered course when RF2 proved this. As it was, he only realised the truth at RF3, by which time he had to alter course to make allowance for the tide in order to pass close to starboard of the leading port-hand buoy since the channel in the very small mouth of the estuary was itself very narrow. This resulted in the boat having to come hard on the wind for the last 12 miles or so of what had been a long and tiring sail.

The navigator aboard a yacht outward bound from Salcombe

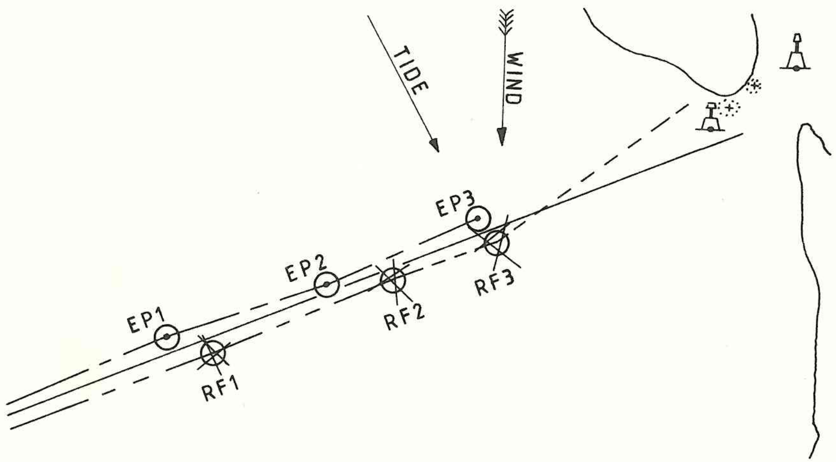


Fig 65

decided two things at the start. Firstly that the trip would take twelve hours to a point 3 miles west of Les Hanois Light, and secondly that he could therefore, quite legitimately, assume that the tides would cancel out. As the passage progressed he found that his RDF fixes were moving to the West of his Estimated Course. After about eight hours the fixes had reduced their westward tendency, returned back across the Estimated Course, and were then to the eastward of it. In other words, the RDF fixes had shown the amount of tidal effect on both ebb and flood. I reproduce the trace here in Fig 66. This bears out my tendency to trust my RDF fixes unless I am given very good reason to doubt

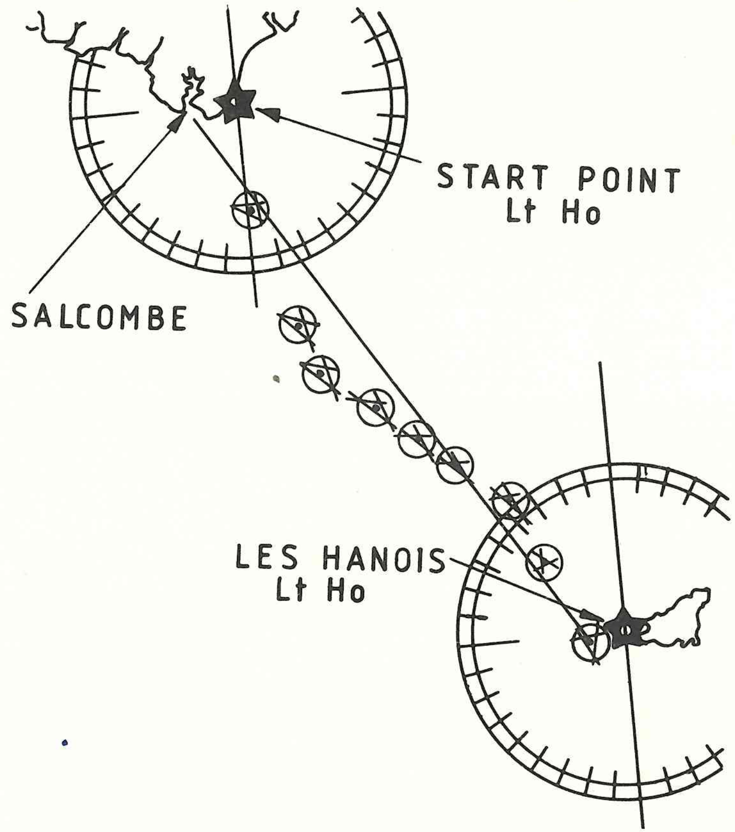


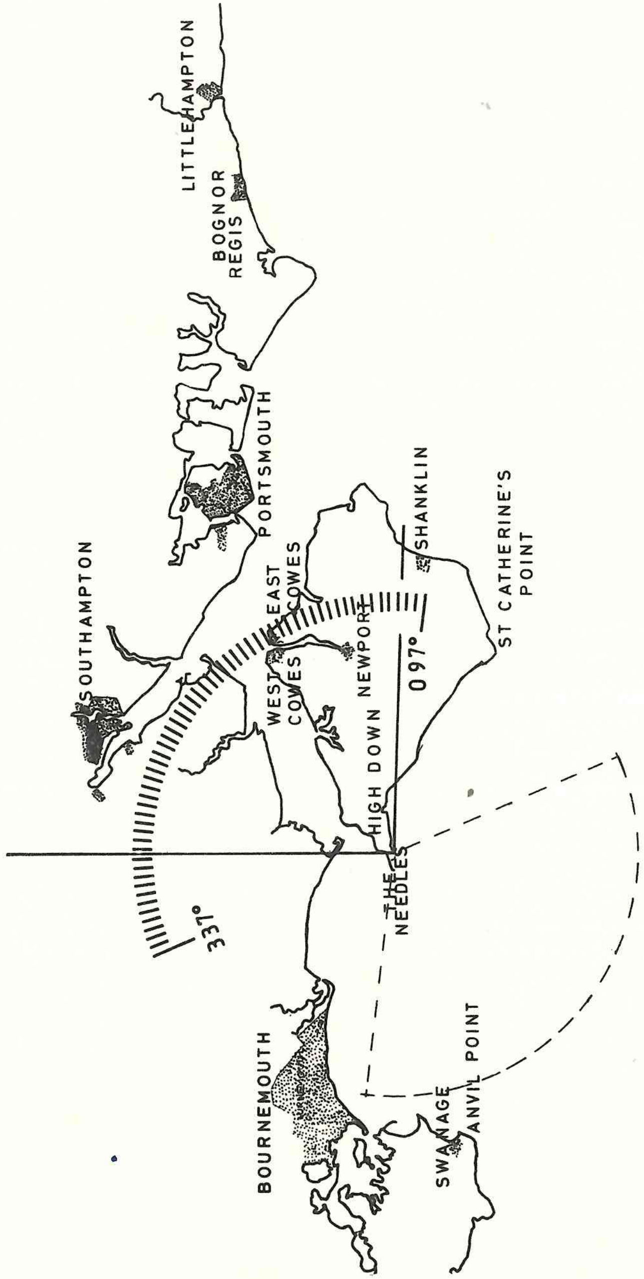
Fig 66

them. This might appear to be a dangerous generalisation, but some years' experience has gone into giving me this trust. After all, what is the sense in spending good money on an item of navigation equipment if you are not going to trust it. I have to admit that it took me some time before I believed it to be really trustworthy. At the present state of the art in electronics, hand-held RDF sets are very reliable. To endorse my belief in small RDF sets still more, I will here state that I have not had to swim for my life as a result of an error in my navigation . . . YET!

All round the coasts of the British Isles and Europe there are a number of aero radio beacons which are for the purpose of assisting in aircraft navigation. They are shown on charts by the letters ARC in magenta. The yachtsman also can use them, and one often finds that a better cut can be obtained from one of these than from a marine radio beacon. Aero radio beacons *which are near the coast* give accurate bearings; all have individual identification signals and similar modes to their marine counterparts, but there is one big difference: they transmit continuously. This last factor makes them of great use to us providing that they are close to the coastline so that they are not affected by land refraction. The ones which are reliable in this sense are shown on most charts. Identification signals and so forth are given in the nautical almanacs.

One last word about RDF equipment, and this applies to all electronic equipment carried aboard small cruisers. Take great care of it if you wish it to retain its efficiency. A hand-held set must *never* be left lying on a cockpit seat. Most of them are supplied with a stowage bracket, and this should be fixed in a dry part of the ship away from any danger of being knocked and damaged. The best practice is to send all electronic instruments back to the manufacturers for servicing at least once every two years; better, annually. Also, in view of the enormous amount of theft from boats these days, removable items of equipment should, if possible, be taken home when not in use, and all items should be individually insured for their replacement value so that, in the event of theft, they can be replaced as quickly as possible. Another security device is to mark your Post Code in special ink on each item of equipment. The local Crime Prevention Officer will be only too pleased to advise on this matter.

There is the question of the uses of VHF radio to the navigator to



HIGH DOWN, SCRATCHELLS BAY VHF RADIO LIGHTHOUSE
RANGE: 20n.miles Position: 50° 39′42″N 1° 34′36″W.
Calibrated 337° to 097°
SEA AREA COVERED BY SIGNALS SHOWN BY DOTTED SEGMENT OF CIRCLE

Fig 67

be answered. I think that its foremost role must be that of safety. All good navigators should be interested in safety, not only for their own vessel, but for all those within range. VHF Channel 16 is the distress and calling frequency and all ships, including yachts, are encouraged to listen in on this channel. A distress call is preceded by the code word MAYDAY repeated three times, and it has priority over all other types of call. It is the duty of anyone receiving a MAYDAY call to wait one minute to find out if the call is answered by the rescue authorities or another ship. If no reply is received, the yacht receiving the call should broadcast a MAYDAY RELAY call. Upon being answered, he passes the original message and then stands by in case his services are required to act as a relay station or to go to the assistance of the vessel in distress if this is at all practicable. It is important that the navigator plots the position of the vessel in trouble, and works out his best course to get to him. It is the unwritten law of the sea that we all, yachtsmen included, go to each other's assistance; there is no excuse for failing to do so once it is known that another vessel in the vicinity is in need of help.

Channel 16 is also used for urgent signals prefaced by the code words PAN PAN. This type of message concerns the safety of a person or vessel, and its priority is second only to a MAYDAY call. Again, a yacht receiving this message must do all in her power to be of assistance. The code word SÉCURITÉ precedes important messages relating to the safety of navigation, and is usually broadcast by a coast radio station. Also, a SÉCURITÉ call can be initiated by a ship to warn all other shipping of a hazard to navigation such as a mark adrift or out of position or, of more immediate interest to small boats, floating dangers such as a container washed off a ship and floating half submerged. This latter could be fatal to a small cruiser should she hit it, and it is the navigator's job to mark its last reported position and probable direction and rate of drift on his chart. From this information he can assess whether or not the hazard is likely to be a danger to his boat and, if so, what action to take to avoid it. All MAYDAY, PAN PAN and SÉCURITÉ calls *must be entered* in the yacht's radio log, as well as any action taken, which should also be entered in the yacht's log.

An additional service, one which is supplied by Trinity House for the VHF user, is the new series of VHF radio lighthouses. Up

until the time of their introduction, there was no means by which it was possible to obtain a fix using VHF radio. Now, with the introduction of these lighthouses, this is possible. Each lighthouse broadcasts on Channel 88 and gives a frequency modulated signal. Some have a range of up to 30 miles, whilst others can only reach out to about 14 miles. The lighthouses work in pairs, and can be used to obtain a crossing fix, whilst a single one can be used for a running fix. Fig 67 shows that the High Down VHF Radio Lighthouse is calibrated from 337° True to 097° True and, working on normal RDF practice, one would suppose that the area covered would be part of Hampshire, the Solent and part of the Isle of Wight. This of course is wrong. The VHF signal one receives from these lighthouses is a reciprocal of the bearings shown on my drawing, so that what actually happens is that the signal is received as a back bearing and, when the 'nul' comes up, the bearing obtained is that of the lighthouse *from* the vessel. That is why Fig 67 shows a dotted quadrant with its two extremities as reciprocals of the two limits of calibration. All one has to do is to count the number of beats heard until the 'nul' comes up. By referring to the tables published for that particular lighthouse, the bearing from the boat to the lighthouse is read off, and laid off on the chart. By repeating this for an associated lighthouse, in the case of High Down it is Anvil Point, it is possible to obtain a two-bearing fix. It must always be remembered, however, that bearings from VHF radio lighthouses are only accurate *to plus or minus 2°* and this is regardless of range so that the fix obtained will only be to that order of accuracy.

Never try to home directly on to a radio lighthouse. Steer to one side or the other, and take a series of running fixes, but always bear in mind the limits of accuracy, and keep well away from outlying dangers; in the case of High Down these would be the Needles to the West, and St Catherine's Point to the East. As experience in using VHF radio lighthouses grows, the navigator's confidence in them will grow also, and he will become more and more confident of the fixes he obtains from them.

What has been written in this book is from hard-earned knowledge gained over the years. Nevertheless, I am the first to admit that many of the ideas and methods I have descibed can be argued about and disagreed with. You may well, in the light of experience, come to disagree with some of the things I have written, but I would ask you to remember this: the way we all live our lives is based upon past experience, and no two people's lives are exactly the same. This applies also to sailing and navigation, and is one of the fascinating aspects of our sport. I learnt to sail and to navigate on the East Coast among the sand and mudbanks of its estuaries and coast. I now live in Cornwall, and the past ten years of sailing in this area have taught me many new things, and have caused me to modify some of my thinking, especially where navigation is concerned. You can afford, at times, to run aground on mud or sand, but you can never afford to hit a rock!

Acknowledgements

John Donne wrote that 'No man is an Island of itself'. This is true of life itself in general, but in writing a book on navigation, or any other specialised subject for that matter, it is doubly true. But for the help I have received from outside sources, I would never have been able to get beyond the first two chapters. In particular I want to thank Tom Wilson Esq of Imray, Laurie, Norrie & Wilson Ltd, and Roger Hunter Esq of Barnacle Marine Ltd for their invaluable assistance on the subject of their charts and publications. Also, my grateful thanks to Monsieur Claude Vergnot, not only for the help given on the publications of Éditions Cartographiques Maritimes, but for understanding my French! My very deep gratitude goes to the Managing Director of Offshore Instruments Ltd for his great generosity in the matter of the Mini-Compass. I would also thank Seafarer Navigation International Ltd for the help given on the subject of their products. To my friend Bernard Lilley I say a most heartfelt thank you for his help with the Mark V Pantograph. To Peter and Michelle Clark, for the loan of their wonderful electric typewriter which so expertly covered up my many typing errors, thank you both very much.

R.M.T.

Useful Addresses

Seafarer and Seafix Range of Electronic Equipment:
Seafarer International Ltd, Fleets Lane, Poole, Dorset BH15 3BW

Charts and Navigation Publications:
Imray, Laurie, Norrie & Wilson Ltd, Wych House, The Broadway, St Ives, Huntingdon, Cambs PE17 4BT
Stanford Maritime Ltd, 12–14 Long Acre, London WC2E 9LP
Barnacle Marine Ltd, The Warehouse, Next to 1 Crowhurst Road, Colchester, Essex CO3 3JN*
Éditions Cartographiques Maritimes, 9 quai de l'Artois, 94170 le Perreux-sur-Marne, FRANCE
Macmillan Silk Cut Nautical Almanac, Room 412, Macmillan Press Limited, Houndmills, Basingstoke, Hampshire RG21 2XS

Cruising Association Handbook:
Cruising Association, Ivory House, St Catherine Dock, London E1 9AY

Brown's and Reed's Nautical Almanacs:
From Yacht Chandlers and Bookshops

*The publication of Stanford's Charts was taken over by Barnacle Marine Ltd in 1983.

APPENDIX A

Beaufort Scale of Wind Force

Beaufort Number	*Description*	*Speed in knots**	*Height of sea in feet†*	*Deep sea criteria*
0	**Calm**	less than 1	—	Sea mirror-smooth.
1	**Light air**	1–3	½	Small wavelets like scales, no crests.
2	**Light breeze**	4–6	½	Small wavelets still short but more pronounced. Crests glassy and do not break.
3	**Gentle breeze**	7–10	2	Large wavelets. Crests begin to break. Foam is glassy.
4	**Moderate breeze**	11–16	3½	Small waves becoming longer; more frequent white horses.
5	**Fresh breeze**	17–21	6	Moderate waves, and longer; many white horses.
6	**Strong breeze**	22–27	9½	Large waves begin to form; white crests more extensive.
7	**Near gale**	28–33	13½	Sea heaps up; white foam blown in streaks.
8	**Gale**	34–40	18	Moderately high waves of greater length; crests begin to form spin-drift. Foam blown in well-marked streaks.
9	**Strong gale**	41–47	23	High waves; dense streaks of foam. Crests begin to roll over.
10	**Storm**	48–55	29	Very high waves with long overhanging crest. Surface of sea becomes white with great patches of foam. Visibility affected.
11	**Violent storm**	56–63	37	Exceptionally high waves. Sea completely covered with foam.
12	**Hurricane**	64+		The air is filled with spray and visibility seriously affected.

* Measured at a height of 33 feet above sea-level
† In the open sea remote from land

APPENDIX B

The Morse Code

The Morse Code should be learned by treating it as a series of sounds, not symbols. Thus B should be learned as 'dah-di-di-dit', not 'dash-dot-dot-dot'. Note that the final 't' of 'dit' is only sounded at the end of a letter code.

Letter	*Code*	*Sound*
A	·–	di-dah
B	–···	dah di-di-dit
C	–·–·	dah-di dah-dit
D	–··	dah di-dit
E	·	dit
F	··–·	di-di dah-dit
G	––·	dah-dah-dit
H	····	di-di-di-dit
I	··	di-dit
J	·–––	di dah-dah-dah
K	–·–	dah-di-dah
L	·–··	di-dah di-dit
M	––	dah-dah
N	–·	dah-dit
O	–––	dah-dah-dah
P	·––·	di-dah dah-dit
Q	––·–	dah-dah di-dah
R	·–·	di-dah-dit
S	···	di-di-dit
T	–	dah
U	··–	di-di-dah
V	···–	di-di-di-dah
W	·––	di dah-dah
X	–··–	dah di-di-dah
Y	–·––	dah-di dah-dah
Z	––··	dah-dah di-dit
Number	*Code*	*Sound*
1	·––––	di dah-dah-dah-dah
2	··–––	di-di dah-dah-dah
3	···––	di-di-di dah-dah
4	····–	di-di-di-di dah
5	·····	di-di-di-di-dit
6	–····	dah di-di-di-dit
7	––···	dah-dah di-di-dit
8	–––··	dah-dah-dah dit-dit
9	––––·	dah-dah-dah-dah dit
0	–––––	dah-dah-dah-dah-dah

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