DEVIATION CARD, No. 1.

Ship's Head by Compass.	Deviation.
	°
North	5 E.
N by E.	8 ,,
N.N.E.	12 ,,
N.E. by N.	15 ,,
N.E.	18 ,,
N.E. by E.	21 ,,
E.N.E.	23 ,,
E. by N.	19 ,,
East	15 ,,
E. by S.	13 ,,
E.S.E.	9 ,,
S.E. by E.	6 ,,
S.E.	2 E.
S.E. by S.	0
S.S.E.	3 W.
S. by E.	7 ,,
South	9 ,,
S. by W.	13 ,,
S.S.W.	16 ,,
S.W. by S.	20 ,,
S.W.	24 ,,
S.W. by W.	24 ,,
W.S.W.	23 ,,
W. by S.	21 ,,
West	18 ,,
W. by N.	15 ,,
W.N.W.	13 ,,
N.W. by W.	10 ,,
N.W.	7 ,,
N.W. by N.	4 ,,
N.N.W.	1 W.
N. by W.	2 E.
North	5 ,,

DEVIATION CARD, No. 2.

Ship's Head by Compass.	Deviation.
°	°
North	5 E.
N. 10 E.	8 ,,
N. 20 ,,	10 ,,
N. 30 ,,	12 ,,
N. 40 ,,	13 ,,
N. 50 ,,	14 ,,
N. 60 ,,	14 ,,
N. 70 ,,	14 ,,
N. 80 ,,	13 ,,
East	12 ,,
S. 80 ,,	11 ,,
S. 70 ,,	10 ,,
S. 60 ,,	8 ,,
S. 50 ,,	6 ,,
S. 40 ,,	4 ,,
S. 30 ,,	2 E.
S. 20 ,,	1 W.
S. 10 ,,	4 ,,
South	6 ,,
S. 10 W.	9 ,,
S. 20 ,,	11 ,,
S. 30 ,,	13 ,,
S. 40 ,,	14 ,,
S. 50 ,,	15 ,,
S. 60 ,,	15 ,,
S. 70 ,,	16 ,,
S. 80 ,,	16 ,,
West	17 ,,
N. 80 ,,	16 ,,
N. 70 ,,	15 ,,
N. 60 ,,	13 ,,
N. 50 ,,	12 ,,
N. 40 ,,	10 ,,
N. 30 ,,	6 ,,
N. 20 ,,	2 W.
N. 10 ,,	1 E.
North	5 ,,

MARINERS' COMPASS

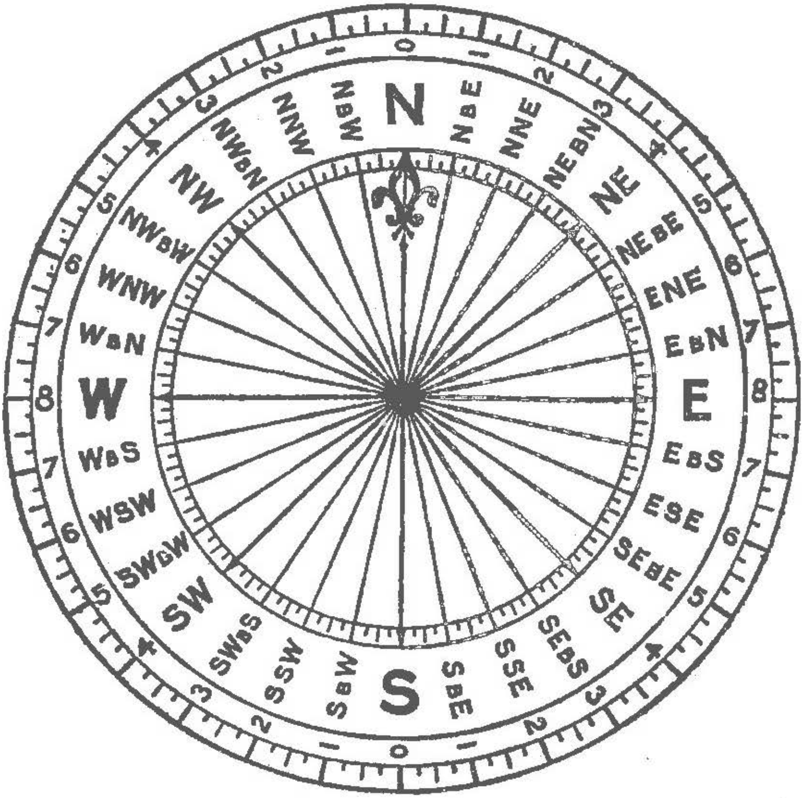

TABLE OF THE ANGLES.

Pts.	°	′	″	Pts.	°	′	″	Pts.	°	′	″	Pts.	°	′	″
¼	2°	48′	45″	2¼	25°	18′	45″	4¼	47°	48′	45″	6¼	70°	18′	45″
½	5	37	30	2½	28	7	30	4½	50	37	30	6½	73	7	30
¾	8	26	15	2¾	30	56	15	4¾	53	26	15	6¾	75	56	15
1	11	15	0	3	33	45	0	5	56	15	0	7	78	45	0
1¼	14	3	45	3¼	36	33	45	5¼	59	3	45	7¼	81	33	45
1½	16	52	30	3½	39	22	30	5½	61	52	30	7½	84	22	30
1¾	19	41	15	3¾	42	11	15	5¾	64	41	15	7¾	87	11	15
2	22	30	0	4	45	0	0	6	67	30	0	8	90	0	0

MODERN CHARTWORK

REVISED BY

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PREFACE TO FIFTH EDITION

IN revising *Modern Chartwork* an attempt has been made to maintain the work in as up-to-date a form as possible.

A considerable part of the book is unaltered. The fundamentals of the subject such as the use of charts and problems worked on charts do not change with time.

An endeavour has been made to strike a balance between 'fathom' charts, widely in use, and the already commenced metrication of British Admiralty charts.

Some sections have been enlarged, notably those on Lattice Charts and the Description of Charts and Publications. Other sections have been rewritten, mainly those on the Correction of Courses and Position Lines. A chapter on Navigation Aids and Systems has been added and many other smaller additions and alterations made. The Examples for Exercise contain a selection of questions likely to be met with in current Examinations.

Acknowledgements are due to public and private organisations who have been of great assistance in the revision. A list appears below.

I trust the book will go some way to meet the needs of professional and amateur seafarers alike.

W. H. SQUAIR.

DUNDEE. *August*, 1970.

ACKNOWLEDGEMENTS

Acknowledgements are due to the following departments and firms for valuable assistance given and, where applicable, for granting permission to reproduce various charts, diagrams and photographs—

Hydrographic Department, Ministry of Defence; U.S. Naval Oceanographic Office; Admiralty Compass Observatory; Decca Navigator Co. Ltd.; Decca Radar Ltd.; Messrs. C. Plath; Cossor Electronics Ltd.; Foreign Construction Syndicate Ltd.; General Electric Company; International Telephone & Telegraph Corporation; Messrs. Kelvin Hughes; Litton Systems, Inc.; Marconi International Marine Co. Ltd.; Northrop Corporation; Radio Corporation of America; Sperry Rand Corporation.

CONTENTS

MODERN CHARTWORK

CHAPTER I

NAVIGATION is the art of conducting a vessel from one port to another, and at frequent intervals fixing her position at sea. Pilotage or coastal navigation is an important branch of the art, and refers to the safe navigation of a vessel when approaching, or in sight of, land and its attendant dangers, or as is usually said, 'in soundings'.

It involves a sound knowledge of the information given on charts; of the graphic methods employed in setting safe courses, fixing and checking position, and other matters which will be explained hereafter, collectively incorporated in the term chartwork.

Before describing charts, or using expressions connected therewith, which have their counterpart on the Earth's surface, it will be expedient to explain, briefly, certain terms to which reference will be made in the following pages. The more important of these are meridians, parallels, great and small circles, latitude and longitude.

The Earth may be regarded as a sphere rotating about an axis passing through its centre, the axis cutting the surface at two diametrically opposite points called the North and South poles.

Imaginary circles are conceived to pass through both poles. These circles, called meridians, are great circles on account of their planes passing through the Earth's centre.

A great circle is supposed to exist midway between the two poles, and its plane, passing through the Earth's centre, divides the Earth into two equal parts. This circle is called the equator.

It is now to be imagined there are small circles encircling the Earth, each of which is parallel to the equator and to one another. The planes of these circles do not pass through the Earth's centre and therefore, in each case they divide the Earth into two unequal parts. Such circles are called parallels of latitude.

Meridians and parallels intersect each other at right angles and are used as ordinates to denote the position of a point.

The prime meridian is that which passes through Greenwich and it is to this meridian the positions of the others are referred.

The equator and parallels are divided into degrees, minutes and seconds of arc (° ′ ″), up to 180° east and west of the prime meridian which is the zero or datum meridian. Hence meridians to the east or west of the Greenwich meridian are referred to as in 'East or West Longitude', respectively.

The meridians are divided into ° ′ ″ of arc commencing with zero at the equator and increasing up to 90° at the poles. Thus a particular parallel is indicated by its angular measure north or south of the equator and is termed the 'Latitude of the Parallel'.

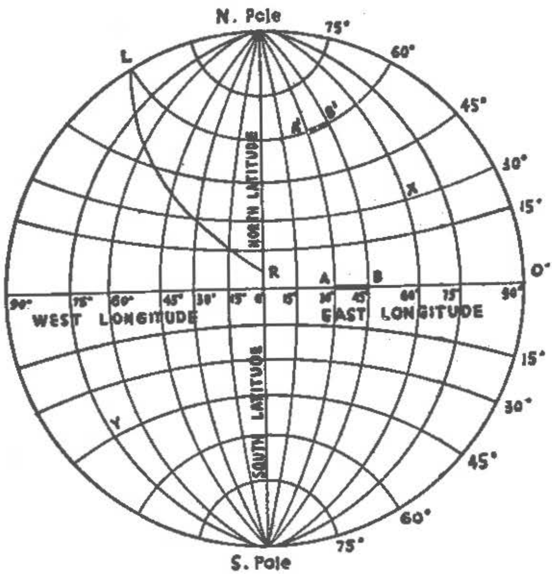


Fig. 1.1

Figure 1.1 shows one half of the Earth's surface with meridians and parallels, 15° apart, drawn thereon. The central meridian and parallel are, respectively, the meridian of Greenwich and the equator.

The usefulness of parallels and meridians is illustrated by reading off the positions of points *X* and *Y*.

X is in Latitude 30° North, Longitude 60° East.
Y ,, ,, 45° South, ,, 75° West.

Observe the meridians converge as they approach the poles, but their *angular* distance apart, as measured on the parallels, remains the same. Thus AB, on the equator, is an arc of 15°. In Latitude 60° N., $A'B'$ is also an arc of 15°. The distance between the two points expressed in miles has, of course, decreased. An arc of 15° of longitude, in Latitude 60°, extends over 450 miles, which is only half the length of the corresponding arc at the equator.

The line RL represents a 'Rhumb Line', which is a line crossing all meridians at the same angle.

MERCATOR'S CHART

Charts, representations of portions of the Earth's surface, are printed specifically for the use of the seaman in order that he may have presented to him in a comprehensive form the trend of the coastline, position of lights, important headlands, rocks, shoals, depth of water, direction of tidal streams, channels and all other information essential for the safe navigation of a vessel in navigable waters.

A vessel at sea maintains the same course for a period which varies with circumstances and, if the course is not due north or south, it crosses successive meridians at the same angle. This is the rhumb line course.

One of the main functions of a chart is to find from it, or lay off thereon, the vessel's course, and it would obviously be a distinct advantage if the course line could be shown as a straight line. Such a line, being the rhumb line course, must necessarily cross, or cut, meridians at the same angle, and to permit this desirable condition all meridians must be shown on the chart as parallel straight lines.

Charts embodying this feature were first constructed by Gerardus Mercator, a Flemish geographer, who conceived the idea of representing the surface of the Earth as a plane surface.

The projection, termed Mercator's projection, although an artificial one, is admirably suited to the special requirements of the seaman, as it shows all rhumb lines, including the equator, parallels of latitude and meridians as straight lines.

It is constructed upon the following principles:—

(a) Rhumb lines on the Earth's surface are represented by straight lines on the chart.

(b) All angles on the Earth's surface are equal to corresponding angles drawn on the chart.

It is manifestly impossible to represent the curved surface of the Earth, or sphere, as a purely plane one without introducing distortion. The distortion is very evident on the Mercator's projection. It increases with the latitude, and in the vicinity of the poles becomes of such magnitude that it is impossible to show this area on the projection.

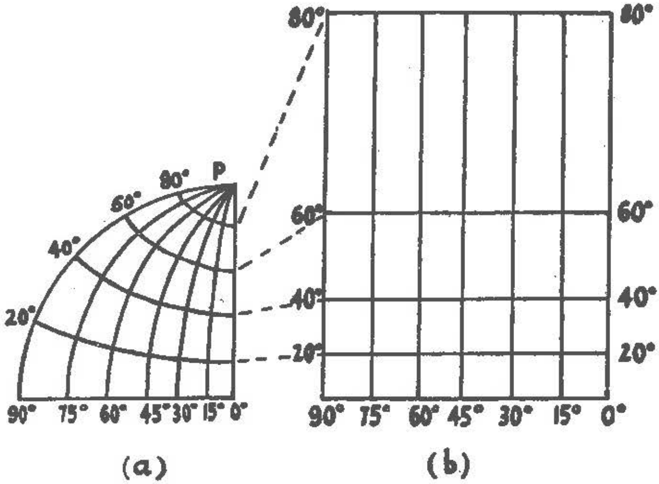


Fig. 1.2

Fig. 1.2 (*a*) represents a small part of the Earth showing thereon meridians of longitude 15° apart and parallels of latitude 20° apart.

Fig. 1.2 (*b*) shows the same meridians and parallels as they would appear on a Mercator's chart.

Opposite page 8 is a chart of the world on Mercator's projection.

Observe the meridians are parallel to each other and the distance between the parallels of latitude increases as the latitude increases. The distortion is very significant if one compares the areas taken up on a Mercator's chart by the Islands of Borneo and Iceland. They appear to be the same but are in actual fact in the ratio of 7 to 1; the land area of Borneo being about seven times that of Iceland.

The departure from the normal shape of the Earth, as depicted by Mercator's chart, does not in any way detract from the general utility of the projection since the form of coast lines is accurately shown, but, of course enlarged, and the true proportions existing between latitude and longitude are maintained. To accomplish the correct relationship, the distance between the meridians remains constant, while the distance between the parallels increases with the latitude—the increase between the parallels being consistent with the increase between the meridians. Thus, with regard to the scales of longitude and latitude:—

The scale of longitude is constant.

The scale of latitude varies, increasing towards the poles.

It will be convenient here to summarise the features of the Mercator's chart as compared with the sphere:—

	SPHERE	MERCATOR'S CHART
Meridians:	Great circles converging as they approach the poles where they meet.	Parallel straight lines.
Parallels:	Small circles equidistant from each other.	Parallel straight lines, the distance between them increasing as the latitude increases.
Scale of latitude:	Constant for all latitudes.	Varies with the latitude.
Scale of longitude, i.e. length of degree:	Varies with the latitude.	Constant for all latitudes.
Rhumb line:	Shown as a curved or spiral line.	Shown as a straight line.

In the above observations no account is taken of the fact that the Earth is not a perfect sphere but an oblate spheroid.

Other important properties of the projection are:—

(1) The meridians and parallels intersect each other at right angles, thus allowing positions to be plotted, and taken off, quickly and accurately.

(2) The track of a ship kept on a true course, the rhumb line course, appears as a straight line on the chart, hence the true course from one point to another can, with the aid of a compass rose, be taken off direct, or laid down, on the chart with facility.

These important considerations illustrate the superiority of Mercator's projections over others for the purposes of navigation.

GNOMONIC, OR GREAT CIRCLE SAILING, CHARTS

Gnomonic, or great circle sailing, charts provide the navigator with a convenient means of obtaining the great circle track from one position to another.

The gnomonic projection is that in which the point of sight, or eye, is assumed to be at the centre of the Earth, or sphere; and the plane of the projection, or primitive, a plane placed tangential to the surface of the sphere. All meridians and parallels are projected on to the primitive plane.

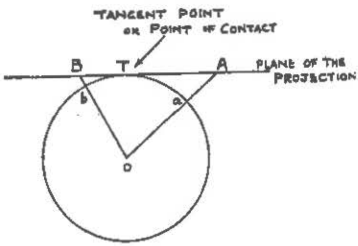


FIG. 1.3

In Fig. 1.3 if *O* is the centre of the earth and *T* the point of tangency, point 'a' will be projected on to the chart at 'A' and point 'b' at 'B' and so on.

The planes of all great circles pass through the centre of the Earth where, as already mentioned, the point of sight is situated. It therefore follows that all meridians, when projected on the plane of the projection, will appear as straight lines converging towards the poles. Parallels, being small circles, will appear as curved or concave lines. These features enable a gnomonic chart to be readily distinguished from a Mercator's chart.

If the north or south pole is selected as the tangential point it will be seen that this constitutes a special case. The meridians will meet at the point of tangency and the parallels of latitude will be concentric circles round this point. Such a chart is called a polar gnomonic chart.

Distortion occurs on gnomonic charts, the amount increasing from the centre of the projection and varying with the distance of the primitive plane from the centre of the sphere.

It may be seen from Fig. 1.3 that it is impossible to portray more than a hemisphere on a gnomonic chart and in practice, of course, less than this is feasible.

The distortion renders it impossible to obtain courses from, or measure distances on, this type of chart.

On this projection a great circle appears as a straight line, hence the great circle track between two positions is readily obtained by joining them with a straight line.

When the track is drawn in, the navigator can discern if land is to intervene or, in the case of high latitudes, if the track leads to latitudes where ice is likely to be encountered. In such cases a modified form of great circle sailing is adopted which is called 'Composite Great Circle Sailing'.

The maximum latitude is decided upon and a straight line drawn from the departure position just to touch this parallel; another is drawn from the point of destination to touch the same parallel. The vessel proceeds along the first great circle track until she reaches the maximum parallel on which she remains until arriving at the second great circle track leading to her destination.

See also Appendix—Projection and Scales.

TRANSFERRING A GREAT CIRCLE TRACK FROM A GNOMONIC TO A MERCATOR'S CHART

It is impracticable for a vessel to follow the great circle track owing to the ever changing course. In practice an approximate great circle track is followed. This track is obtained as follows:

The latitude and longitude of a series of points relatively close together along the great circle track, as shown on the gnomonic chart, are picked off and transferred to the appropriate Mercator's chart. The fairest curve possible is now drawn through the positions or alternatively the points are joined together by straight lines, each of which is a rhumb line course, and their combination forms an approximate great circle track of practical value.

Plate 1.1 shows a gnomonic projection.

Plate 1.2 shows a Mercator's projection.

On Plate 1.1 a straight line is drawn from the position off Cape Horn to the position off the Cape of Good Hope. The positions *A*, *B*, *C*, *D*, etc. which are 10° of longitude apart are marked and their latitudes noted. The latitude and longitude of each point in turn is then marked on the Mercator's chart, Plate 1.2 and the great circle drawn in as described above.

The track thus indicated approximates very closely to the actual great circle track, and the tedious process of calculating the positions of the points is avoided.

REMARKS ON MERCATOR AND GNOMONIC GREAT CIRCLE SAILING CHARTS

Mercator and gnomonic great circle sailing charts have one feature in common—each shows the course line (appropriate to the chart) between two positions as a straight line.

On the former, the course can be quite easily ascertained from the chart with the aid of a compass diagram or protractor; and, moreover, the distance between the positions can be measured with a fair degree of accuracy.

The gnomonic chart does not possess these advantages.

The great circle track on a gnomonic chart, unlike the rhumb line on a Mercator's chart, crosses successive meridians at a varying angle, and the course therefore is constantly changing. Any compass diagram printed on the chart would only apply to a particular position on a meridian and would merely give the course at that position. The variation in the scales of latitude and longitude renders it impracticable to measure distance.

Note that on a gnomonic chart a great circle appears as a straight line and a rhumb line appears as a curve towards the equator. (Plate 1.1). On a Mercator's chart a rhumb line appears as a straight line and a great circle appears as a curve towards the pole.

Referring to Plate 1.2, where both tracks are shown between Cape Horn and Cape of Good Hope, it will be seen the tracks diverge on leaving the former point. Proceeding eastward, the divergence continues until position *X* is reached, when the tracks cease to diverge and begin to converge. At *X* the great circle course is the same as the rhumb line course and this position is known as the 'Point of Maximum Separation'.

The great circle appears to be the longer of the two tracks but this is not so, the distances being—great circle 3594 miles, rhumb line 3791 miles.

On the great circle a vessel is always heading for her destination as if it were in sight directly ahead.

On the rhumb line course a vessel is only apparently heading for her destination. She is, in fact, proceeding along a spiral curve and only heads directly for her port when it is in sight.

PLAN CHARTS

A small portion of the Earth's surface may be regarded as a plane surface; and charts, such as anchorages, harbours and their approaches which contain much detail, are usually constructed on this projection.

These plane projections, which are usually termed plans, may or may not have graduated meridians and parallels. All new plans are graduated and older plans which are revised are being graduated as opportunity offers. In ungraduated plans the latitude and longitude of some important position, such as an observatory or lighthouse, is given.

SCALES (CHARTS)

All charts have two scales, latitude and longitude; the former is found at the sides, and the latter at the top and bottom edges of the chart, and are termed graduated meridians and graduated parallels, respectively.

SCALES (PLANS)

As mentioned above plans may be graduated or ungraduated. In graduated plans the meridians at the sides are graduated, also the parallels at the top and bottom edges, and in addition a scale or scales of distance may be given. In ungraduated plans the edges and sides are not graduated but scales of latitude, distance and longitude are given. *See* Plate 1.3, page 19. In some cases only a scale of distance is given.

Since a plan covers a very small area, the scales of latitude and distance will be of the same length and will differ only in their method of division. (*See* Appendix, page 351.)

GRADUATION

The graduated meridians and parallels of all charts are primarily divided into degrees and minutes, and the latter perhaps subdivided; this subdivision being possibly halves (30″), fifths (12″) or tenths (6″).

Before taking off positions on any particular chart it is necessary to inspect the graduation to ascertain the subdivision used.

Graduation in plans may have a slightly different, more open appearance from graduation on charts.

An interesting Admiralty chart (No. D. 6697) is published which gives full details of graduations and scales used for charts and plans.

SCALE OR NATURAL SCALE

The scale or natural scale of a chart or plan is found under the title. It is expressed as a fraction, thus:— $\frac{1}{200,000}$ or 1 : 200,000.

In the case of a chart which covers an appreciable area, the scale is given for a particular latitude. For instance, in a coastal chart it is usually given for the middle latitude of the chart.

For example, on a chart may be printed:—

Natural Scale $\frac{1}{298,000}$ (at Lat. 55° 30′ N.)

The scale or natural scale is the ratio between a unit of length measured on the chart and a corresponding unit measured on the Earth's surface. Thus in the above example, one inch measured on the chart is equivalent to 298,000 inches on the Earth's surface, i.e. one inch of the chart portrays 298,000 inches at Lat. 55° 30′ N.

In the case of a plan or of a chart where the area covered is small, it is unnecessary to quote a latitude for the scale.

For example, on a plan may be printed:—

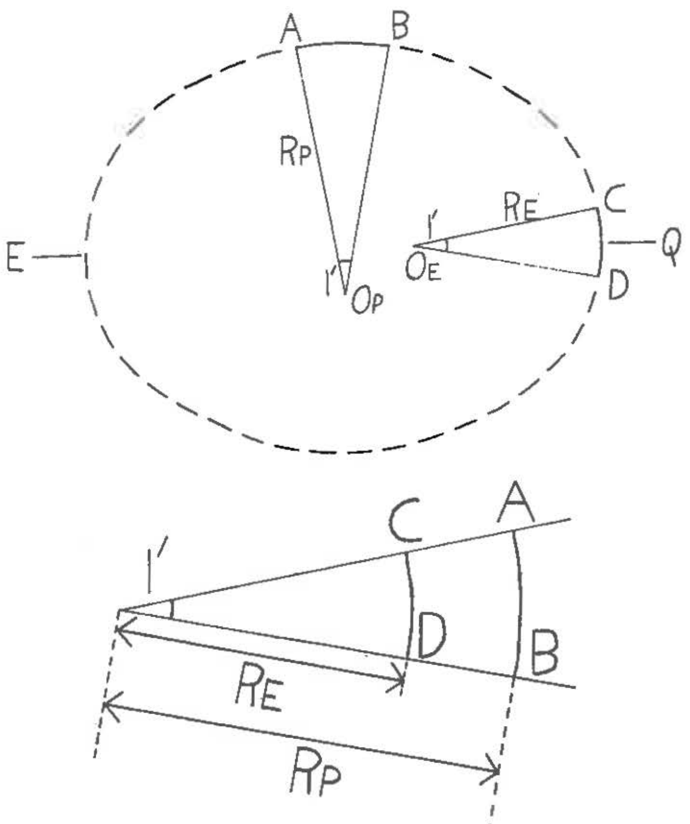
NATURAL SCALE 1 : 12,500

In Metric Charts and Plans the term 'natural' has been dropped and the nomenclature appears in the form SCALE 1 : 50,100 at lat. 31° 50′. The principle of course is unaltered and the 'inch' quoted in the example above could have been a centimetre or any other unit of length.

THE NAUTICAL MILE

The nautical, or sea, mile is used in navigation to measure distances. It may be defined as the length of a minute of latitude or the length of a minute of arc measured along a meridian.

The Earth is not a perfect sphere. There is a flattening in the vicinity of the poles resulting in the equatorial diameter exceeding the polar diameter by approximately 27 miles.



FIGS. 1.4 (*a*) and 1.4 (*b*)

A meridian on the surface of the Earth is not in reality a perfect circle but is an ellipse. In view of this the length of one minute of latitude will vary with the latitude.

Thus the nautical mile at any place is accurately defined as the length of an arc of the meridian subtending an angle of 1′ at the centre of curvature of the place.

Fig. 1.4 (*a*) shows a meridian; *EQ* is the line of the equator.

O_P is the centre of the earth's curvature at the pole.

O_E is the centre of the earth's curvature at the equator.

R_P is the radius of the curvature at the pole.

R_E is the radius of the curvature at the equator.

AB is the arc of the meridian subtended by an angle of 1′ at O_P

CD is the arc of the meridian subtended by an angle of 1′ at O_E.

Thus *AB* and *CD* are the lengths of a nautical mile at the pole and at the equator respectively.

In Fig. 1.4 (*b*) an angle of 1′ is drawn. The radii and their corresponding arcs from Fig. 1.4 (*a*) are set off. It can be seen that *CD* is shorter than *AB*.

Thus a nautical mile is shortest at the equator where its length is 6046 feet (1·8428 km) and longest at the poles where it is 6108 feet (1·8617 km).

The nautical mile is divided into 10 cables, a cable being usually accepted as 600 feet.

In order that the speed at which a vessel is steaming can be expressed, a standard length for the nautical mile has been decided upon. By international agreement the chosen length of the International Nautical Mile is 1·8520 km (6076·1 feet). The British (or U.K.) Nautical Mile of 6080 feet (1·8532 km.) was used for many years.

Note—*see* appendix, page 351.

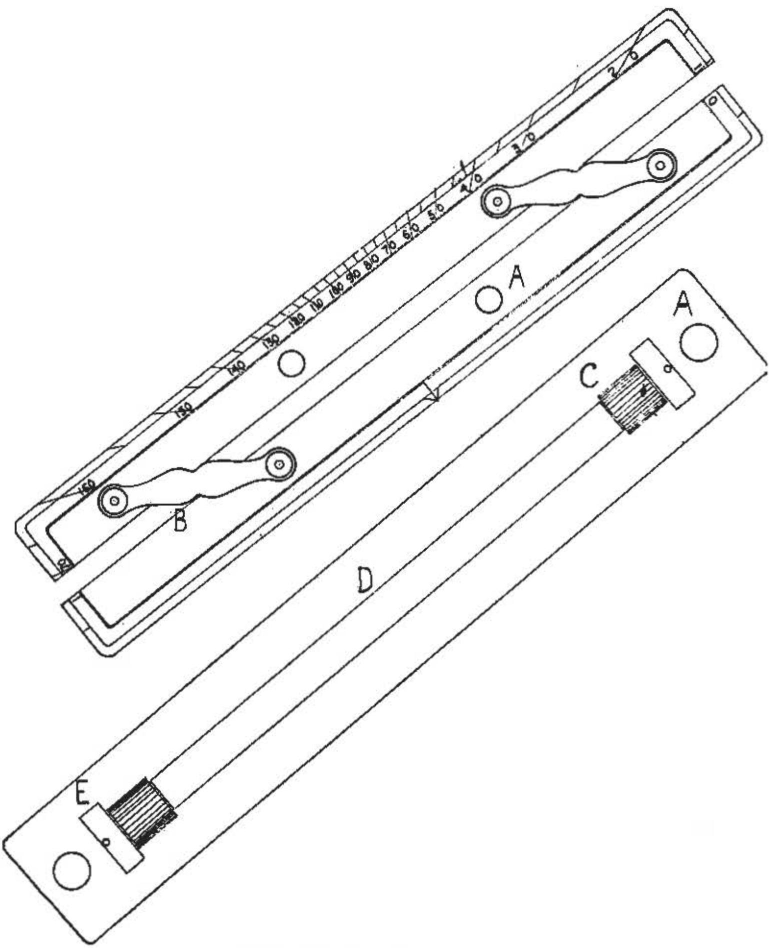
THE KNOT

The knot is the nautical measure of speed. It is always used to indicate a vessel's speed or the rate of a current, and the term is to be understood as including both distance and unit of time. Thus a speed of 12 knots means 12 nautical miles per hour. A rate of 1 International knot means 1 mile (1·8520 km) per hour; a rate of 1 U.K knot means 1 mile (6080 feet) per hour.

Even with the adoption of metric charts there is no requirement to change from nautical miles, cables and knots to kilometres and kilometres per hour. The international nautical mile is in general use on the charts of nearly every nation.

INSTRUMENTS

In chartwork the user will find that he has to employ the basic instruments of geometry, notably ruler, compasses, dividers and protractor. The great frequency with which it is necessary to draw



FIGS. 1.5 (a) and 1.5 (b)

one line parallel to another has meant the evolution of the ubiquitous *parallel rules*. While it is indeed possible to proceed in chartwork by making parallel lines in the geometrical manner with set-squares placed at right angles to each other, parallel rules facilitate the operation to such an extent that they have come to be regarded as an essential instrument of chartwork.

Fig. 1.5 shows parallel rules. Fig. 1.5 (*a*) shows the two-rule hinged type and fig. 1.5 (*b*) shows roller rules. Each has its advantages and disadvantages but the hinged type is more commonly met with.

In the sketches:—

A—hand knob.
B—hinge.
C—milled roller.
D—roller axle cover.
E—roller axle bearing cover.

Parallel rules are often graduated in degrees of arc, over 180°. This enables the rules to be matched on to a meridian or parallel and thus orientated on the chart to any direction of the compass. Practical use is made of this in laying down and taking off courses and bearings as described in Chapter IV.

MEASURING DISTANCE

In chartwork a distance is expressed in nautical miles, and when the distance is less than one mile by cables.

Measuring or marking off distances on a Mercator's chart must be performed with great care, and particularly so if the chart covers a considerable change of latitude. Distance is always measured on the latitude scale, i.e. on the graduated meridian.

To measure a distance, place the points of the dividers on the two positions whose distance apart it is required to know.

Transfer this measurement to the graduated meridian directly abreast of the two places and read off the degrees and mi between the points. Reduce this to minutes and the result is the distance in nautical miles.

NOTE—It is very important when measuring distances to place the dividers on the graduated meridian directly abreast of the positions between which it is required to measure the distance.

If the measurement is taken to the northward or southward of the positions, the distance in the former case will be too small and in the latter too large, if the chart is of the Northern hemisphere and *vice versa* if of the Southern hemisphere. When both are in or about the same latitude, place the points of the dividers on the graduated meridian equally above and below the latitude of the places and read off as before.

The parallels of latitude are divided into degrees of longitude, but since the meridians on the Earth's surface converge as they approach the poles the length of these degrees varies according to the latitude in which they are measured. Hence longitude cannot be used for measuring distances.

THE LOG

The practical measurement of distance as a ship travels through the water is accomplished by means of a 'log'.

The sailor's traditional log which is towed either astern or from a boom is still in use but is challenged by a variety of types which mount equipment at the vessel's bottom and display readings in the chartroom or bridge. The towed log may also have a display on the bridge.

Devices employed in the functioning of logs include impellers or fins rotated by the movement of the water, instruments to measure water pressure, electro-magnetic equipment and sonar doppler apparatus.

The electro-magnetic and the sonar doppler logs have no moving parts in sea water. They are claimed to have improved accuracy and reliability and are independent of water conditions and trim and movement of the vessel.

The electro-magnetic log operates on the principle of a voltage proportional to the ship's speed being generated within an underwater sensor assembly. Conversely, when the ship is at anchor or alongside the log measures the movement of the warer past the ship.

The sonar doppler log is a modification of the sonar doppler navigator device, briefly described in Chapter XIII. It is primarily designed for use in coastal waters. Up to depths of 500 ft. to 600 ft. (150 metres to 180 metres) it measures the ship's track relative to the sea bottom. Beyond this depth measurements are relative to the water mass.

Logs may indicate distance only or distance and speed.

Inputs from ships' logs may be supplied to other navigational equipment such as radar or a navigation data logger.

It is important to note that a log, except the sonar doppler log in shallow water as mentioned above, measures the distance or speed through the water and not that over the ground.

PLOTTING AND TAKING OFF POSITIONS ON CHARTS

A position is actually a point, which has no magnitude, and is determined by the intersection of two ordinates. On a chart the ordinates are a parallel and a meridian which, of course, intersect at right angles.

To plot a position.

Latitude—Place the edge of the parallel rulers along a parallel and carefully manoeuvre the ruler, preserving the original direction of East–West, until the bevelled edge coincides with the given latitude. Now draw in the parallel.

Longitude—Place the edge of the ruler along a meridian, then manipulate the ruler, maintaining the North–South direction, until the edge passes through the given longitude on the scale of longitude. Draw in the meridian.

The point of intersection of parallel and meridian is the required position.

To take off a position.

Latitude—Referring to page 152, Plate 8.2 represents a small portion of a chart showing a graduated parallel and meridian. Suppose it is required to take off position *O*. The edge of the parallel ruler is placed to coincide with the graduated parallel. It is now carefully moved until the edge passes through the position of *O* and the parallel *OY* is drawn in.

Longitude—The edge of the ruler is placed along the meridian of 11° and then manipulated until its edge passes through *O*. The meridian *OZ* is now drawn in.

The position of *O*, as read off the scales, is found to be—Latitude 55° 44′ N., Longitude 10° 55′ W.

Another Method—Having understood the measurements required to plot or take off a position, it is to be mentioned that the operation of taking off a position can be quickly and conveniently performed by the use of a good pair of dividers.

Latitude—Again referring to Plate 8.2, place one leg of the dividers on position *O* and with the other just touch the graduated parallel. Transfer this measurement to the graduated meridian, placing one leg of the dividers on the same parallel as before; the other will indicate the latitude of position *O*.

Longitude—Place one leg of the dividers on position *O* and with the other just touch the meridian of 11°. Transfer this measurement to the graduated parallel. Place one leg on the 11° meridian; the other will indicate the longitude of *O*.

NOTE—It can be ascertained whether the chart is of the Northern or Southern Hemisphere by observing how the latitude increases. If it increases to the northward the chart is of the Northern hemisphere, and if to the southward the chart is of the Southern hemisphere.

If the longitude increases to the right or eastward the chart is of East longitude; and if to the left or westward, it is of West longitude.

Other Ordinates.

It might be remarked at this point that some modern navigation systems give a position relative to ordinates other than the conventional parallels and meridians. The position might be given with reference to a grid or, in the case of air navigation, with reference to a great circle from departure point to destination or perhaps given with reference to the predetermined path or position of an artificial satellite. Such a system may in addition present the ship's or aircraft's position in terms of latitude and longitude.

The lattices on the charts described in Chapter XII are examples of grids. The position fixing systems discussed in that chapter provide grids which, when superimposed on ordinary ocean or coastal charts, change these sheets into what is known as lattice charts.

TAKING OFF POSITIONS ON PLANS

As before mentioned, on an ungraduated plan the latitude and longitude of some important point is given which will be found under the title of the chart.

Through this point draw a meridian and a parallel. This can be done by placing the edge of the parallel rulers on the *true* North and South points of the compass and carefully moving them along to the given position when the meridian can be drawn. Now place the edge of the rulers on the *true* East and West points of the compass and draw in the parallel in a similar manner.

Latitude—Place one leg of the dividers on the position that it is required to take off and with the other just touch the parallel drawn in.

Transfer this measurement to the scale of latitude and read off the difference of latitude. Apply this difference of latitude to the latitude of the position of reference, according to whether the vessel is North or South of this point, and the latitude of the vessel is asoertained.

Longitude—Place one leg of the dividers on the position and with the other just touch the meridian drawn in. Transfer this measurement to the scale of longitude and read off the difference of longitude.

Apply this difference of longitude to the longitude of the position of reference, according to whether the vessel is East or West of this point, and the longitude of the vessel is ascertained.

In those plans which have a graduated meridian and parallel, the position can be taken off in a manner similar to that on a chart.

Referring to Plate 1.3, this represents a plan chart, L a lighthouse, the latitude and longitude of which is given.

It is required to take off the position of A. Through L draw MN and CD a parallel of latitude and a meridian of longitude, respectively.

Take AX in the dividers and find from the scale of latitude and distance the difference of latitude which it represents.

Add this difference of latitude to the latitude of the lighthouse and this will give the latitude of A. Now take AY in the dividers and find from the scale of longitude the difference of longitude

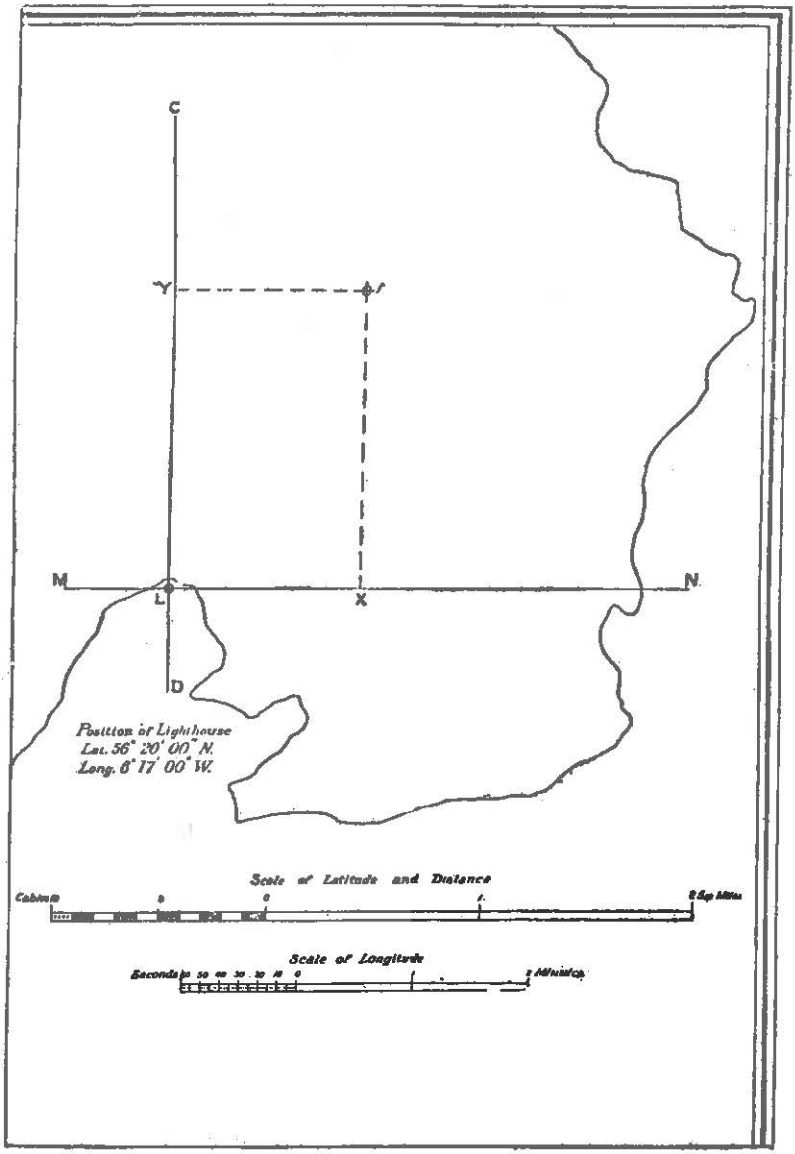

C
Y
f
M
L
X
N
D
Position of Lighthouse
Lat. 56° 20' 00" N.
Long. 6° 17' 00" W.
Scale of Latitude and Distance
Scale of Longitude

PLATE 1.3

which this represents. Subtract this difference of longitude from the longitude of the lighthouse and this gives the longitude of A.

In the above case since the lighthouse is in North latitude and the difference of latitude North it has been added to give the latitude of A.

The lighthouse being in West longitude and the difference of longitude East it has been subtracted.

TO TAKE OFF LONGITUDE WHEN NO SCALE OF LONGITUDE IS GIVEN

Scales on plans are described earlier in this chapter. In some plans only a scale of latitude or distance is given and no scale of longitude. The following methods may be used to determine the difference of longitude between the position of the vessel and the meridian drawn through the given position.

(*a*) Place one leg of the dividers on the position of the vessel and with the other just touch the meridian drawn in. Transfer this measurement to the scale and ascertain the distance. With the latitude of the position as a course enter the Traverse Table, find the above distance in the D.Lat. column, and the d.Long. will be found in the Distance column abreast of it. Apply this d.Long. to the longitude of the given position and the longitude of the vessel is obtained.

(*b*) At the end of the scale of latitude and distance make an angle equal to the middle latitude of the chart. Then from the other end of the scale draw a line to cut the line already drawn in at right angles and draw lines parallel to this from each of the graduations on the scale of latitude. We now have a triangle, the hypotenuse being the scale of latitude, an angle equal to the middle latitude of the chart and the adjacent side representing a scale of longitude.

In fig. 1.6, let AB be the scale of latitude and distance equal to 10 cables, $\angle CAB$ equal to the middle latitude of the chart, then AC is equal to one minute of longitude. Since the latitude scale is divided into cables or tenths of a mile each division on the longitude scale is equal to one-tenth of a minute, or 6″.

The difference of longitude between the position of the vessel and the meridian drawn in can be ascertained and thence the longitude of the vessel in the manner already explained.

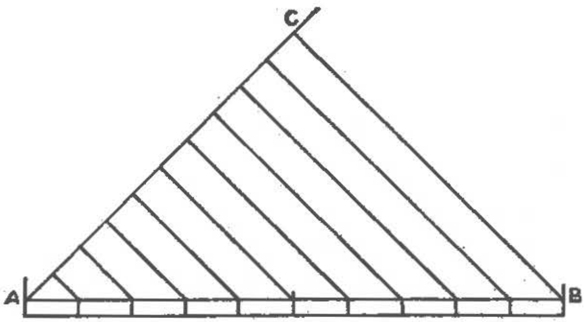


FIG. 1.6

TO FIND THE SCALE OF LONGITUDE FROM THE SCALE OF LATITUDE

As before remarked, on a Mercator's chart the scale of longitude is constant, all the meridians being parallel straight lines. The scale of latitude and distance varies in accordance with the following formula:—

Scale of 1′ latitude = scale of 1′ longitude × secant of latitude.

By transposing, a formula can be found for obtaining the scale of longitude thus:—

Scale of 1′ latitude = scale of 1′ longitude × secant of latitude.

Scale of 1′ longitude = scale of 1′ latitude ÷ secant of latitude.

Scale of 1′ longitude = scale of 1′ latitude × cosine of latitude.

In order, therefore, to construct a scale of longitude on a plan chart, when a scale of longitude is not already given, measure the given scale of latitude for 1 mile and multiply this measurement by the cosine of the middle latitude of the chart and the scale of 1′ of longitude is obtained.

Example—On a plan chart the scale of latitude is 2 inches to 1 mile, the middle latitude of the chart is 50° 04′ 00″; find the scale of longitude.

Middle latitude 50° 04′, cosine	=9·807465
Scale of 1′ lat.=2 inches, log.	=0·301030
Scale of 1′ longitude, log.	=0·108495
Scale of 1′ longitude	=1·284 inches

CONVENTIONAL SIGNS AND ABBREVIATIONS

In general the greater part of the chart is occupied by the delineation of the sea. This is accomplished by showing, where possible, by small figures the depth of water, by letters the nature of the sea-bottom, and by certain conventional signs the presence of rocks, awash and uncovered; rocky ledges; banks, sandy or mud, which dry at low water; breakers; overfalls; tide-rips; anchorages; telegraph cables, etc.

In order that the nature of the coast-line and the position of conspicuous objects may be denoted, conventional signs are also used on the land part of the chart to indicate a cliffy coast-line, steep coast, sandy and shingly shores, positions of lights, churches or chapels, beacons, triangulation stations, etc. On many coastal charts views of the land, on a given direction of approach, are shown.

A reproduction of the Admiralty Chart of 'Symbols and Abbreviations' is given at the end of this book.

In order to read a chart intelligently as many symbols and abbreviations as possible should be committed to memory so that they can be immediately recognised.

Style, Types, Symbols.

An Admiralty Standard Reference Chart showing style, type, symbols, etc., is published. Drawn upon an imaginary coastline and harbour, this chart gives practical illustrations of the features shown on Admiralty charts. For example an island may be shown with a drying foreshore and shallow water surrounds. An area of rocks offshore is enclosed by a danger line. Height contours are drawn and the highest part of the island marked. A lighthouse on the island has its light and associated radio beacon described by the conventional symbols and abbreviations.

This chart is published in association with the chart of Symbols and Abbreviations (above-mentioned) and with the chart of Graduations and Scales mentioned earlier in this chapter under 'Graduation', page 10.

SOUNDINGS

Approaching a coast, in a channel, or when coasting, it is of vital importance to the navigator to know the depth of water in which his vessel is sailing.

The depth of water is found by a 'cast of the lead' or by echo-sounding apparatus. Echo sounders are discussed in Chapter XIII.

During the survey of the charted area the various depths are recorded and, as mentioned in the preceding section, subsequently appear on the chart as small numbers. These numbers or soundings indicate the depth of water below chart datum. The centre of the space occupied is the position of the depth indicated.

To achieve clarity, soundings must be marked a reasonable distance apart and the numbers must be kept large enough to be clearly seen. The actual sea area taken up by any one number depends upon the scale of the chart and the size of the numbers used. This aspect introduces limitations on the depiction of sudden changes in depths.

Soundings in *open style* charts tend to be spaced further apart. Metric charts are constructed in an open form and here the size of the figures used tends to be slightly larger.

Chart Datum.

Chart datum, by an international resolution, should be a level so low that the tide will not frequently fall below it. Modern Admiralty surveys are planned for a datum approximating to the lowest predictable tide under average meteorological conditions.

Earlier Admiralty surveys may have been based on arbitrary datums of various kinds, such as Mean Low Water Springs.

Mariners are cautioned that many datums are above the lowest level to which the tide can fall and charts do not therefore always show minimum depths. Normally, however, there will be more water underneath the ship than is charted and a margin of safety is provided.

When the quality of the bottom has been determined, this is indicated, if desired, by printing below the sounding an abbreviation. Thus $\frac{15}{S}$ reads 15 fathoms sand; $\frac{22}{fS}$ on a new style Admiralty chart indicates 22 metres fine sand; the form *S/M* indicates sand over mud; the initial letter of nouns being shown as a capital (on old editions small letter), and of adjectives a small letter. The soundings may be in feet, or in fathoms, or in metres: the measure adopted is stated in the title of the chart.

In 'fathom' charts, shoaler soundings (such as under 10 fathoms) may be given in fathoms and feet or in fathoms and fractions of a fathom. On a chart where the soundings are in feet the shoaler soundings are naturally also in feet.

In metric charts shoaler soundings (such as under 20 metres) are given in metres and decimetres.

In certain places where soundings have been taken up to a certain depth, no bottom has been found. The fact is shown on the chart by the symbol $\dot{\overline{70}}$ $\dot{\overline{100}}$ which signifies respectively no bottom found at a depth of 70 or 100 fathoms or metres as the case may be.

A rock or a patch of the sea-bed which uncovers on the fall of the tide is said to *dry*. The amount by which a rock or bank dries out at the level of chart datum is noted on the chart.

Such *drying heights* are indicated by an underlined figure or by a statement. Drying heights are given in feet or in metres and decimetres, above the datum of the soundings.

For example, On a 'fathom' chart $\underline{5}$ means 'dries 5 feet'.
On a 'metric' chart $\underline{0_4}$ means 'dries 0·4 mètres'.

Heights (other than drying heights) are given in feet or in metres. The datum is either Mean High Water Springs or Mean Higher High Water, as stated under the chart title or according to whichever is given for the locality in the Admiralty Tide Tables.

Heights are referred to a high water plane as opposed to the low water plane datum for depths. This provides a margin of safety in the opposite direction so to speak by making objects stand generally higher out of the water than is indicated on the chart. A 'distance-off' worked from a vertical sextant angle and using the charted height of an object will therefore normally indicate that the ship is closer inshore than is actually so and will thus provide her with a safety margin. Vertical sextant angles are discussed in Chapter VI.

Vertical clearances, such as under bridges or overhead cables, are indicated by an overlined figure. For example, $\overline{20}$ indicates a vertical clearance of 20 feet or 20 metres as the case may be.

In places where there is no appreciable tide all charted depths and heights are referred to Sea Level.

Depth Contours.

A vast number of soundings placed close together on the chart would become confusing if a method of showing relief were not adopted, as in certain cases it would be difficult readily to determine if the water shoaled rapidly or otherwise. This information,

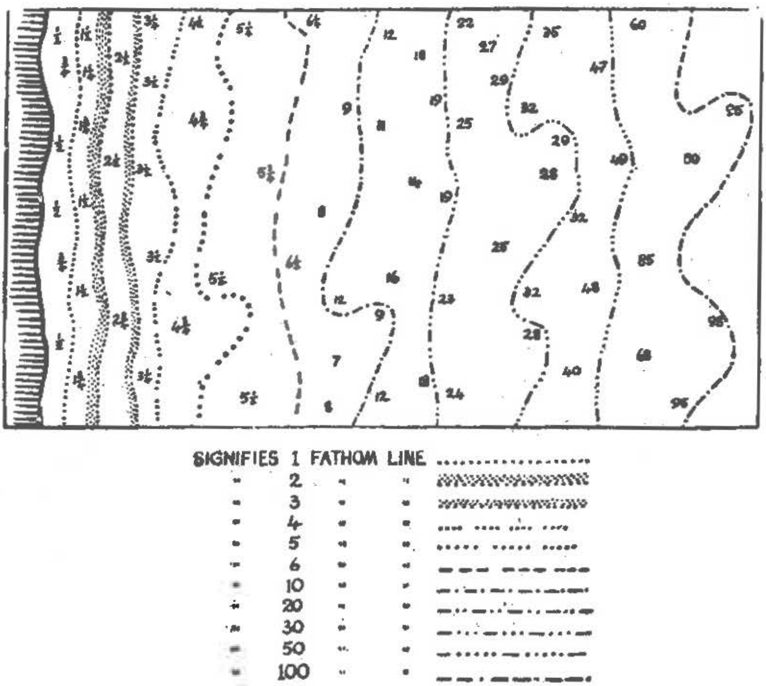


FIG. 1.7 (*a*)

however, and the direction of shoaling water, is at once apparent by showing the contour of the sea-bottom through the insertion of fathom lines or depth contours in metres. Such a fathom line or depth contour in metres is a line drawn through positions having the same depth of water below chart datum.

Fig. 1.7 (*a*) represents a small portion of a chart showing the different fathom lines. Between the 6-and 10 fathom lines the depth of water below chart datum will be more than 6 and less than 10 fathoms, increasing to the right.

A full list of up-to-date contours used will be seen in Section R of the Symbols and Abbreviations chartlet. In many older charts 30 and 40-fathom lines are shown; Fig. 1.7 (*a*) for instance shows a 30-fathom line.

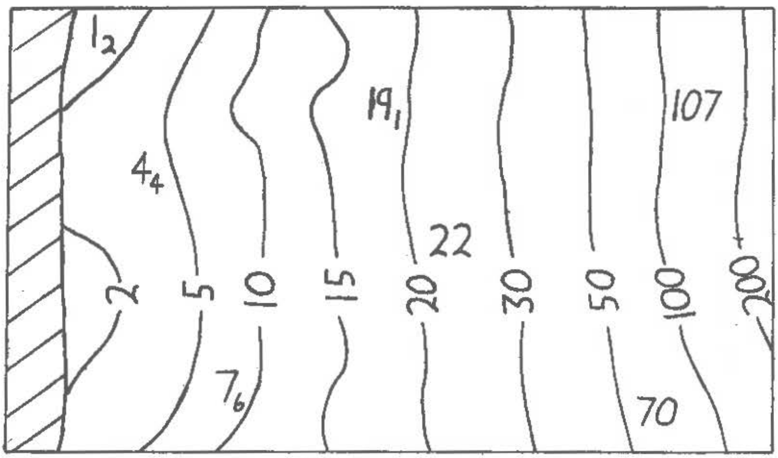


Fig. 1.7 (*b*)

Fig. 1.7 (*b*) represents a similar portion of a New Style Admiralty Chart. The contours are drawn on selected depths; in this case on 2, 5, 10, 15, 20, 30, 50, 100 and 200 metres. No attempt is made to identify a contour by the nature of the line. All lines are plain and each is depth-appended as shown.

Colour.

Colour in the form of a blue tint is used in some charts to emphasise the shallow water areas. Normally the tint is inserted between the H.W. line and the 3-fathom line, and a ribbon of tint added on the shoal side of the 6-fathom line, but on some charts other fathom lines may be so tinted. Each chart should be examined to check the limiting depth of the tint.

Such colour is used in all metric charts, the blue tint being inserted between the H.W. line and the 5-metre line and the ribbon tint added on the shoal side of the 10-metre line. However, always check on the depths tinted.

Open Style.

Certain large-scale charts are compiled in an 'open style', partly to simplify production and maintenance and partly in the hope that navigation will be facilitated by making the charts clearer and easier to scrutinise.

Features of these charts are that the overall number of soundings and therefore the density of the soundings has been reduced to give a more open appearance to the chart. Sufficient soundings however have been inserted to meet the needs of the navigator. The 1-fathom and 3-fathom lines are shown as continuous thin lines instead of the significations in fig. 1.7 (*a*). The seaward edge of the drying banks, whether sand or mud, is shown as a fine pecked line. Shallow water blue, as described above, is used on these charts.

The 10-fathom line or 20-metre line along a rocky or shelving coast should be regarded as a caution or danger line for deep draught vessels. 20 fathoms and about 40 metres should be regarded as the figures for very deep draught vessels. Vessels drawing less than 20 feet should look upon the 6-fathom line or 10-metre line as the danger line.

METRIC CHARTS

To cater for the movement of the United Kingdom towards the metric system, to facilitate the use of modern techniques in production and in the hope of improving the legibility and usefulness of Admiralty Charts for the mariner a new style of chart is produced by the Hydrographic Department. Such charts are sometimes referred to as 'New Style' Admiralty Charts or New Metric Charts, or they may simply be known as Metric Charts.

Although called metric charts, more than a simple changeover from fathoms and feet is involved and modernisation has been maed to coincide with metrication. A substantial amount of the old Admiralty chart has in fact disappeared.

Metric charts are in four colours: black, magenta, blue and buff.

'Land' has been given a buff tint, providing the most striking change and materially altering the traditional grey appearance of the Admiralty chart.

Shallow water blue is used and buff, overprinted on this, gives a fifth colour, green, to indicate 'drying' patches.

As with all later Admiralty charts extensive use is made of magenta to draw attention to features or cautionary notes. Examples are lights, radiobeacons, cables, traffic separation routes. Many of these are mentioned in their respective places in this book.

Lettering and depth figures are in a more readable style and emphasis is given to land features of navigational importance.

Depths and heights are in metres. A conversion diagram metres/fathoms/feet is embodied. The charts are metric in the vertical plane only. As stated under 'The Knot' the nautical mile, etc., will continue to be used. However, on larger scale charts a horizontal metric scale is given. [*See* Scales (Plans) p. 9.]

Generally the charts are of simplified content and have a more open appearance, while retaining information essential for safety and convenience. The trend for a reduction in topographical detail shown has been continued in metric charts.

The charts are designed for use in daylight or under orange light.

Metrication is being undertaken by producing where possible blocks of metric charts in particular areas in order to avoid constant change of units when changing charts.

Metric charts will become increasingly numerous and will eventually replace the traditional Admiralty chart entirely.

TIDAL STREAMS

Tidal streams are, as the name implies, related to tides, both being created by the same forces. The tide, however, has a rise and fall, i.e. a vertical motion, whereas the tidal stream has a horizontal motion.

When the turn, or change, in direction of the stream takes place near the time of high-water the terms 'flood stream' and 'ebb stream' are applied to the rising and falling waters, respectively. Where the turn of the stream differs considerably from the time of high-water the terms *north-going stream* and *south-going stream*, *east-*

going stream, and *west-going stream, ingoing stream* and *outgoing stream,* etc., are used.

In channels the direction of the stream is confined more or less to the direction of the channel: in other localities the direction may change hourly.

The set, or direction, in which the tidal stream is moving is given *true;* thus a tidal stream setting 135° denotes the stream is running south-east. The rate is always given in knots, and generally varies with spring and neap tides.

At given intervals before and after high-water, the direction of the tidal stream remains the same, although the rate will vary with spring and neap tides. Thus it is possible to give tidal information relative to a 'Port of Reference'.

On many of the Admiralty coastal charts of Britain tidal information is given in tabulated form as shown below:

Tidal Streams referred to H.W. at DOVER

Hours		(A) 54°30′0N. 0°30′0E.			(B) 54°30′0N. 3°36′0E.			(C) 54°30′0N. 5°56′0E.			(D) 54°33′0N. 7°53′0E.		
		Dirⁿ	Rate(kn) Sp.	Np.	Dirⁿ	Rate(kn) Sp.	Np.	Dirⁿ	Rate(kn) Sp.	Np.	Dirⁿ	Rate(kn) Sp.	Np.
Before H.W. Dover	6	152°	1·1	0·6	063°	0·2	0·1	Slack			230°	0·3	0·2
	5	125°	0·5	0·3	070°	0·6	0·4	084°	0·5	0·3	154°	0·5	0·3
	4	029°	0·2	0·1	088°	0·6	0·4	095°	0·9	0·5	138°	0·9	0·5
	3	347°	0·8	0·4	087°	0·6	0·4	102°	0·8	0·5	131°	1·7	0·6
	2	348°	1·2	0·7	082°	0·4	0·2	097°	0·8	0·5	125°	0·9	0·5
	1	332°	1·3	0·8	157°	0·1	0·1	113°	0·4	0·2	114°	0·6	0·3
H.W.		331°	1·1	0·6	241°	0·2	0·1	162°	0·1	0·1	030°	0·2	0·1
After H.W. Dover	1	313°	0·8	0·4	270°	0·5	0·3	261°	0·4	0·2	330°	0·5	0·3
	2	Slack			285°	0·7	0·4	262°	0·7	0·4	321°	0·8	0·5
	3	164°	0·7	0·4	267°	0·6	0·3	278°	0·8	0·5	313°	0·9	0·5
	4	157°	1·2	0·7	263°	0·4	0·2	278°	0·8	0·5	304°	0·8	0·5
	5	152°	1·4	0·8	270°	0·1	0·1	270°	0·6	0·4	293°	0·6	0·3
	6	148°	1·1	0·6	Slack			313°	0·2	0·1	262°	0·3	0·2

On the chart from which the foregoing table is reproduced the navigator would observe the tidal position reference, (A) in Lat. 54° 30′ N., Long. 0° 30′ E. and is thus referred to the table. The table is printed in a convenient position and gives all available information concerning the tidal streams in the localities indicated.

It will be observed the port of reference in this case is DOVER.

On later charts each tidal position reference letter, i.e. *A*, *B*, etc., and its enclosing diamond appears in magenta. On some other charts the diamond only may bear a magenta overprint.

A comparison between the prevailing time and the time of the nearest high-water at the port of reference will give the interval before or after high-water with which to enter the table and extract the required tidal information. Thus at two hours before high-water at DOVER in position ◇A, the tidal stream sets 348° at a mean rate of 1·2 knots at springs and 0·7 knots at neaps. At 2 hours after high-water at DOVER there is no tidal stream running at this spot.

This method of predicting tidal streams by reference to a suitable standard port, while feasible in European waters, is not possible in some other parts of the world. Predictions for a number of such places are listed in the *Admiralty Tide Tables*.

In large-scale, modern charts a panel of other tidal information is included. This normally consists of mean heights of high and low water at springs and neaps at important harbours or points taken in by the chart. Details are given of the datum used for the chart.

On certain charts, arrows (*see* Chart of Symbols and Abbreviations) are used to give tidal information, the symbol being flood stream ⟶, ebb stream ⟶.

The rates may or may not be inserted above the arrow.

CURRENTS

Currents are generated by friction between the wind and surface of the water, producing a drift current. When this type of current meets an obstruction, such as land or a reef, its direction may be altered and a stream current formed. A current is, therefore, a horizontal movement of the waters of the ocean.

Difference in specific gravity also produces currents.

A current is always reckoned whither it flows; in other words, the direction in which it sets, and its velocity in knots.

On a chart, a current is denoted by the symbol 〰→.

Again a rate may be added above the arrow.

SUBMARINE CABLES AND PIPELINES

Cables and pipelines on the sea-bed and vessels trawling or anchoring provide a mutual hazard. Fouling a high-voltage cable is obviously dangerous. A fractured gas pipeline will result in a sudden release of gas at high pressure with an effect like an explosion and there will be an immediate fire hazard.

From the opposite point of view sophisticated modern cables are costly to repair and the loss of revenue considerable when they are out of service.

The marking of cables and pipelines on charts is therefore receiving increasing attention. Cables are depicted thus: ~~~~~~~~~~ on Admiralty charts. (*See* Chart of Symbols and Abbreviations in the pocket of this book.) On later charts the line is shown in magenta; on earlier charts in black.

Sometimes, especially on older charts, no attempt is made to trace the routes of individual cables and only a cable area is shown, bounded by pecked lines on older charts and by a special 'Limit of Cable Area' symbol on later charts.

Occasionally there may also be cautionary notes.

Other arrangements adopted on later charts are as follows:—

> Where possible, routes of individual cables are charted in depths of less than 500 fathoms, rather than depicting a cable area or a cautionary area.
>
> Cables known to carry high voltages are labelled 'Power'; other cables may, however, carry high voltages without being so marked.
>
> To avoid congestion on charts only active cables are shown. However, on Fisheries Charts (page 38) abandoned cables are also shown.

Submarine pipelines are shown on later charts by a special magenta-pecked line thus:—· —· —· —· —· —· . Pipeline areas are shown by a pecked line, in magenta, with the legend 'Pipeline Area'. Older charts indicate a pipeline by a pecked line.

Eventually all cables, cable areas and pipelines will appear in magenta; many charts however still show them in black.

OFFSHORE RIGS

These structures include drilling rigs and production platforms for oil or gas. They are sometimes known as oil rigs or gas rigs and may be encountered by mariners in various parts of the world, perhaps the best known being the Gulf of Mexico and the North Sea.

The rigs are capable of being moved from one drilling site to another and no attempt is therefore made to show them in printed form on charts. Movements of drilling rigs around the British Isles are reported in the Navigational Warning system. (NAVEAM—see page 43). Structures in other parts of the world are similarly accounted for by local authorities. Vessels traversing such waters should make certain that details of drilling rigs are marked on their charts. The recommended symbol is 

Rigs are normally lit and sound fog-signals. Those in European waters exhibit a system of white and red flashing lights, both lights and fog-signal featuring the morse letter '*U*'.

Unoccupied wells or drillings sites or unlighted moorings are marked by light and bell buoys.

Rigs may be in association with pipelines.

DANGERS

Items which are termed 'dangers' on charts are generally in the nature of rocks or reefs, and wrecks or other obstructions.

Those considered dangerous to navigation are often encircled by a *danger line* as marked on the chart. Details of the markings for dangers will be found in the chartlet on Symbols and Abbreviations.

The least depth of water likely to be encountered over a wreck is the criterion which decides whether or not the wreck will be declared dangerous. A suitable arbitrary figure is chosen (e.g. 15 fathoms or 28 metres in 1968) and is kept under review. With the increasing drafts of large vessels the selected figure tends to a corresponding increase.

In the preceding pages an attempt has been made to give details of some important features of charts. Other features are described in Chapter II. The chartlet Symbols and Abbreviations indicates the great number of items and features which can be met with in Admiralty charts.

TYPES OF CHARTS AND PUBLICATIONS

Information Given

The Hydrographic Department of the Admiralty publish many types of charts, publications, diagrams and other material, each of which contains useful information for the seaman. A full list of these is contained in the publication entitled *Catalogue of Admiralty Charts and other Hydrographic Publications.*

Charts.

Mention may be made of the following:—

Charts of the World, Ocean Charts, Polar Charts, Coastal Charts, Harbour Plans, Gnomonic Charts.

Special types of charts issued include:—

Lattice Charts, Instructional Charts, Charts dealing with the Earth's Magnetic Field, Meteorological, Climatic and Oceanographic Charts and Diagrams, Routeing Charts, Radio and Radar Charts, Charts for Ships' Lifeboats, Tidal Charts and Diagrams, Wall Charts, Exercise Area Charts, Yachtsmen's Charts, Fisheries Charts.

Charts of the world are constructed on a small scale and are non-navigational charts. In addition to the general chart of the world these charts are issued on such important matters as variation and other magnetic elements, ocean currents, climates.

Other examples of charts of the world are:—

Time Zones, Load Line Zones.

Ocean charts cover a large expanse and are also drawn upon a small scale. They give few details and are mainly used for deep-sea navigation.

A great many special versions of ocean charts are issued. They cover such subjects as routes, meteorology, great circle sailing, position fixing systems (lattice charts). Other examples will be found in the description of types of charts in this chapter.

Coastal charts are constructed to various scales and contain full information for the area covered. The greater part of the material in this book is concerned with work on coastal charts.

Special varieties of coastal charts are numerous; some are described in this chapter.

The majority of the above are drawn on Mercator's projection.

The Gnomonic projection is used on:—

(*a*) Ocean charts which are designated great circle sailing charts. They provide a convenient means of obtaining the great circle track and have already been described in this chapter.
(*b*) Polar charts, when Mercator's projection is unusable.
(*c*) Charts having a natural scale larger than 1/50,000—i.e. large-scale charts. (*See* Appendix, Projection and Scales.)

Harbour plans are a special form of gnomonic chart. They are drawn on a large-scale plane projection, the small area of the Earth's surface concerned being considered to be flat. Such plans contain much detail of harbours, estuaries and approaches.

The reader is strongly advised to study such charts when the opportunity occurs and become familiar with the information given thereon. This will vary to some extent with the locality covered by the chart.

The following are the more important features:—

Title of chart: This is printed in a convenient position and, in general, in fathom charts, under it is given:—

Statements regarding the survey.
Natural scale.
Projection.
Abbreviations used.
Heights, how expressed, and datum of measure.
Bearings, manner in which they are given.
Cautions.
Tidal information.
Port of reference.
Soundings, whether given in feet or fathoms.

In metric charts, in compliance with the desire for simplification, minimum information is given under the title. Statements appear on depth, heights, scale, projection, soundings and authority for publication of the chart, that is, upon what survey or previous chart is the present chart drawn up.

Cautions or notes are added where applicable. Included in these are any notes on tidal or current information.

Against each compass rose is printed the Variation, year for which it is given and annual change.

Other particulars regarding Admiralty charts consist of:—

Date of publication: Printed in middle and outside bottom margin.

Date of new edition: Alongside and to the right of date of publication.

Number of chart: Printed in bottom right-hand corner. It may also be printed in the top left-hand corner, upside down, and may also appear outside on the label.

Date of printing: Shown in the manner:—190.69. This indicates the day of the year and the year in which the particular copy was printed, i.e. the 190th day of 1969.
In later charts this information is carried on the label on the reverse of the chart, e.g. 'Printed 100.70'. In earlier charts the printing date appears at the top right-hand corner of the chart, outside the margin.

Dimensions: The small figures which appear at the south-east corner of the chart, outside the margin, indicate the size of the plate between the neat lines (the inner lines of the graduation). The information is useful as a check against distortion of the chart. The dimensions are in inches or in millimetres. The larger length is given first and the figures may be in brackets.

Large corrections: Beside date of new edition.

Small corrections (labelled 'Notices to Mariners' in metric charts): Given in bottom left-hand corner.

When the corrections comply with information given in a Notice to Mariners, they are shown thus:—1968 ·1988·2114· signifying that the chart has been corrected in accordance with Notices to Mariners, Nos. 1988 and 2114 of the year 1968.

When the chart is corrected from information not published in a Notice to Mariners, the date of the correction is shown thus

1965 VII.26 or 1968 [1.13] indicating 26th July, 1965 and 13th January, 1968, respectively.

The reliability of a chart may be estimated from an examination of the following particulars:—

Date of survey (if given).
Dates of large and small corrections.
Scale of the chart.
Completeness, or otherwise, of detail along the coastline.
If the soundings are regular and closely spaced, or thinly scattered; bearing in mind that soundings will be deliberately left further apart in metric and open-style charts.
Continuous, or broken, depth contour lines (fathom lines).

Brief descriptions of some special charts follow:—

Lattice Charts—These are described in Chapter XII.

Instructional Charts—These are reproductions of parts of Admiralty Coastal Charts. They are printed on thin, tough paper, are not corrected from *Admiralty Notices to Mariners*, and are sold on the understanding that they will not be used for navigational purposes.

Charts Dealing with the Earth's Magnetic Field—This type of chart deals with the direction and intensity of the earth's magnetic field. An example is the chart of 'Curves of Equal Magnetic Variation', mentioned in Chapter X.

Meteorological, Climatic and Oceanographic Charts cover a wide field. Examples which might be quoted include meteorological working charts, charts of sea surface temperature and sea surface density.

Climatic Charts show average conditions for elements such as pressure, winds, currents, temperature, ice, fog and rainfall.

The Meteorological Office also publish a useful series of *Climatological and Sea-Surface Current Charts.* In these are included information on winds, currents, air and sea temperatures, fogs, tropical revolving storm tracks, limits of ice, and steamship tracks. They are published one for each month and in many ways are similar to routeing charts described below. Most sea areas are covered. Similar charts are published by the U.S. Naval Oceanographic Office.

The Meteorological Offices of many countries publish charts or chartlets on which weather maps of various types may be drawn or reproduced. Vessels at sea may obtain a completed weather chart by means of a Radio Facsimile Weather Recorder as described in Chapter XIII.

Routeing Charts—The Chart Users Advisory Panel is a body which advises the Hydrographer on the chart requirements of the British Merchant Fleet. The publication of Routeing Charts was one of the results of their work.

These charts are intended to provide shipowners and shipmasters with a graphic summary of factors which may affect the loading of a vessel and may affect the choice of route when making an ocean passage. The ultimate object being to assist in economical running.

Features include main shipping tracks and distances between major ports, positions of major and minor ports, load lines in force and zones in which the discharge of persistent oils is prohibited.

Meteorological information concerns winds, ocean currents and mean limits of ice. Insets on the chart show distribution during the month of mean values of air temperature, sea temperature and dew point. The percentage frequency of fogs, assigned positions of weather-ships and tropical revolving storm tracks are also shown.

As many of the above features change with the time of year a chart is published for each month. Colours are used and all ocean areas are covered.

Radio and Radar Charts—Radio-Beacon chartlets give the position of and brief information on each beacon in the locality. Marine beacons are shown in red, aero beacons, which may be useful to seafarers, are shown in blue. Radio Information charts give information regarding radiobeacons and certain radio-telephone services on the U.K. coast, with the needs of yachtsmen, fishermen and small craft particularly in mind.

Of a variety of other printings there may be mentioned Coverage and Accuracy Diagrams for position fixing systems (that is, the hyperbolic systems dealt with in Chapter XII).

Ships' Boats' Charts—These interesting charts give, in simple form indications of winds, currents, ice and magnetic variation. On the reverse side appear notes on chart use, winds, weather and currents, and management of boats.

They may be installed in ships' lifeboats for use in the event of mariners finding themselves in the position of having to navigate such boats across ocean stretches.

The charts are printed on strong paper and may be supplied in a waterproof wallet as a set for all oceans.

A few charts or diagrams showing Tidal Streams or giving Tidal information are published. *See* also Tidal Publications referred to later.

A large number of Wall Charts and Outline Charts are published. These are of a general nature, often they are large charts and usually they are on a very small scale.

Exercise Area Charts—Known as the PEXA series, these charts show the limits and purpose of the service practice and exercise areas in home waters. They are on small scale and cover the coasts of Britain. Mariners have the right of way but they are cautioned not to remain in the areas concerned longer than is necessary. The charts are updated, for the most part, by Notices to Mariners.

Yachtsmen's Charts—A special series of small charts is published by the Admiralty with the needs of yachtsmen particularly in mind. These are of the popular yachting areas of the United Kingdom and are printed in simplified form. Water depths are in feet and details of yachting facilities are shown.

Fisheries Charts—The series of North Sea Fisheries Charts has been prepared to meet the special needs of fishermen. On Mercator's projection, on a scale of 1:300,000, the charts are designed to show all essential detail boldly and simply, and are distinctive from normal Admiralty charts.

Soundings are in metres and the shape of the sea-bottom is depicted by closely-spaced depth curves. A table to change metres to fathoms and feet is included.

Special emphasis is given to the nature of the sea-bottom. Stone or mud areas, wrecks and other obstructions are marked by special symbols. Cables, active and disused, are shown.

Fishing limits around coasts are indicated.

All charts bear a Decca lattice and in areas covered by more than one Decca chain separate versions are issued.

Publication is undertaken jointly by several West European countries.

Fisheries charts are not corrected by *Admiralty Notices to Mariners* and larger scale charts should be consulted for coastal navigation.

Charts of a similar nature are published commercially. For instance there is published a series of Decca Plotting Sheets, Kingfisher Charts and General Charts with the needs of fishermen particularly in mind.

Fishery Limits (six and twelve miles) are shown on selected normal coastal charts of the U.K.

Traffic Separation.

Segregation of lanes of seaborne traffic in congested waters is desirable. Several schemes of traffic separation for such waters have been devised. Many are upon the recommendation of the Inter-Governmental Maritime Consultative Organisation; some have been drawn up by local administrations.

Localities concerned are in the nature of narrow straits, around headlands and port approaches. Examples are, the Dover Straits, rounding the Casquets, the Baltic and the approaches to San Francisco.

Details of a traffic separation arrangement are overprinted in magenta on the ordinary Admiralty coastal charts of the area concerned. Generally a 'keep to starboard' code is adopted. Arrows indicate the general direction of traffic flow in each lane. If the lanes are fairly close together a separation zone or buffer zone is inserted. Sometimes such a zone may contain a danger or an obstruction, such as a small island with a lighthouse on it. Inshore coastal traffic zones may be included in addition to through traffic routes. Where several routes converge a traffic 'roundabout' may be set up with a circular separation zone.

The lanes are not mandatory and do not give special rights of way to ships using them, nor do they affect the International Regulations for Prevention of Collision at Sea, which must always be observed.

A traffic separation scheme requires to be used intelligently and warning notices to this effect are printed on charts.

Analogous to the above and again shown on charts are the Shipping Safety Fairways of the Gulf of Mexico. These provide safer routes through the numerous offshore rigs in the area.

Publications.

Closely allied with chartwork are many of the Hydrographic Department's publications.

Mention may be made of the following:—

The Admiralty Sailing Directions (Pilots).
The Mariners' Handbook.
Ocean Passages of the World.
The Admiralty List of Lights, Fog Signals and Visual Time Signals.
The Admiralty List of Radio Signals.
Tidal Publications.
Route Books.
Admiralty Notices to Mariners.

There are many more publications, productions and diagrams associated with the above list.

Admiralty Sailing Directions (Pilots)—A large number of individual volumes cover the world. They contain general information likely to be useful to navigators in each particular vicinity, e.g. *The Norway Pilot*, Vol. III, covers the northern part of the Norwegian coast.

Indication is given of Admiralty charts covering the area, also some general information is furnished. A brief description of and information on the country concerned is given. Details appear of items such as communications, fuel, signals, coastguard arrangements and fisheries.

Some general directions are offered and relevant charts suggested. Tidal and current information is given and a section deals with climate and weather.

The main part of the book contains detailed descriptions of the area covered, usually taking it in sections, working round the coast. At the top of each page is annotated the number and name of the largest scale chart of the area being described. At the bottom of each page is annotated the numbers of the general charts of the area.

Among items listed in the appendices are lists of ports showing depths and facilities. Reported radar ranges and details of local statutory requirements such as territorial waters may also be given. In later volumes, the well-known 'views' are collected and listed at the end of the book.

The volumes are correctible from *Admiralty Notices to Mariners*. In addition supplements appear from time to time and these should be consulted when using a Pilot Book.

The Mariners' Handbook—This book might be said to be a companion volume to the *Admiralty Sailing Directions* (*Pilots*). It contains much useful information and has been compiled with the needs of regular mariners and yachtsmen in mind. Some of the contents were formerly included in the preliminary pages of all volumes of the 'Pilots'. To save repetition this material is now collected under one cover in the *Mariners' Handbook*.

Contents of *The Mariners' Handbook* include information about charts and publications and remarks on certain aspects of practical navigation. Notes appear on many items such as tides, buoyage, life-saving, navigational warnings. There are sections on meteorology and ice.

Ocean Passages—What the *Admiralty Sailing Directions* are to coastal passages, the book of *Ocean Passages* is to deep-sea voyages.

Recommended routes for a large number of possible ocean passages are given accompanied by extremely interesting, relevant information on winds, currents, ice and other items. Various types of vessels are catered for.

The Admiralty List of Lights, Fog Signals and Visual Time Signals—Twelve volumes cover the world and give details of all navigational lights, fog-signals and visual time-signals. Light-vessels are included but not light-buoys which are mentioned in the *Sailing Directions* and are shown on charts.

Remarks on lights, ranges, fog-signals, light-vessels, wreck-marking vessels and offshore rigs are included.

The volumes are corrected from *Admiralty Notices to Mariners*.

The Admiralty List of Radio Signals—Several volumes cover radio requirements of ocean and coastal vessels. The chart user may consult these for details of radio stations, radio beacons, position-fixing systems (hyperbolic systems), navigational warnings, meteorological services, port services, and many other items.

The volumes are corrected from *Admiralty Notices to Mariners* and supplements may also be issued.

Tidal Publications—A number of books and forms are published dealing with tides and tidal streams.

The *Admiralty Tide Tables* appear in three volumes covering the world. In addition to general tidal information daily predictions are given for times and heights of high and low water at certain places called 'Standard Ports'. Data is provided to enable times and heights of high and low water to be calculated for other places related to standard ports.

Tidal Streams are also dealt with in the Tide Tables for areas other than European waters. In European waters tidal streams may be deduced from tables printed on charts of each locality (*see* page 29).

Tidal Stream Atlases show in pictorial form in a series of maps the tidal streams over a selected area, a map usually being given for hourly intervals. Such atlases are popular with coastal navigators as they enable the complete tidal stream situation to be viewed at a glance.

Route Books—These are loose-leaf binder books with individual page contents. They refer to World Mine Danger Areas.

Two books are issued, NEMEDRI and CHINPACS.

The name NEMEDRI means North European and Mediterranean Routeing Instructions, and the book covers the North-Eastern Atlantic, Mediterranean and adjacent seas.

CHINPACS covers the China Sea, Indian Ocean and Pacific Ocean.

The United States section of the North Atlantic is covered by *Annual Notices to Mariners.*

In addition to general instructions the books give details of areas dangerous due to mines and details of swept routes through and between such areas. Chartlets are provided to facilitate the use of the books. The routes at sea may be marked by special buoys. A lane may be two-way, or one-way lanes may be used with a separation zone in between.

Note that mined areas are not printed on charts. However, the above-mentioned swept routes may be indicated on charts of the areas concerned.

Amendments to NEMEDRI and CHINPACS appear in *Admiralty Notices to Mariners.*

It is intended to abolish the books when the mine situation permits.

Admiralty Notices to Mariners—These contain information primarily for the correction of Admiralty charts and publications. The Notices are published daily and are collected in booklet form in a weekly edition.

An Annual Summary published at the beginning of each year features Annual Notices. These are generally of a cautionary or descriptive nature and they may vary from time to time.

The weekly edition contains details of corrections to Admiralty charts, publications, List of Lights and List of Radio Signals. New and revised charts and publications are mentioned. Also included are amendments to Route Books and a list of Navigational Warnings in force.

Navigational Warnings—These concern dangers or incidents which it is considered should be brought to the notice of shipping as quickly as possible, e.g. a light temporarily extinguished.

Radio Warnings may be of Local or Long-Range type.

Local warnings are broadcast from the country of origin. For waters around the British Isles they are broadcast by Coast Radio Stations.

Long-Range warnings are broadcast by long-distance radio stations and may be re-broadcast by other countries.

Radio Warnings go under different names in different parts of the world. For example, in home waters the long-range warnings are called NAVEAMS.

An example of navigational warnings not broadcast is the UKNAVs series. UKNAVs consist of warnings of lesser importance. They appear in printed form, available from Custom Houses.

Most radio warnings are of a temporary nature but it is possible they may later be repeated as a correction to a chart or publication.

The International Hydrographic Bureau.

Perhaps it might not be out of place to end this chapter with a mention of the International Hydrographic Bureau.

This body has its seat in Monaco and is representative of many countries. The bureau is concerned with all aspects of hydrography. Of particular interest to present readers might be mentioned attempts to obtain uniformity as far as possible in charts and hydrographic publications; for instance in such things as abbreviations and conventional signs used on charts.

CHAPTER II

COASTAL AIDS TO NAVIGATION

AIDS to navigation which are mainly of a coastal nature include lighthouses, light-vessels, wreck-marking vessels, buoys, fog-signals and radio and radar stations.

LIGHTHOUSES

Lighthouses are erected on prominent headlands and capes where vessels are likely to make their landfall; on such dangers as reefs and outlying isolated rocks; in the approaches to a harbour where they may function as leading marks.

They form one of the most important and reliable aids to navigation. Their positions are accurately known and are, therefore, eminently suitable in the selection of objects for fixing position.

They can be recognised during daylight by the type of building and distinctive markings; during darkness by the character and period of light they exhibit, and during fog and low visibility by the particular fog-signal allotted to them.

On the chart their position is indicated by one of the two symbols, thus ☆ ✱ and adjacent to the position are given the character of the light, its range and height.

The character of a light is generally described as flashing, occulting or isophase.

An occulting light is one in which the period of light exceeds the period of darkness. That is, it is the reverse of a flashing light.

An isophase light has all durations of light and darkness equal.

Sometimes lights are made to flash letters of the morse code, but this is largely confined to lights of local importance, to buoys and to drilling rigs or structures.

Main lighthouses are usually allotted a very simple character.

Examples of descriptions of lights:—

1. Fl. 10 sec. 130 ft. 17M. — Flashing every 10 seconds. Height 130 ft. Range 17 miles

2. Occ.*WR*.15sec 17m 10,8M	Light occults every 15 seconds. It has white and red sectors. Height 17 metres. Range 10 miles for the white sector, 8 miles for the red.
3. Mo. (U) *W*. 15 sec.	Flashes short-short-long in white, every 15 seconds.

The height given against the lighthouse is the height of the focal plane of the light in feet or metres above mean high water spring tides or mean higher high water, whichever is given (for the locality) in the Admiralty Tide Tables. In places where there is no tide the height given is the height above sea-level.

The visibility, or range, is the distance the light can be seen and is calculated for a height of eye of 15 feet or 5 metres above the sea.

Positions of lights on lighthouses, light-vessels and buoys are given a magenta flash to make them conspicuous to the chart user.

Lights which do not show the same colour in all directions may have the arcs over which the different colours show indicated on the chart by sectors of circles.

Important—These arcs of circles do *not* show the range of visibility of the light, but merely the arc over which the colour is seen.

Alternating lights are rhythmic lights which exhibit different colours during the course of each sequence.

It is likely that lighthouses using laser beams will be used to aid navigation in certain localities. Laser (light amplification by stimulated emission of radiation) is a device used for the amplification or generation of coherent light waves. A parallel, intense beam, focused to a fine point is emitted by the laser. Such beams can be seen up to 40 miles out to sea and their feasibility for maritime purposes is being tested.

LIGHT-VESSELS

Around coasts there are many shoals and other dangers to navigation upon which it is impossible to erect lighthouses; light-vessels are therefore stationed in the vicinity of such dangers in order to warn approaching vessels.

A light-vessel may carry a distinguishing mark, such as a ball, diamond, triangle, etc., at the masthead so that in daylight it can readily be recognised when some distance off; moreover, the name of the vessel is painted in large white letters upon her sides.

Scottish and English light-vessels are painted red; Irish light-vessels are painted black.

From sunset to sunrise a light-vessel exhibits a light having characteristic phases. During fog she sounds a fog-signal.

On the chart a miniature drawing of a light-vessel indicates the presence of such vessels. Adjacent thereto is given name of light-vessel; character, period and visibility of light; height of focal plane; fog-signal.

It is common practice to operate a radiobeacon from a light-vessel and Radar Beacons (Racons) are increasingly being numbered among the services provided.

For a light-vessel to be of use as a navigational aid she must keep her station with great reliability. The vessels are very securely moored and the position must be checked frequently by all available means. For light-vessels in proximity to the coast this presents little difficulty in fine weather. Checking in other circumstances may be facilitated by the mooring of a 'watch buoy' close to the light-vessel, thus providing an independent check.

Radio position fixing systems, generally in association with lattice charts (Chapter XII), may be of help and around the U.K. coasts the Decca system is particularly applicable.

Working in conjunction with a standard Decca receiver an Alarm Unit may be fitted. The acceptable Decca co-ordinates for the light-vessel's normal swinging circle are ascertained. Should the vessel drift out of these or should the equipment fail, audible warning is sounded.

Light Structures and Automatic Buoys.

A modern tendency is to replace light-vessels with grounded structures or with buoys. The choice depends largely upon the location and in each case the structure or buoy is of such a nature that it can adequately fulfil the duties of its predecessor.

Structures may be of tubular steel or concrete construction and they may be fully self-sufficient with their own power plant and helicopter platform.

Buoys are of large and substantial construction. A British model known as the Large Automatic Navigational Buoy is 40 feet in diameter with the lantern about 40 feet above sea-level. It is powered by diesel generators and is fully automatic. A control station ashore monitors the buoy's position and can also control the buoy's equipment.

Both structures and buoys are equipped with a powerful light and fog-horn and can operate electronic aids such as a radiobeacon and a radar beacon (Racon). Meteorological or oceanographic data recording equipment may be carried and provision for shipwreck victims is allowed.

The large light buoys are shown on charts by the symbol for a high focal plane buoy, with the elevation and range added. (*See* Symbols and Abbreviations chartlet, Section L.)

Structures and buoys are included in the *Admiralty List of Lights* and *List of Radio Signals*, as appropriate.

AERO LIGHTS

Some lights for the use of aircraft may also be of assistance to shipping if situated near a coastline. These are marked 'Aero' on charts.

Aero Obstruction Lights.

Radio masts, chimneys or other obstructions to aircraft are often marked by lights. These are generally of low intensity and are shown on charts as '(Red L^{t})', '(Fl. R. L^{t})' etc., as appropriate.

In certain cases where an obstruction light is of high intensity and of navigational value it may be charted as an Aero Light.

Such lights may be extinguished without warning.

Details of the lights mentioned above are found in the *Admiralty List of Lights*.

BUOYS

Buoys form one of the most common aids to navigation. They can be accurately placed to mark a danger or define a channel and their positions altered when required. They are of various shapes and colours, the shape being of more importance than the colour, as certain shapes are used for particular purposes. A buoy may be lit and it may have a topmark.

Radar Reflectors.

Buoys, and especially conical buoys, make poor radar targets. To overcome this some buoys are fitted with a radar reflector in addition to, or in place of, a topmark. The abbreviation [illegible] may be placed against such a buoy.

This enables a vessel navigating by radar to distinguish the line of the channel for some distance ahead during poor visibility, or in the case of buoys in open water, enables them to be picked up at a greater range.

Floating aids to navigation are liable to get out of position through the action of strong winds, high seas in exposed positions and the effect of currents. Hence such aids should be used with caution.

The position of a light-vessel or buoy on a chart is denoted by a small circle at the middle of its water line.

UNIFORM SYSTEM OF BUOYAGE

In narrow channels, rivers, and approaches to harbours, which are frequently strewn with hidden dangers such as rocks, shoals, wrecks, etc., aids to navigation are provided in the form of buoyage marks, light-vessels, and wreck-marking vessels.

The buoyage marks are not indisciminately placed; on the contrary their disposition is in accordance with certain rules.

In principle, the position of marks in the system is determined by the general direction taken by the mariner when approaching a harbour, river, estuary or other waterway, from seaward, and may also be determined with reference to the main stream of flood tide.

Principle Types of Marks.

The principle types of marks employed are:—

Conical, can and spherical.

Shapes of Topmarks.

The topmarks for which provision is made are:—

Cone, can, sphere, diamond, St. George's Cross, 'T'

Marking Sides of Channels.

STARBOARD-HAND MARKS.

Shape: Conical.
Colour: Black, or black and white chequers.
Topmark (if any): Black cone, point upwards, or, for purposes of differentiation, a black diamond, except at the entrance to a channel.
Light (if any): White showing 1 or 3 flashes.

PORT-HAND MARKS.

Shape: Can.
Colour: Red, or red and white chequers.
Topmark (if any): Red can, or, for purposes of differentiation, a red 'T', except at the entrance to a channel.
Light (if any): Red, showing any number of flashes up to 4 or white, showing 2 or 4 flashes.

Middle Ground Marks.

Marks at the ends of Middle grounds have the following characteristics.

Shape: Spherical.
Colour: R.W.H.B. (red and white horizontal bands) where the main channel is to the *right* or the channels are of *equal* importance.
B.W.H.B. (black and white horizontal bands) where the main channel is to the *left*.
Topmarks (if any): (*a*) Main channel to the *right*
Outer end, a can } Painted
Inner end, a 'T' } Red.
(*b*) Main channel to the *left*.
Outer end, a cone } Painted
Inner end, a diamond } Black.
(*c*) Channels of equal importance.
Outer end, a sphere } Painted
Inner end, a St. George's Cross } Red.
Light (if any): As far as possible lights will be distinctive, but no colours will be used other than white or red and neither colour nor rhythm will be such as

to lead to uncertainty as to the side on which the mark shall be passed.

Mid-Channel Marks.

Mid-channel marks serve to indicate the deep-water channel or fairway.

Shape: To be distinctive and different when possible from the principal characteristic shapes (viz.: conical, can or spherical), e.g. Pillar.

Colour: B.W.V.S. or R.W.V.S. (black and white or red and white vertical stripes).

Topmark (if any): To be a distinctive shape other than cone, can or sphere.

Light (if any): To be a character different from neighbouring lights on marks at the sides of the channel.

Isolated Danger Marks.

Shape: Spherical.

Colour: Wide black and red horizontal bands separated by a narrow white band.

Topmark (if any): Sphere painted black or red, or half black and half red, horizontally.

Light (if any): White or red with flashing character.

Landfall Marks.

Shape: Distinctive where possible. Usually pillar or spherical.

Colour: Black and white or red and white vertical stripes.

Light (if any): Flashing character.

WRECK-MARKING BUOYS AND VESSELS

Green is the colour used for all purposes connected with wreck-marking, viz.:—

For lights, buoys, balls, shapes, flags, wreck-marking vessels, etc.—Vessels and buoys have the word 'WRECK' painted in white letters on a green ground on their sides. The buoys may be either can-shaped, conical or spherical. Wreck-marking vessels exhibit lights, carry shapes and make sound signals during darkness, in daylight and in fog, respectively, to indicate their purpose.

OTHER BUOYS

Buoys are used for many purposes besides the delineation of channels and the marking of harbour approaches, wrecks and dangers as described above.

Some of these buoys may be laid on a 'permanent' basis and will thus be shown on charts. Examples of these might be the watch buoy mentioned under Light-vessels, a Danger Area buoy, possibly marking a dumping ground for explosives and a Spoil Ground buoy, marking a dumping ground for dredgings.

Other buoys are laid on a strictly temporary basis. Examples might be fishermen's dan buoys, survey buoys or buoys for seismic operations. These, of course, would not appear on charts but may be marked in temporarily.

Oceanographic Buoys

Buoys, or occasionally a grounded structure or tower, may be established for oceanographic research purposes.

As part of an Ocean Data Acquisition System instrumented buoys may be placed in almost any sea and numerically they can be expected to increase.

The buoys vary considerably in size and may be moored or free-floating.

The positions of moored buoys are promulgated as widely as possible. If a moored buoy is considered to be of a permanent enough nature its position is charted.

Recommendations for such ODAS buoys are as follows:—

Colour—Moored Buoys—Wide yellow and red vertical stripes.
Free-floating Buoys—Wide yellow and red horizontal bands.

Light—A distinctive white-bluish, high-intensity light, with a character consisting of quick flashes for a few seconds, followed by a longer period of darkness.

Radar Reflector fitted.

Identity code number prominently displayed.

The buoys may be met with in unexpected areas, often deep water. Mariners are requested to report their positions.

Fuel cells, both chemical and radioisotope, have been developed which may allow lit buoys and beacons to operate without servicing for periods ranging up to several years.

RADIO AND RADAR STATIONS

Coastal radio and radar apparatus is frequently of importance to navigators. There follows a brief description of types of stations often met with.

The symbol ⊙ is used to mark the position of a radio or radar station on a chart. The symbol is accompanied by a legend giving the nature of the service offered. In the examples of radio stations which follow two possible legends are given: the first, appearing on later Admiralty charts, being the abbreviation recommended by the International Hydrographic Bureau; the second, appears on older charts.

On all charts the outer circle of the symbol ⊙ is in magenta. On later charts the radio legend is also in magenta; on older charts the legend is in black. The name of the station always appears in black.

A full list of legends will be found in Section M of the Symbols and Abbreviations Chartlet.

Radio Direction Finding Stations—⊙ RG or ⊙ Rº D.F.

A radio direction-finding station is fitted with apparatus by means of which can be determined the direction from which wireless signals are being transmitted by a vessel.

The shore-based, direction-finding service around the coasts of the United Kingdom has been discontinued, there not being sufficient demand to justify its retention and the needs of vessels in distress being met by other methods.

Coast Radio Stations—⊙ R or ⊙ Rº

These stations handle the normal radio traffic for vessels in their areas. They also transmit on request for the use of the ships D.F. apparatus. Such service is known as a Q.T.G. Service, these letters being used in the radio contact procedure.

Circular Radiobeacons—⊙ RC or ⊙ R^{o} B^{n}

Radiobeacons are automatic transmitting radio devices which transmit at set intervals of time, some of them in all weathers but many only in conditions of reduced visibility. Their signals may be heard round 360°, as opposed to Directional Radiobeacons (below).

Radio beacons have largely superseded radio direction-finding stations.

The reader is referred to Chapter XI for further information on radio bearings.

Aero Radiobeacons—⊙ Aero RC or ⊙ Aero R^{o} B^{n}

Certain radiobeacons for the use of aircraft if situated in coastal regions may be useful to shipping. They are listed in the *Admiralty List of Radio Signals* and are shown on up-to-date charts. Mariners are warned that the charted position of an aero radiobeacon not so listed may be in error. Operation of an aero radiobeacon is generally continuous.

These beacons should be used with caution by seamen. There can be no guarantee of the accuracy of bearings observed at sea level; also, the station may be sited some miles inland (*see* p. 208).

Some administrations have established 'Aero-marine' beacons in coastal regions. These are beacons which it is hoped will be suitable for both marine and aerial users. However, the differing requirements of ships and aircraft make it generally better to have two separate beacon systems.

Directional Radiobeacons—⊙ RD 095° 30′ or
⊙ Dir R^{o} B^{n} 095° 30′.

A Directional Radiobeacon is a special type which transmits an 'on course' signal on a given sector or 'beam', the centre of such sector being indicated on the chart. In the example illustrated the directional radiobeacon would be established with the intention of helping vessels navigate a channel running in the direction 095° 30′. Often such a direction indicates the centre of an approach channel to a port.

Such a beacon is rather like the radio equivalent of leading marks or lights. (*See* page 61).

Signals from a directional radiobeacon should not be received through the ship's D.F. equipment.

RADAR EQUIPMENT SHOWN ON CHARTS

Coast Radar Station. ⊙ Ra.

A manned Radar Station. On request, a radar bearing and distance may be obtained by vessels from certain of these stations.

Radar Beacons.

⊙ Racon	Radar Responder Beacon—a radar beacon which transmits on reception of a pulse from the ship's radar. A characteristic paint on the P.P.I. indicates bearing and range. The position of the lighthouse or light-vessel mounting the Racon is clearly identified on the ship's radar picture; a helpful piece of information in crowded waters or along a featureless coastline.
⊙ Ramark	Radar Beacon—An independent radar beacon which operates continuously. The paint appears as a radial line on the P.P.I. indicating bearing but not range.

Masts and Towers.

⊙ Radio Mast— A radio mast forming a landmark for visual fixing only.

A similar notation is used for a radio tower, television mast or tower, radar tower or scanner.

Consol Beacon—⊙ Consol B^{n}

A Consol Station of the type discussed in Chapter XII.

Details of the Radio and Radar aids mentioned above are found in the Admiralty List of Radio Signals and the chart user is recommended to familiarise himself with the relevant parts of these volumes.

FOG-SIGNALS

Much endeavour has gone into devising reliable methods of assisting vessels to navigate through fog. Possibly radar is the most important single aid in this respect but fog-signals have their part to play.

An air fog-signal is frequently installed on such sites as lighthouses, harbour entrances, jetties and on light-vessels or structures.

The diaphone, siren and reed are three fog signals worked by compressed air, the note and power of each being different.

The horn is similar to the above signals but may be operated by compressed air or electricity.

Diaphone—Usually powerful low-pitched note. May end with a 'grunt'.

Siren—Variety of types differing in sound and power.

Reed—Weak, high-pitched sound.

Horn—A general term to embrace a variety of types which differ greatly in their sound and power. The fog signals formerly known as Tyfon, Nautophone and Electric Fog Horn are among those indicated on later charts and publications by the collective term 'Horn'.

Other air fog-signals include bells, gongs, steam or compressed air whistles and explosives.

All these signals may give one or more blasts, each of which may be of different or varying tone or pitch. Alternatively they may sound a letter or number of the morse code.

For example, a fog-signal may be annotated on a chart as: Horn Mo. (K)—Meaning horn sounding long-short-long.

Air fog signals are capricious and may or may not be heard in various circumstances.

Fog Detector Lights.

These are fitted at certain light-stations for the automatic detection of fog; they are in addition to the main light.

A detector exhibits a powerful light which may be continuous or may be in the form of a powerful flash of about one second's duration.

The light will probably be concentrated into a narrow beam and the beam may sweep back and forth horizontally over a stated arc or may remain fixed on one stated bearing.

They are shown on the chart as Fog Det^r. L^t.

Submarine Signals.

These consist of sounds transmitted under water by submarine bells or oscillators. Many light-vessels and shore stations are fitted with apparatus for the emission of submarine signals which can be picked up at considerable distances by ships fitted with the necessary receiving gear, and the direction of the transmitting station ascertained. A station fitted with an oscillator transmits a form of Morse signal allotted for its use. Such signals are normally operated in foggy weather.

Synchronised Radio Fog-Signals and Automatic Sound Signals.

Synchronised signalling between a radio fog-signal, or beacon, and an automatic sound signal, submarine or aerial, enables the observer to determine his distance from the sound transmitter. This is rendered possible through the difference in the rate of travel of sound in air and water, while that of a wireless signal is instantaneous.

The rate of travel of sound in air is 1130 ft. per second (344·4 metres per second), varying with the temperature. Sound travels faster through water, being about four times the rate of travel in air and varying with the density.

For all practicable purposes the speeds may be taken to be—

Air	0·18	miles	per second
Water	0·8	,,	,,

If a particular phase of a wireless signal is transmitted simultaneously with the beginning of a sound signal, the interval of time between their reception on board will be a measure of the distance from the sound transmitter. The wireless signal, which is heard the instant it is transmitted, signifies to the observer the exact moment when the sound signal is made. The observer then listens for the sound signal and notes the time, in seconds, it has taken to reach him. The time intervals multiplied by the factor 0·18 in the case of an air signal, or factor 0·8 for a submarine signal, will give the distance in miles from the position where the sound was emitted. It does not give the distance from the wireless station which is not necessarily in the same position as the sound-signalling station.

In a variation of this device the commencement of a morse radio signal is marked by the transmission of a submarine sound signal. The morse radio signal consists of a succession of dashes, evenly spaced and of equal duration.

The receiving vessel counts the number of dashes until the submarine sound signal arrives. The number of dashes counted is a measure of the distance from the transmitting station. A light-vessel may operate such a service.

Mariners are warned that fog-signals cannot be implicitly relied upon and the practice of taking soundings should never be neglected.

Admiralty volumes in which fog-signals are described include the *List of Lights, Fog Signals and Visual Time Signals*; the *Sailing Directions*; the *List of Radio Signals.*

CHAPTER III

THE expressions, bearing and course, are used to indicate direction; the former with reference to the direction in which a point, ship, object, etc., bears, or lies; and the latter the direction in which a vessel is heading. Both bearing and course being directions are therefore lines, and since they may be directed to any part of the horizon must have an angular relation to some fixed line.

The cardinal points of direction are North, South, East and West, the reference line being the North-South line which may be true, magnetic, or compass.

Directions are reckoned from 000° to 360° clockwise, and should be written in the three-figure notation.

Sometimes the quadrantal notation is used. Here directions are reckoned from North and South towards East and West, e.g.

Three-figure notation	*Quadrantal notation*
080°	N. 80° E.
170°	S. 10° E.
250°	S. 70° W.
315°	N. 45° W.

TRUE DIRECTION

The true North and South line is the meridian which passes through the vessel. True direction is related to this meridian.

The *True Bearing* of an object is therefore the angle at the observer's position contained between the observer's true meridian and the great circle passing through his position and the object.

MAGNETIC DIRECTION

Magnetic direction is related to the magnetic meridian.

The Earth is likened to a huge magnet whose poles are situated, the South one to the southward of Australia, and the North in the vicinity of Baffin Land. Lines of force pass in varying directions from the South to the North pole.

The compass needle when undisturbed by any other influence aligns itself parallel to these lines of force and thus indicates North and South magnetic—the magnetic meridian.

The angle which the magnetic meridian makes with the true meridian at any given place is known as the variation.

A *Magnetic Bearing* is the angle at the observer's position contained between the observer's magnetic meridian and the great circle passing through his position and the object.

COMPASS DIRECTION

Compass direction is related to the line taken up by the compass needle.

The compass needle is, in a varying degree, deflected from the magnetic meridian by the magnetism in the vessel; the deflection, or angle which the compass needle makes with the magnetic meridian is termed the deviation. If the needle is drawn to the right of the magnetic meridian, the deviation is easterly; if drawn to the left, it is westerly.

Further information concerning variation and deviation is given in Chapter X.

The *Compass Bearing* of an object is the angle at the observer's position contained between the line of the compass needle and the great circle passing through the observer's position and the object.

BEARINGS

True, magnetic and compass bearings as defined above may be illustrated by means of Fig. 3.1.

In Fig. 3.1, let L represent the position of a lighthouse and B the position of an observer. BL the arc of a great circle passing through the observer and lighthouse is the bearing of L from B. The distance being small, it can be drawn as a straight line. The direction in which L bears from B can be expressed in three different ways, viz. true, magnetic and compass.

Suppose TN to indicate the true meridian. Then the true bearing of L is $\angle TBL$, i.e. 040°. This bearing is true in every sense of the word since TN is fixed.

Let MG represent the magnetic meridian, or the direction in which a magnetic needle would lie when acting under the Earth's magnetic influence. The magnetic bearing of L is $\angle MBL$, i.e. 060° M.

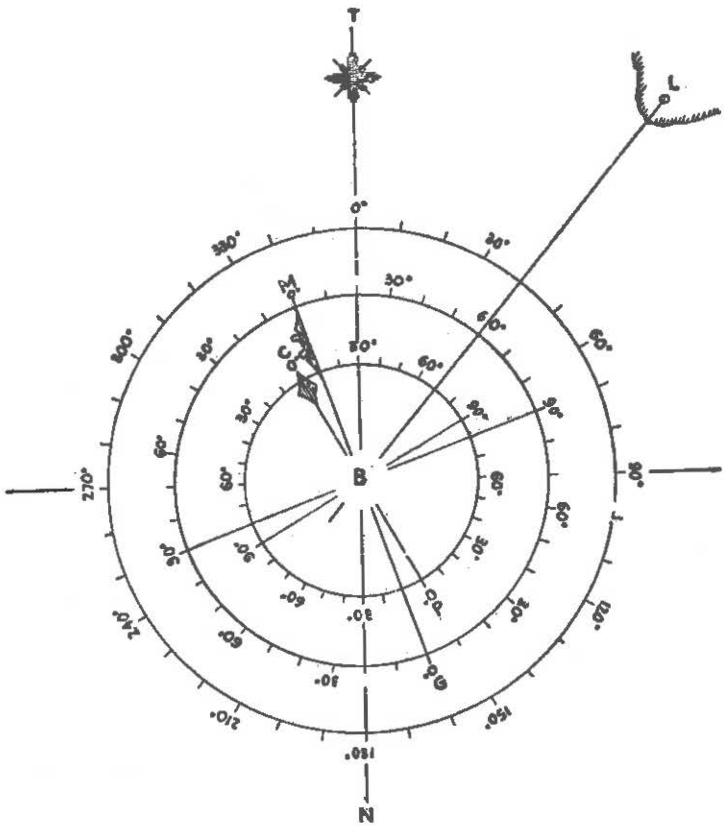


Fig. 3.1

If CP is the direction of the observer's compass needle, then $\angle CBL$ is the compass bearing of L from B. It is 070° C.

$\angle TBM$ = 20°, represents a variation of 20°, West
$\angle MBC$ = 10°, „ a deviation of 10°, West
$\angle TBC$ = 30°, „ compass error of 30°, West

Point of land 'L'	True Bearing	040° T. or N. 40° E.
	Magnetic Bearing	060° M. or N. 60° E.
	Compass Bearing	070° C. or N. 70° E.

These terms will be explained more fully in a subsequent chapter with instructions regarding the conversion of one form of bearing into another, and notes on the manner in which each may alter.

Azimuth Mirror—The practical measurement of bearings from a compass card is by means of an azimuth mirror or similar instrument. Terrestrial or astronomical bearings may be taken and azimuth mirrors are used with all types of compass equipment.

TRANSIT BEARINGS

For two objects to be in transit the vessel must be in such a position as to see both objects in the same line; therefore, if a bearing is taken of two objects when in line, it is known as a transit bearing. The symbol for a transit bearing is ⌀, *A* ⌀ *B* meaning that *A* and *B* are in line.

LEADING MARKS AND LIGHTS

In many channels, especially the approaches to harbours, two conspicuous objects kept in line will lead a vessel into a channel or deep water. These objects are termed leading marks and are denoted on the chart by either one straight line or occasionally two parallel lines drawn close together through the objects. The names of the objects and their bearing when in transit may be printed somewhere on the line.

Dotted or single extensions to leading lines are inserted to give the lines more prominence. The extensions are not to be taken as part of the lines.

Leading marks, if lit for use at night, are called 'leading lights'.

Marine Beacon—A highly directional marine beacon has been devised which obviates the need for two leading lights and provides a more efficient and versatile replacement.

The beacon comprises a central white sector to be aligned on the safe bearing and, in one form, a green sector and a red sector bounding the white. In all the light may be divided into five sectors with fast-flashing zones for general navigational use, outside three inner sectors.

All the illumination is accomplished with one light. Horizon range may be attained or the power may be limited for close-up use.

Besides its value in places where two leading lights are difficult to fit or align, the marine beacon has applications in the fields of surveying, dredging and pipeline laying.

CLEARING LINE

A clearing line is a line drawn through two conspicuous objects on the chart such as two lighthouses. A vessel should be kept outside of this line in order to clear some danger.

CLEARING BEARING

When clearing lines are not shown on the chart, a conspicuous object is selected and a bearing leading clear of the danger laid off from it. A vessel kept on this bearing will then pass clear of the danger.

COURSES—TRUE, MAGNETIC AND COMPASS

The direction in which a vessel is heading is indicated by her fore and aft line and the angular relationship of this line to the true or magnetic meridians, or to the compass needle, is her course. Thus the course can be true, magnetic or compass.

A true course is the angle which a ship's fore and aft line makes with the true meridian.

A magnetic course is the angle which a ship's fore and aft line makes with the magnetic meridian.

A compass course is the angle which the ship's fore and aft line makes with the compass needle.

All are reckoned clockwise from true North, that is 0° to 360°, but occasionally the quadrantal notation may be used.

Compass cards can be obtained with the degrees marked in three-figure or quadrantal notation.

The 0° to 360° notation is normally used for true, magnetic and compass courses and bearings. True, magnetic and compass directions should be qualified by the letters T., M. and C., respectively. Thus 170° T., 170° M., and 170° C.

True, magnetic or compass courses as defined above may be illustrated by means of Fig. 3.2.

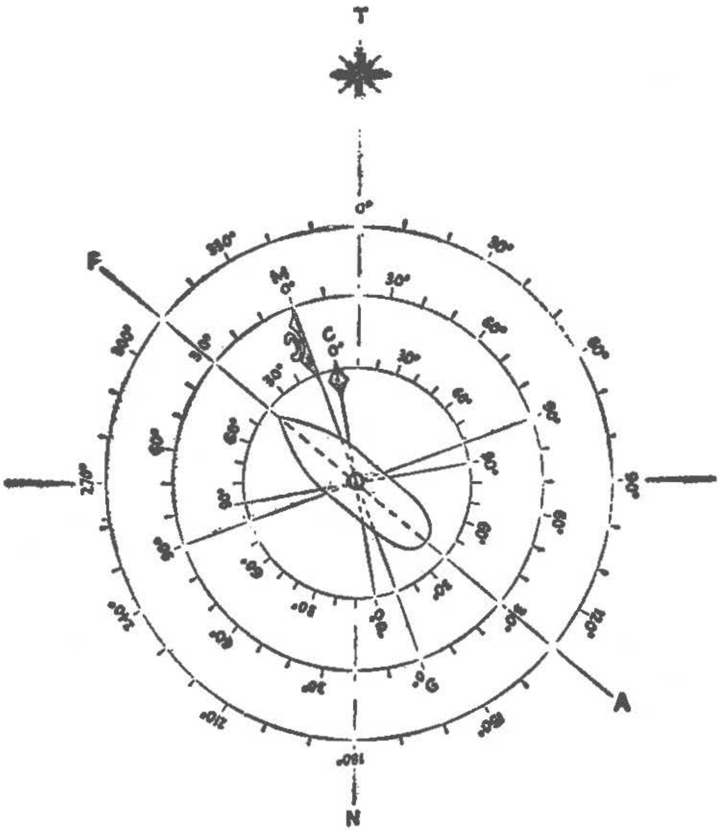


FIG. 3.2

In Fig. 3.2, let

	TN	represent the true meridian	
	MG	,,	magnetic meridian
	CP	,,	compass needle
and	*FA*	,,	ship's fore and aft line

Then $\angle TOF$ is the true course = 310° T. or N. 50° W. true.
$\angle MOF$,, magnetic ,, = 330° M. or N. 30° W. mag.
$\angle COF$,, compass ,, = 320° C. or N. 40° W. comp.

THE PELORUS

A useful instrument aboard some vessels is the pelorus or 'dumb compass card'. This consists of an inner metal plate on which is stamped out the graduations of a compass card. An outer fixed ring contains a lubber line. The inner plate revolves round a central axis and may be clamped in any position. Also rotatable around the central axis is an azimuth mirror or direction vane assembly.

The whole instrument is set up on a platform or pedestal, previously notched in such a way that the lubber line in the fixed ring can only indicate the fore-and-aft line of the vessel.

By carefully selecting positions for the pedestals all-round compass scanning may be attained. Usual positions are on the wings of the bridge and perhaps also abaft the funnel. A pelorus is particularly useful in vessels where the siting of the standard compass gives restricted vision. Astronomical or terrestrial bearings may be taken.

The pelorus facilitates the taking of relative bearings. In this case the card is set at 0° against the lubber line. Thereafter all directions are relative to the ship's head.

True bearings may be taken by setting the true direction of the ship's head against the lubber line. Thereafter all observed directions are true. Allowance has to be made of any amount the ship's head may have been off her projected course (compass or true) at the moment of taking the bearing by pelorus.

A pelorus is often of assistance in the process of calibrating a D.F. apparatus. Many other uses of this versatile instrument may be devised and will become apparent with practice.

As the positions mentioned as possible stances for the pelorus are often the sites chosen for gyro-compass repeaters the pelorus is an instrument which is probably not used as much as it otherwise might be.

THE GYRO-COMPASS

Most sea-going ships have a gyro-compass in addition to their magnetic compass. Such an instrument is mechanically and electrically controlled and is designed to indicate true North. It is totally independent of magnetic directions.

At times a small error may develop due to minor malfunction of parts. If constant this error may be applied as if it were a 'compass error' as described here and in Chapter X. If a gyro-compass develops a large or varying error the instrument should not be used.

Other Methods—It is interesting to note that Automatic Navigation Systems as described in Chapter XIII can provide the true direction of the ship's head and this may, where applicable, be used as a steering datum instead of that provided by the normal compasses. It should be remembered, however, that the high precision gyro is an integral part of any such automatic navigation system.

CHAPTER IV

THE COMPASS ROSE

Compass roses are printed at convenient positions on most charts to facilitate the processes of laying down and taking off courses and bearings.

A compass rose consists of two compasses with a common centre, the outer being true and the inner magnetic.

The true compass is graduated in degrees and reckoned continuously, clockwise, from 0° to 360°, the North-South direction, 0°—180°, being the direction of the true meridian.

The magnetic compass is also graduated in the 360° notation. The North-South line is parallel to the magnetic meridian and the angle it makes with the true North-South line is the variation at the position.

Since the value of the variation undergoes a yearly change, the year for which the magnetic rose applies, along with the annual change, is printed on the East-West line. It will be obvious that when the chart is used for a year different from which the magnetic rose is drawn a correction will have to be made to compensate for the change.

It is to be noted that when the variation is westerly half a fleur de lis is drawn, on the West, or left, side of the North point. If the variation is easterly it is drawn on the East, or right, side. Fig. 4.1 shows the form of compass rose printed on 'Fathom' Admiralty charts.

On new metric charts there may be given a main compass rose which is very similar to that illustrated in Fig. 4.1, although slightly simplified. In addition one or more supplementary compass roses are likely to be printed in other parts of the chart. These show only the true compass rose but include a small arm from the centre, indicating the direction of the magnetic meridian. Variation information is given along the east/west line of the true compass rose. Some metric charts display only these modified compass roses. The general policy is to show full compass roses on charts covering fishing grounds or island groups where mariners may still be using the magnetic compass.

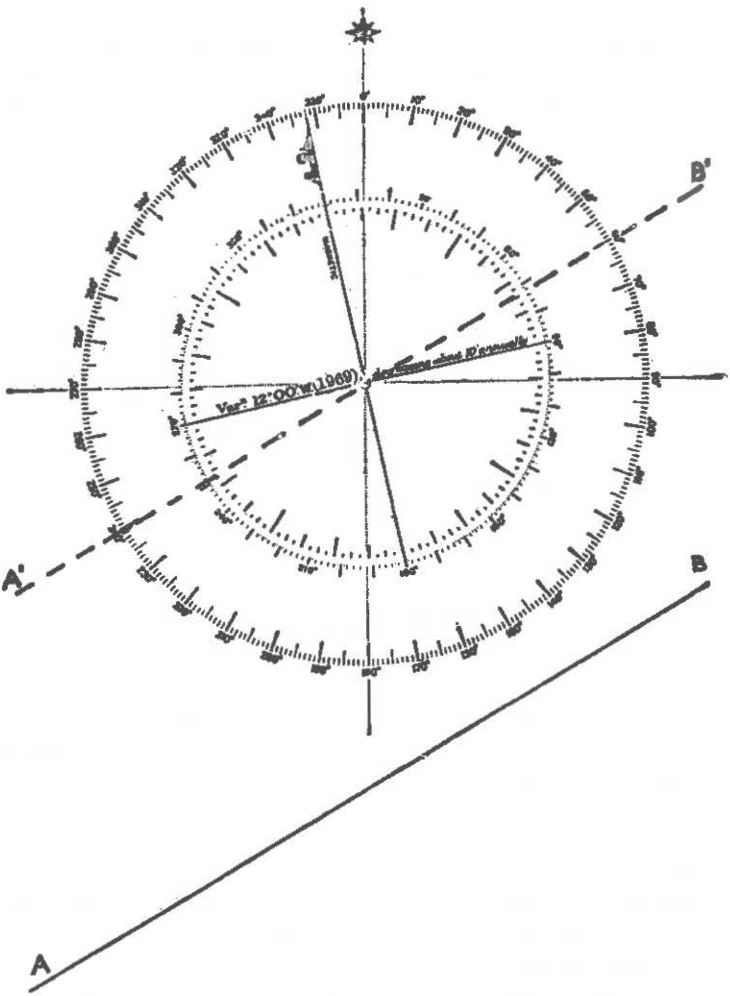


FIG. 4.1

TO TAKE OFF A COURSE

Join the points of departure and destination, or position where course is to be altered, by a line. Place the edge of the parallel rulers on the line and carefully move the rulers until the edge passes through the nearest compass rose. The course may then be read off in degrees, true or magnetic, as required.

Referring to Fig. 4.1, *A* is the point of departure, *B* the point of destination. *AB*, the course line, is transferred by parallel rulers to *A'B'* which passes through the centre of the compass rose.

The course is 060° T. or 072° M.

TO LAY DOWN A COURSE

To lay down a course, place the edge of the rulers through the centre of the compass and the degree mark indicating the course. Move the rulers to the position of the vessel, or point of departure, and draw in the course line. Thus, again referring to Fig. 4.1, a course of 060° T. or 072° M. can be laid off from position *A* by reversing the process described above.

TO LAY DOWN BEARINGS

To lay down a bearing of, say, 050°, place the edge of the rulers so that it passes through the centre of the compass rose and the 050° mark of the true compass. Then carefully move the rulers to the object and draw in the bearing.

A magnetic bearing may be laid off in the same manner using the inner, or magnetic, compass.

Frequently, however, the annual change in the variation renders this method inconvenient and it is more usual to calculate the magnetic bearing arithmetically using the true bearing and the variation for the place and the year. This process is dealt with in Chapter X and examples occur there and elsewhere in the book.

TO TAKE OFF BEARINGS

Bearings can be taken off a chart by reversing the above method

COURSES AND BEARINGS FROM GRADUATED PARALLEL RULES

Fig. 1.5 illustrates parallel rulers as used so often in chartwork and mentioned frequently in this book.

Generally these rules are graduated and as stated under Fig. 1.5, may thus be orientated to any compass direction. This offers an alternative to the compass rose as a means of ascertaining direction on a chart.

Instead of working to and from a compass rose when laying down and taking off courses and bearings the parallel rules may be manoeuvered to and from a meridian or parallel and the angle noted from the graduation.

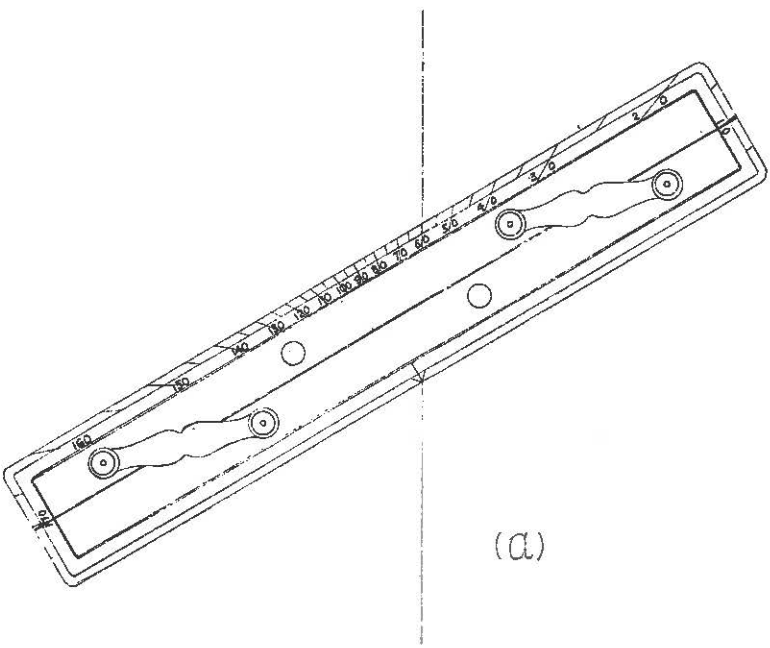


Fig. 4.2 (*a*) shows parallel rules matched on a meridian to an angle of 60°, thus indicating a direction on the chart of 060° T. or 240° T.

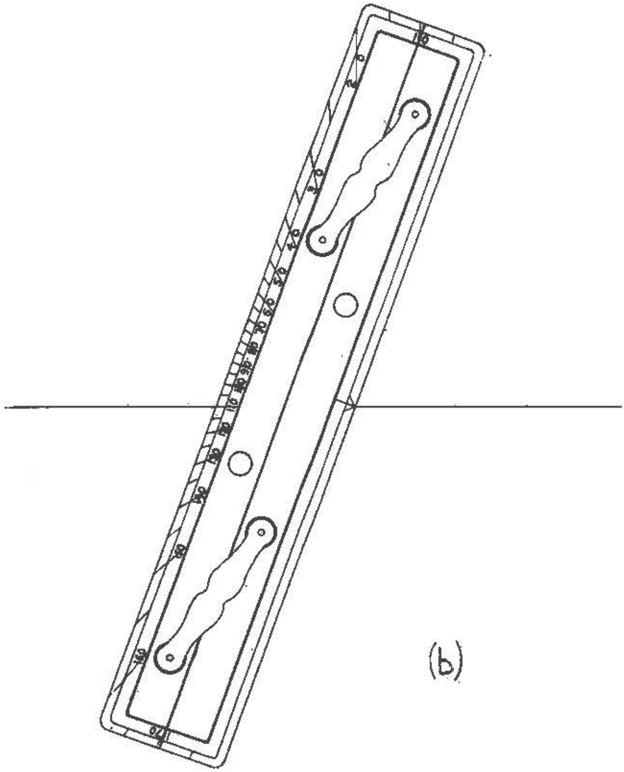


Fig. 4.2 (*b*) shows parallel rules matched on a parallel to an angle of 70°, thus indicating a direction on the chart of 020° T. or 200° T.

Since the graduations are finer towards the centre of the rule the chart-user will soon appreciate that for directions close to East/West it is better to use a meridian and for directions close to North/South it is better to use a parallel.

TO PASS A GIVEN DISTANCE OFF AN OBJECT

When it is required to pass a given distance off an object such as a headland, lighthouse, light-vessel, etc., with the given distance as a radius and the object as a centre, describe a circle, then the approaching course must be drawn as a tangent to this circle in order to maintain the given distance off the object.

TO FIND A COURSE TO STEER TO BE ABEAM OF A GIVEN POINT IN A GIVEN TIME, THE SPEED OF THE VESSEL BEING KNOWN

With the distance the vessel will steam in the given time as a radius and the position of the vessel as a centre describe a circle. From the given point draw a tangent to this circle.

The point of contact of the tangent will give the position to steer for.

Example:—Find the course to steer from position *A* to be abeam of point *B* in 20 minutes, the vessel steaming 12 knots.

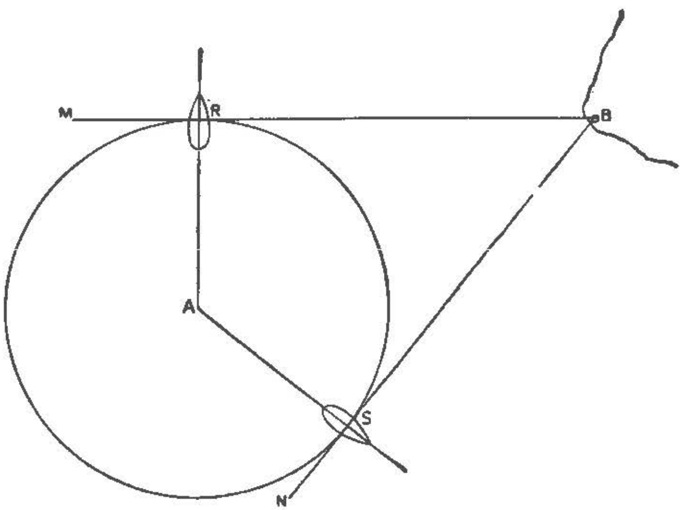


FIG. 4.3

Now since the vessel is steaming 12 knots she will travel 4 miles in 20 minutes. Then with centre *A*, (Fig. 4.3), and radius 4 miles describe a circle. From *B* draw *BM* and *BN*, tangents to this circle.

Then *R* or *S* the points of contact will be the positions to steer for to be abeam of *B* in 20 minutes. If it is required to have *B* abeam on the port side *AS* is the course to steer and if on the starboard side *AR*.

TO STEER A COURSE IN ORDER TO MAKE A POINT OF LAND A GIVEN NUMBER OF DEGREES ON THE BOW AND A GIVEN DISTANCE OFF

With the given distance off as a radius and the object as a centre describe a circle. Then enter the Traverse Table with the given number of degrees on the bow as a course, and the given distance off in the distance column, and take out the departure.

Now, with this departure as a radius and the object as a centre, describe another circle. A tangent to the inner circle, drawn from the ship's position, will give, at its point of intersection with the outer circle, the position for which the vessel must steer in order to have the light the given number of degrees on the bow and the given distance off.

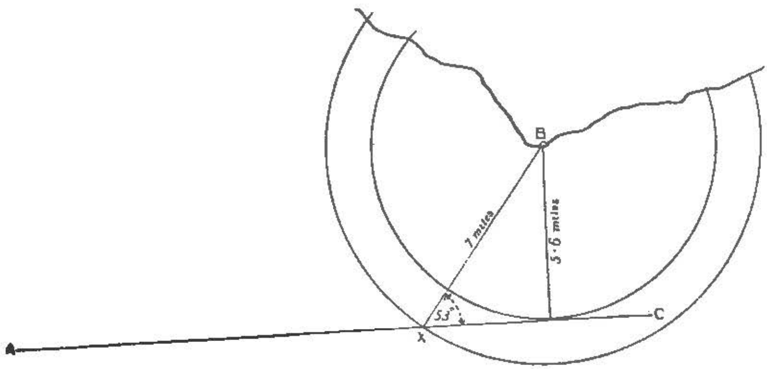


FIG. 4.4

Example:—In Fig. 4.4, a vessel at position *A* requires to make point *B* 53° on the port bow when distant 7 miles.

Enter the Traverse Table with 53° as a course and 7 miles as a distance and take out the *departure*. With centre *B* and radius 7 miles, describe a circle. With centre *B* and radius 5·6 miles, which is the departure, describe another circle.

From *A*, the position of departure, draw *AC* a tangent to the inner circle. Then where this line cuts the outer circle in *X* is the position for which to steer so that the light will be 53° on the port bow when 7 miles distant.

When the length over the chart from ship to point of land is not too great the use of a station pointer can facilitate a quick solution to the above type of problem.

If the reader is not familiar with the instrument known as the station pointer he is referred to Chapter VI where the instrument itself is described and its use in association with horizontal angles explained.

Applying the method to the example illustrated in Fig. 4.4, one leg of the station pointer is set to the angle AXB and the other leg disregarded. Thus, set the right-hand leg to (180–53)° or 127° from the fixed leg. Manoeuvre the station pointer along the arc of the circle of radius 7 miles until the ship and the point of land are simultaneously touched by a leg. In this case when the fixed leg passes through A and the moveable leg passes through B the centre of the station pointer will be over X. Mark this point through. The required angle has now been fitted into the problem and X must be the position for which to steer. Join AX and this is the required course to steer.

If the station pointer angle ($\angle AXB$ in this case) be laid off on a sufficiently large piece of plastic or transparent paper the limitation of length over the chart caused by the size of the station pointer does not of course apply.

TO FIND THE COURSE TO STEER TO COUNTERACT A CURRENT

It is essential for the navigator to be conversant with the graphic method adopted to find the course to steer to counteract the effect of a current or tidal stream.

In a body of moving water the vessel is, naturally, carried along with the water, and since the direction of this movement cannot be controlled, the vessel's course, which is under control, must be adjusted to impel her to move in the required direction. The problem is one of ensuring that the *resultant* of the two forces, ship's motive force and effect of current or tidal stream, will be the *course* it is desired to *make good*.

The parallelogram of forces provides the solution.

In Fig. 4.5, suppose a vessel at position A wishes to reach position B, which is N. 70° W. distant 24 miles from A, and a current is setting S.W. at 2 knots. Vessel's speed is 8 knots. What is the course she must steer?

Join *A* to *B*. From *A* lay off *AC*, S.W. 2 miles, to represent the effect of one hour's current.

Take in the dividers the distance the vessel steams in one hour, i.e. 8 miles. Place one leg of the dividers on *C*, and with the other cut the line *AB* in *D*.

Join *C* to *D*. Then *CD* is the course to steer; it is 303° T. or N. 57° W. The vessel moves along *AB* while heading in the direction *CD*.

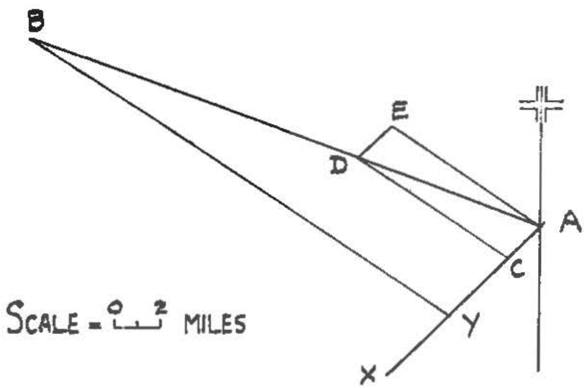


FIG. 4.5

In the figure the lines *ED* and *AE*, which are parallel to *AC* and *CD*, respectively, are inserted to complete the parallelogram of forces. Thus *AC* and *CD*, which represent one hour's current effect and one hour's steaming distance, respectively, are the adjacent sides of a parallelogram of which *AD*, the resultant, is the course it is desired to make good.

NOTE—It is not necessary to draw in the lines *ED* and *AE*. They are merely shown in the figure for explanatory purposes.

In the above example, the unit of time is one hour. If two hours or half an hour had been taken, the course to steer would have been the same. It is to be thoroughly understood that, whatever may be the amount of current used in the construction, an equivalent steaming distance must be utilised. The following diagram will make this clear:

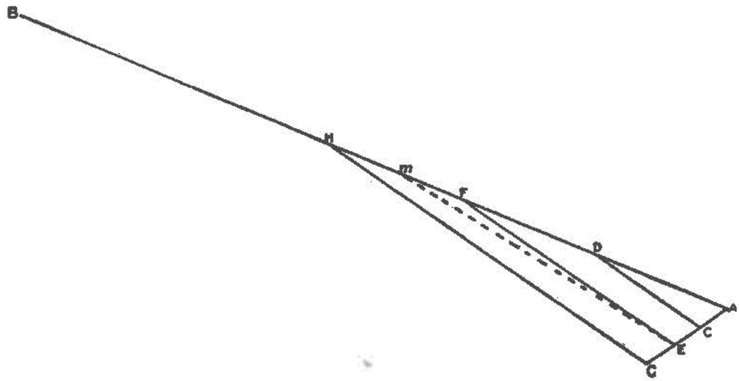


Fig. 4.6

In Fig. 4.6, *A* to *B* is the course it is required to make good

A C	represents	*half an hour's* current
CD	,,	distance steamed in *half an hour*
AE	,,	*one hour's current*
EF	,,	distance steamed in *one hour*
AG	,,	*one and a half hour's* current
GH	,,	distance steamed in *one and a half hours*.

Thus *CD*, *EF* and *GH* are parallel to each other.

TO FIND THE TIME A VESSEL WILL TAKE TO MAKE GOOD A GIVEN DISTANCE WHEN STEERING A COURSE TO COUNTERACT A CURRENT

Referring to Fig. 4.5, *D* is the position arrived at after one hour's steaming at 8 knots, so therefore *AD* is the distance made good in one hour.

The time it would take to go from *A* to *B* can be found by simple proportion.

AB is given as 24 miles. *AD* is, by measurement, 8·7 miles.

Hence:—

Time taken to make good 8·7 miles $= 60$ minutes

$\therefore$,, ,, ,, ,, ,, 1 mile $= \dfrac{60}{8\cdot7}$,,

$\therefore$,, ,, ,, ,, ,, 24 miles $= \dfrac{60}{8\cdot7} \times 24$ minutes

$= 165$ minutes

Therefore the time taken to go from A to B is 2 hours 45 minutes.

It could also be found by producing the current to X (Fig. 4.5) and drawing in BY parallel to DC.

Then BY divided by the ship's speed CD is the steaming time.

Note that BY is also the distance by log, or the distance steamed through the water.

TO FIND THE DISTANCE A VESSEL WILL MAKE GOOD IN A GIVEN TIME WHEN STEERING A COURSE TO COUNTERACT A CURRENT

Having found, by measurement from the chart, the distance made good in a given time, the distance to be made good during any other interval of time can be found by proportion.

Thus, again referring to Fig. 4.5, the vessel makes good 8·7 miles in one hour. What distance will the vessel make good in, say, 1 hour 48 minutes?

Distance made good in 60 mins. $= 8\cdot7$ miles

$\therefore$,, ,, ,, ,, 1 min. $= \dfrac{8\cdot7}{60}$,,

$\therefore$,, ,, ,, ,, 108 mins. $= \dfrac{8\cdot7}{60} \times 108$ miles

$= 15\cdot66$ miles

Therefore the distance made good towards B in 1 hour 48 minutes is 15·66 miles.

This information, however, could be found directly from the chart by, in the first instance, laying off 1 hour and 48 minutes current effect and using the steaming distance corresponding to the same interval to find the course to steer and distance made good.

In the foregoing examples it is, of course, assumed that the direction and rate of the current remain constant.

It may be required to increase or decrease speed while steering a course to counteract a current. In such case it is necessary to find a new course to steer in order to make good the given course.

Referring to Fig. 4.6, suppose the speed of the vessel had been 10 knots instead of 8 knots as stated, then by taking the distance steamed in one hour, i.e. 10 miles, and placing one leg of the dividers on *E* as before, the other leg will cut the line *AB* in *m*. Then by joining *E* to *m* the course to steer for a speed of 10 knots is obtained. Thus the course to steer differs for different speeds.

TO FIND THE SPEED A VESSEL MUST STEAM TO MAKE GOOD A GIVEN DISTANCE IN A GIVEN TIME, STEERING A COURSE TO COUNTERACT A CURRENT

The occasion may arise when it is necessary to increase or decrease speed in order to arrive at a predetermined position at a given time.

In localities where the effect of current or tidal stream has not to be considered, the required speed is obtained simply by dividing the intervening distance by the time interval.

When, however, the effect of an external influence has to be taken into account, the following graphic method may be adopted.

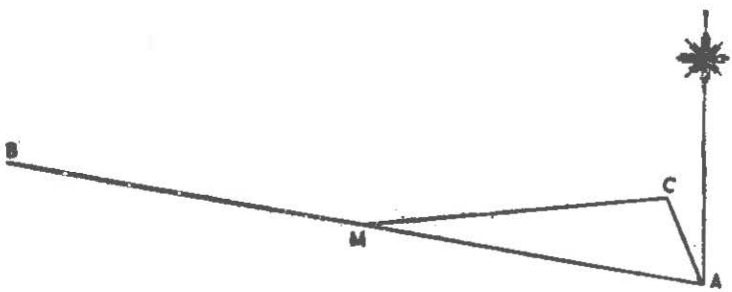


FIG. 4.7

Referring to Fig. 4.7, a vessel at *A* wishes to reach position *B*, which is N. 80° W. and 24 miles distant, in two hours, steaming through a current known to be setting 338° T. at 3½ knots. Required her speed and course to steer.

Join *A* to *B*. Bisect *AB* in *M*. Then *AM* is the distance to be made good in one hour.

From *A* lay off *AC* representing the effect of 1 hour's current. Join *C* to *M*.

The measure of *CM* denotes the speed at which the vessel must steam to reach *M* in 1 hour, and, of course, the speed to arrive at *B* in two hours. Speed is 10½ knots.

CM also represents the course to steer.

It is to be noted that instead of bisecting *AB*, two hours' current effect could have been laid off from *A*; and the end of the current line joined to *B* would represent two hours' steaming distance and the course. Half the steaming distance would be the required speed.

LEEWAY

In strong winds and high seas the pressure on the weather side of the vessel drives her to leeward of the course she is steering, and unless due allowance has been made for leeway the actual course made good over the ground will differ from that which it is desired to make good.

The application of leeway causes considerable difficulty with students who are at an elementary stage.

The point of confusion often is 'when is the leeway allowed into the wind and when is it allowed away from the wind?'

Take two examples:

(i)

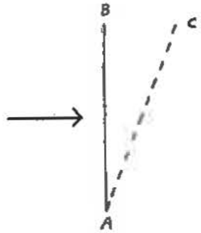


FIG. 4.8 (*a*)

Point *B* is due north of Point *A*. A vessel wishes to sail from *A* to *B* and on leaving *A* she steers straight for *B*, i.e. she steers 000° T.

A strong W'ly wind is blowing. Plainly the vessel will not go along the line *AB* but will make good a course something in the nature of the line *AC* although all the time she will be heading in a direction parallel to *AB*.

The angle BAC is called the angle of leeway or simply the *leeway*.

It is plain from example (1) that in order to sail from A to B under the conditions prevailing the vessel must head up into the wind a bit, in order to make good the course AB.

If the leeway angle BAC is applied in the other direction so that $\angle DAB = \angle BAC$ then AD will be the direction in which to head the ship so that she will make good the course 000° T.

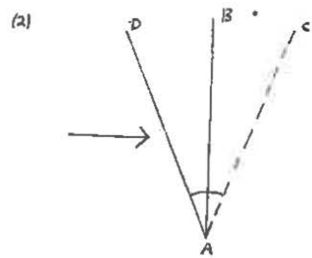


FIG. 4.8 (*b*)

To sum up:

In example (1) the ship goes crabwise up the line AC while heading in the direction AB.

In example (2) the ship goes crabwise up the line AB while heading in the direction AD.

Thus if we are told the ship is steering a certain course the leeway must be applied away from the wind. If we are told the course the ship wishes to make good (i.e. the course to steer is required) the leeway must be allowed into the wind.

Examination questions use the phrase 'allowing so-many degrees for leeway' regardless of the type of question. That is, they use it in each of the above cases and it is up to the student to read the information given and so decide whether the question is of type (1) or type (2) above.

Do not be misled by the wording of the question.

The allowance for leeway must be made before the deviation is found and thence the compass course to steer.

When the wind is right ahead or dead astern the vessel makes no leeway.

No definite rule can be given as to the amount of leeway to allow as, under the same conditions of wind and sea, different ships will make a different amount of leeway, depending upon their draft, under-water shape of the hull and amount of superstructure. The amount of leeway which a vessel is making may be ascertained by noting the angle between her fore and aft line and her track through the water.

Occasionally leeway may be quoted as a direction and distance in a similar manner to set and drift (Chapter V).

For instance, instead of saying 'the vessel made 5° of leeway', it might be possible to say 'the leeway was 038° T.—2 miles'. That is, due to the wind the vessel was displaced 038° T.—2 miles in a given period of time.

TO FIND THE COURSE TO STEER TO COUNTERACT CURRENT AND LEEWAY

If a course to make good is known or is given in an examination question and the set and rate of the current and also the amount of leeway are known, then the course to steer is established by combining the principles already described in this chapter. The course to steer to counteract the current is found first, then the leeway is applied to that course.

An example will make this clear.

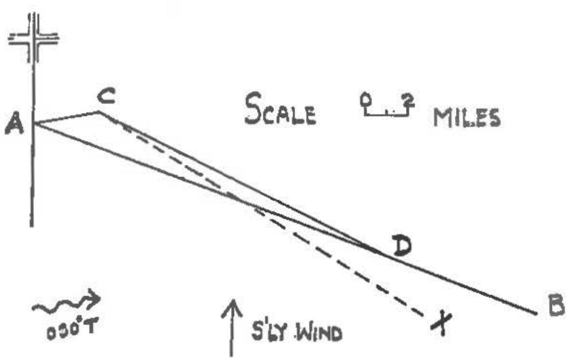


FIG. 4.9

A vessel at *A* is required to sail to *B*, which is 110° T. from *A*. A current sets 080° T. at 3 knots and there is a strong southerly wind blowing which is expected to cause 5° of leeway; vessel's speed 15 knots. Find the course to steer.

The course to make good from *A* to *B* is 110° T.

From *A* lay off the current for one hour, that is 080°— 3 miles. Call this point *C*.

With centre C and radius the ship's speed, that is 15 miles, draw an arc to cut AB in D.

CD would be the course to steer if there was current only and no leeway. This is measured as 116½°T.

Allow 5° of leeway —that is, into the wind in this case.

$$116\tfrac{1}{2}° + 5° = 121\tfrac{1}{2}° \text{ T.}$$

Draw CX equal to 121½° T. (that is $\angle DCX = 5°$).

Thus 121½° T. is the course to steer to counteract current and leeway. In a practical example, if both current and leeway have been estimated correctly then the ship would in fact proceed along AB.

CHAPTER V

In coastal navigation it is prudent to check, or fix, the vessel's position at every opportunity. This is done by various means, the most common of which is to take bearings of prominent objects, or navigation aids, whose positions are accurately known. Thus position lines are obtained on which the vessel is situated.

POSITION LINE

A position line, as the name implies, is simply a line drawn on a chart somewhere on which the vessel is situated.

Position lines may be obtained in a variety of ways and may be short straight lines or curved lines.

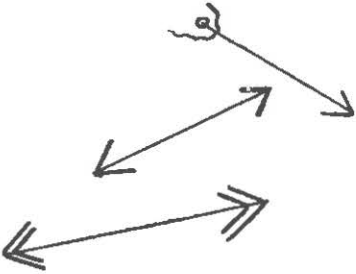
For instance, the bearing of a lighthouse, although actually a small part of the arc of a great circle, may be plotted as a short straight line and is a position line. Any bearing that can be plotted is necessarily a position line since the observer must be situated somewhere along the bearing.

When the latitude of the vessel is obtained the parallel of latitude is a position line.

If the distance from a fixed point or object, whose position is accurately known, is ascertained and an arc of a circle, radius equal to distance off, is described about the fixed point, the arc is a position line.

Position lines are again discussed in Chapter VIII.

Marking Position Lines—A convention sometimes used in marking position lines on charts is as shown in Fig. 5.1.



(*a*) A Terrestrial Position Line, i.e. a bearing from a shore object.

(*b*) An Astronomical Position Line.

(*c*) A transferred Position Line

FIG. 5.1

A FIX

When two position lines intersect, the position of the vessel is said to be *fixed*. An *absolute fix* is therefore the point of intersection of two or more position lines on which the vessel is situated simultaneously.

In the selection of objects to be observed, fixed shore objects are to be preferred to floating objects, near objects to distant ones, and the angle of cut 90° or as near thereto as possible.

Such a *fix* may be obtained from:—

Cross bearings
Transit bearings and angle
Bearing and angle
Horizontal angles
Bearing and distance
Two or more ranges
Astronomical observations
Radio Aids to navigation
An Automatic Navigation System

Also some help may be obtained from soundings, e.g.

A bearing and a sounding
A line of soundings

These, however, should be viewed with great caution and while the methods can be useful a position obtained using soundings should be regarded as only approximate.

A *running fix* is the method of fixing the vessel's position when an interval has elapsed between the finding of two position lines. All methods are dealt with in subsequent pages.

TRUE POSITION

The true position of a vessel is the position found directly from bearings of objects whose positions are known.

POSITION BY CROSS BEARINGS

This is the most common form of finding a ship's position and is, as already stated, usually termed a fix. It has already been explained that a bearing of an object is in reality a position line therefore if bearings of two objects are taken simultaneously then two position lines are obtained on both of which the vessel must be.

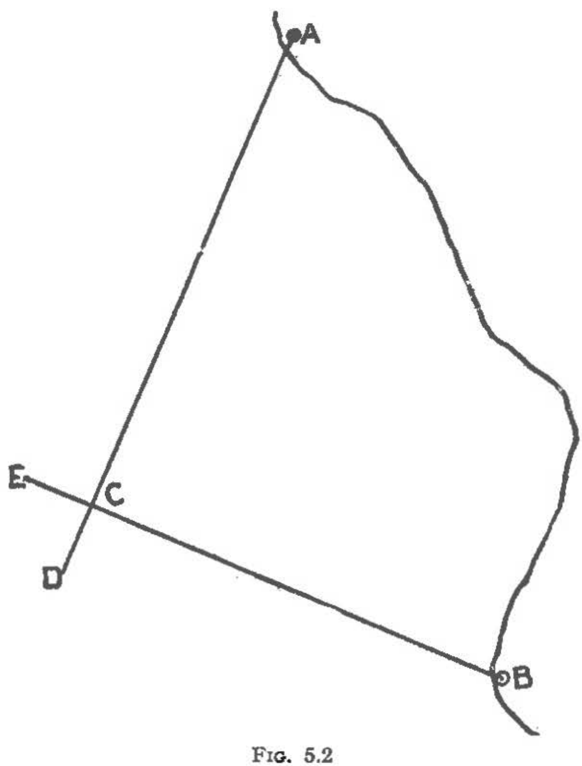


FIG. 5.2

In Fig. 5.2, let *A* and *B* be the two objects, *DA* and *EB* their respective bearings from the observer, then since the vessel must be on both bearings at the same time it is obvious that she must be where they intersect, i.e. the point *C*.

POSITION BY TRANSIT BEARING AND ANGLE

This is a common method of fixing a vessel's position and is similar to that by cross bearings.

Example—A vessel steering 340° T. observes two lighthouses, *A* and *B*, in transit and at the same time the angle subtended by the nearer lighthouse and a church spire was found to be 80 degrees.

Find the ship's position.

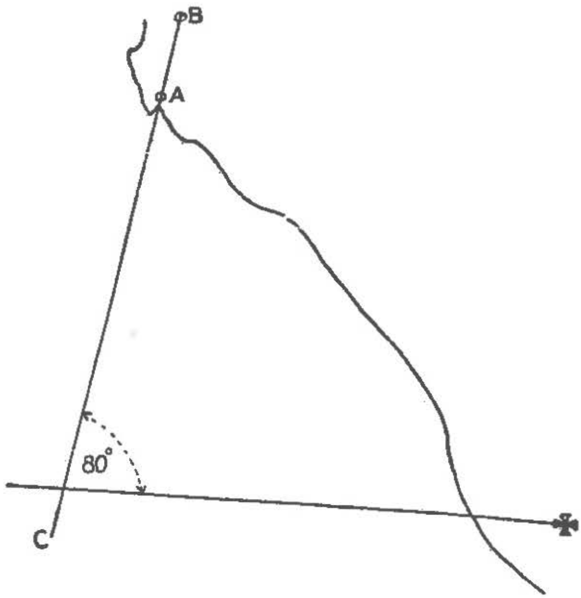


Fig. 5·3

In Fig. 5.3, let *A* and *B* be the lighthouses and ✠ be the church spire. With the parallel ruler make an angle of 80 degrees with *CB* the transit bearing, move the parallel ruler until its edge passes through the position of the church, draw a line and where it cuts the transit bearing is the ship's position.

Note—If the bearing of the church is given the position of the vessel is found in the same manner as in cross bearings.

POSITION BY BEARING AND ANGLE

Example—A vessel steering 340° T. observes a lighthouse bearing 010° T. and the angle subtended by a flagstaff and the lighthouse was found to be 80°. Find the ship's position.

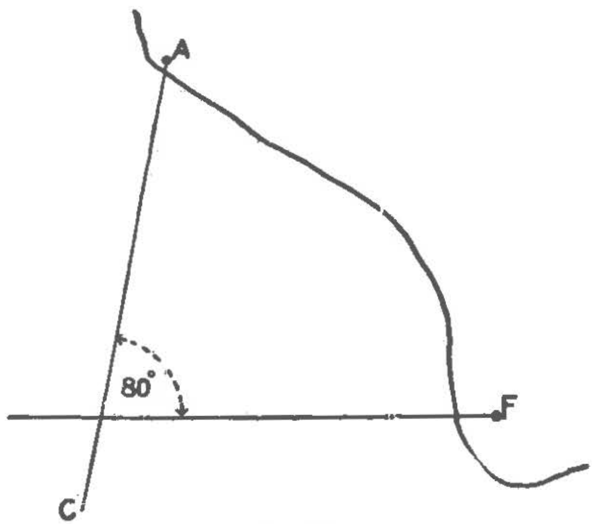


FIG. 5.4

In Fig. 5.4, let *A* be the lighthouse and *F* the flagstaff. Lay off *CA* the given bearing, then with the parallel ruler make an angle of 80° with *CA*.

Move the ruler till the edge passes through the flagstaff and draw in the line; where this line cuts *CA* is the ship's position.

BEARING AND SOUNDING

A fix by bearing and sounding is only to be regarded as approximate due to the many inaccuracies which may be present.

For reasonable results:—

(1) The depths must change fairly rapidly.

(2) The depth contour lines (in fathoms or metres) must be clearly depicted on the chart.

(3) Allowance for the height of tide must be made before comparing the ship's sounding with the sounding shown on the chart.

(4) *Either* (i) the bearing and the depth line should make as nearly as possible a right angle cut [Fig. 5.5 (*a*)].

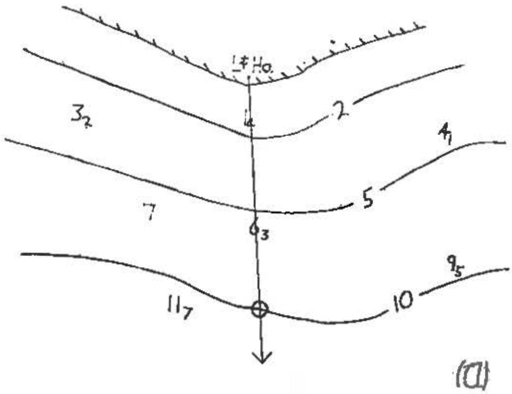


FIG 5.5 (*a*)

or (ii) the sounding should be an isolated one, [Fig. 5.5 (*b*)].

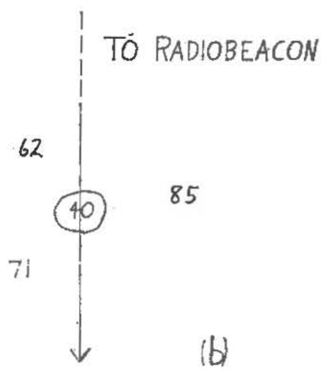


FIG. 5.5 (*b*)

In Fig. 5.5 (*a*) best results would be obtained if the vessel was steering towards or away from the coast; but she could also use this method if sailing along the coast.

In Fig. 5.5 (*b*) when the echo-sounder indicates the vessel is on the patch a DF bearing is taken. Such a position line could also have been obtained from an astronomical observation or from another radio aid.

A danger with isolated soundings, shoaler than surrounding depths, is that there is no knowing how closely the spot may have been examined. Use in conjunction with a bearing, however, should diminish this disadvantage to a certain extent. It is inadvisable to accept a spot shoal sounding on its own as a fix.

OPEN BEARINGS OR RUNNING FIX

The position of a vessel can be ascertained by taking a bearing of an object, and after an interval taking a second bearing of the same object, or the bearing of another object, the course steered and distance steamed between the bearings, and the set and drift of the current or tidal stream, if any, being known.

Example—A vessel steering 000° at 8 knots observes a lighthouse bearing 050°. After an interval of 45 minutes the lighthouse bears 110°. Find the ship's position at the time of taking the second bearing.

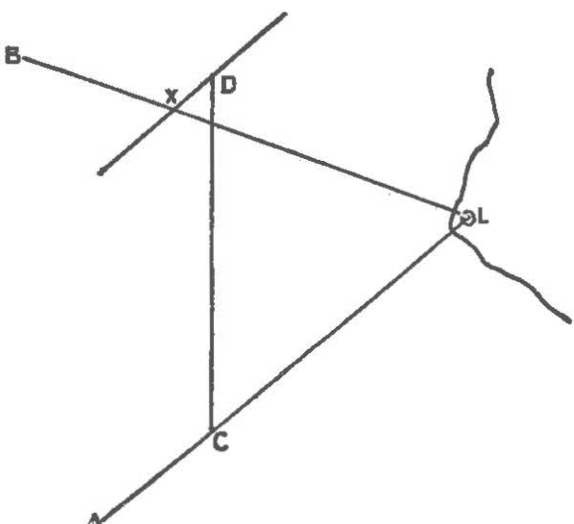


FIG. 5.6

In Fig. 5.6, let *L* be the lighthouse, *AL* and *BL* the 1st and 2nd bearings, respectively. From any point on *AL* lay off *CD*, the course steered and distance steamed between the bearings, i.e. 000° 6 miles.

Through *D* draw a line parallel to *AL*; where this cuts *BL* at *X* is the ship's position at the time of taking 2nd bearing.

Example—A vessel steering 140° at 10 knots observes a lighthouse bearing 100°. The vessel then steams for 30 minutes through a current setting 248° at 2 knots when the lighthouse bears 030°. Find the position of the vessel at the time of taking the 2nd bearing.

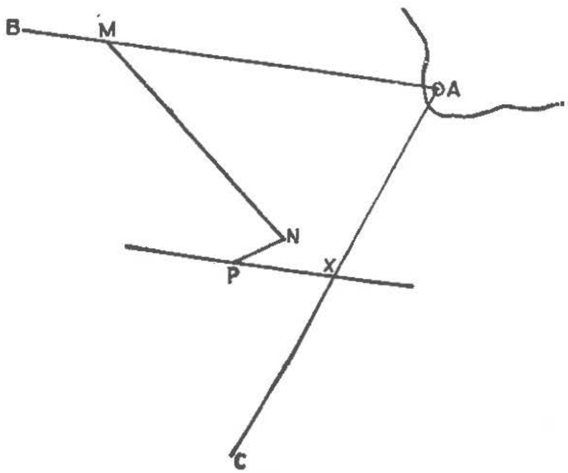


FIG. 5.7

Referring to fig. 5.7, let *BA* be the 1st bearing and *CA* the 2nd, then from any point on *BA* lay off *MN* the course steered and distance steamed, i.e. 140° 5 miles.

From *N* lay off *NP* the current experienced, i.e. 248° one mile. Through *P* draw a line parallel to the 1st bearing; where it cuts the 2nd bearing at *X* is the ship's position.

Example—From a vessel steering 135° at 8 knots through a current setting 195° at 2 knots, a lighthouse *A* was observed to bear 090°. After an interval of 45 minutes another lighthouse *B* was observed to bear 020°. Find the vessel's position when the bearing of lighthouse *B* was taken.

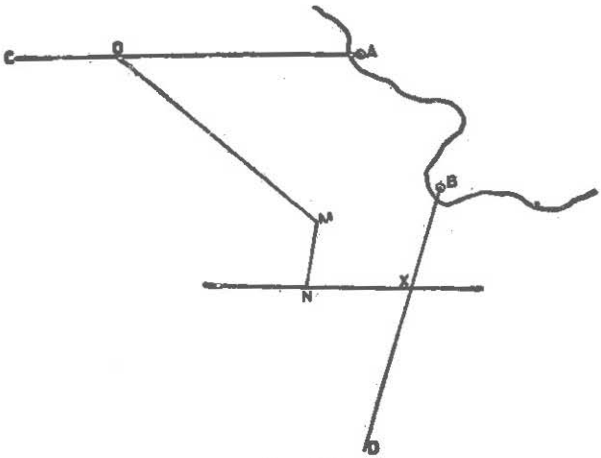


FIG. 5.8

In fig. 5.8, let *CA* and *DB* be the 1st and 2nd bearings, respectively. Then from any point on *CA* lay off *OM* the course steered and distance steamed, i.e. 135° 6 miles.

At the end of this run lay off *MN*, the current experienced between the bearings, i.e. 195° 1½ miles.

Through *N* draw a line parallel to the 1st bearing; where it cuts the 2nd bearing in *X* is the ship's position.

Example—A vessel steering 090° at 12 knots observes the bearing of a tower to be 050°. After an interval of 40 minutes the

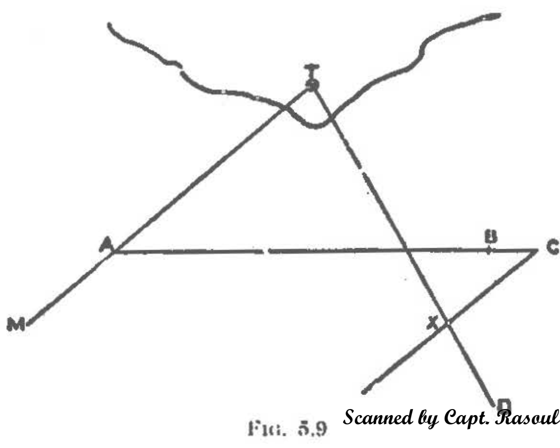


FIG. 5.9

tower is observed to bear 330°. Making due allowance for the effect of a current setting 090° at 1½ knots, find the position of the vessel at the time of taking the 2nd bearing.

In fig. 5.9, let *T* be the tower, *MT* the 1st bearing, *DT* the 2nd bearing. From any point on *MT* lay off *AB* the course steered and distance steamed in 40 minutes, i.e. 090° 8 miles.

At the end of the run lay off *BC* the current experienced during the run between the bearings, i.e. 090° 1 mile.

Through *C* draw a line parallel to the 1st bearing; where it cuts the 2nd bearing at *X* is the ship's position at the time of taking the 2nd bearing.

Example—A vessel steering 090° at 12 knots observes a tower bearing 050°. After an interval of 40 minutes the tower bears 330°. If the current is estimated to set 270° at 1½ knots, find the position of the vessel at the time of taking the 2nd bearing.

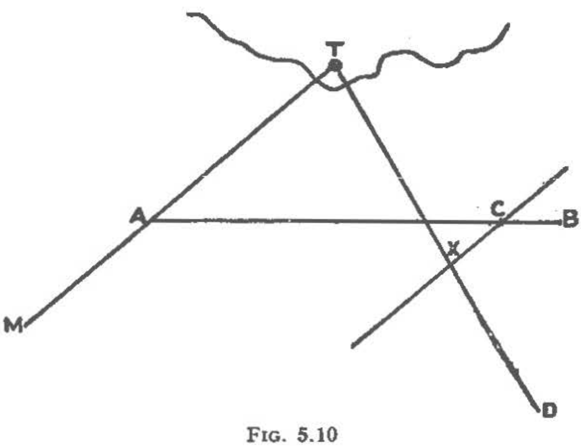


FIG. 5.10

In fig. 5.10, let *T* be the tower, *MT* and *DT* the 1st and 2nd bearings, respectively. From any point on the 1st bearing lay off *AB* the course steered and distance steamed in 40 minutes, i.e. 090° 8 miles. From the end of this run lay off *BC* the current experienced during the run between the bearings, i.e. 270° 1 mile.

Through *C* draw a line parallel to the 1st bearing; where this line cuts the 2nd bearing in *X* is the ship's position.

In the foregoing examples on finding the position of the vessel by running fix, it has been emphasised that the course steered and distance steamed between the bearings can be laid off from any point on the 1st bearing. The following example will make this clear.

From a vessel steering 080° at 10 knots a point of land was observed to bear 035°, and 36 minutes later it bore 310°, the current being estimated to set 120° at 2½ knots.

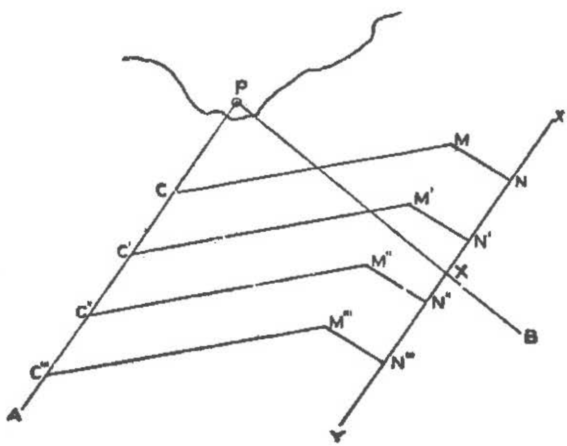


FIG 5.11

In fig. 5.11, let P be the point of land, AP and BP the 1st and 2nd bearings respectively, CM, $C'M'$, $C''M''$, $C'''M'''$, each representing the course steered and distance steamed between the bearings, and MN, $M'N'$, $M''N''$, and $M'''N'''$ the current experienced. It will now be seen that XY, a line drawn through the ends of the current lines, parallel to the 1st bearing, cuts the 2nd bearing in X, the vessel's position when the 2nd bearing was taken.

TO FIND THE POSITION OF THE SHIP ON THE FIRST BEARING

In the foregoing examples it has been shown how to find the ship's position at the time of taking the 2nd bearing of an object.

It may be desired to find the position of the vessel at the time of taking the 1st bearing of an object.

If the position at the time of taking the 2nd bearing is known the position on the 1st bearing can be ascertained by laying off, in the reverse direction, from the position on the 2nd bearing the course made good; and where this line cuts the 1st bearing is the ship's position on that bearing.

Example—From a vessel steering 225° a flagstaff bore 280° and 30 minutes later it bore 350°. If the vessel is steaming 12 knots and a current is setting 125° at 3 knots, find the position of the vessel at the time of taking the 1st bearing.

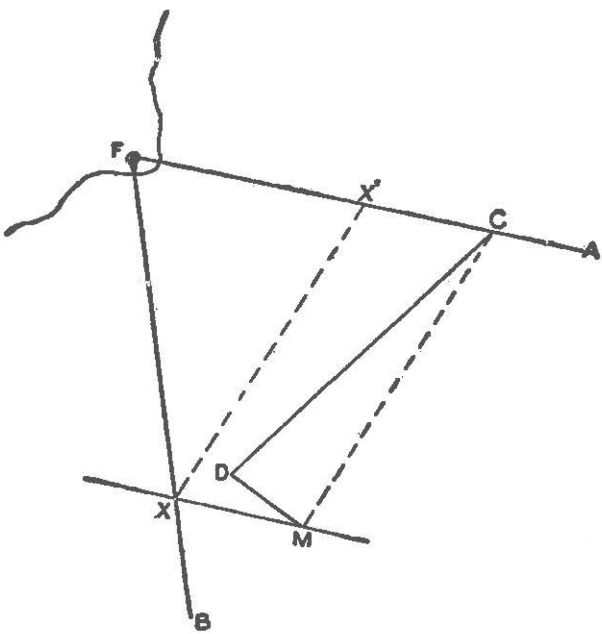


FIG. 5.12

In fig. 5.12, let F be the flagstaff, AF and BF the 1st and 2nd bearings, respectively. Lay off CD the course steered and distance steamed, i.e. 225° 6 miles, from any point on the 1st bearing.

At the end of this run lay off DM the current experienced between the bearings, i.e. 125° $1\frac{1}{2}$ miles. Then through M the end of the current draw a line parallel to the 1st bearing; where it cuts the 2nd bearing in X is the ship's position. Now since CD is the course steered and distance steamed and *DM* the current experienced between the bearings, then *CM* is the course made good. From the position on the 2nd bearing draw a line parallel to the course made good; where this cuts the 1st bearing in *X'* is the ship's position at the time of taking that bearing.

Example—From a vessel steering South at 10 knots through a current setting South at 2 knots a point of land bore S.E. and 36 minutes later it bore N.E. Find the ship's position at the time of taking the 1st bearing.

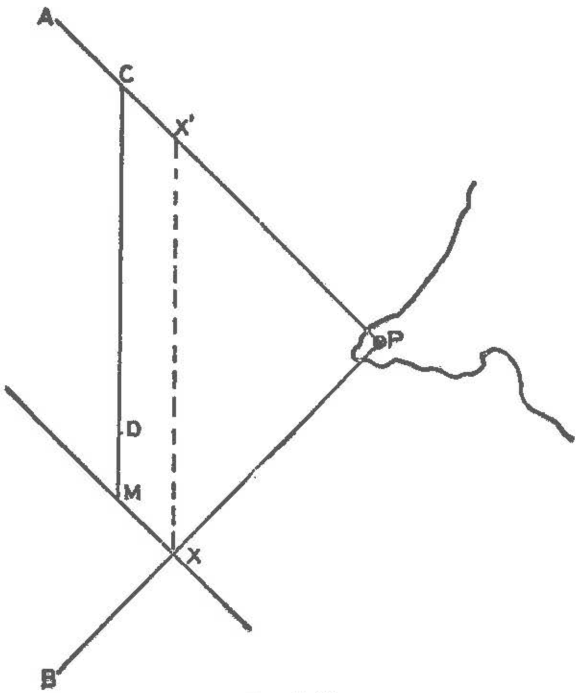


FIG. 5.13

In fig. 5.13, let *P* be the point of land, *AP* the 1st bearing and *BP* the 2nd. From any point on *PA* lay off *CD* the course steered and distance steamed between the bearings, i.e. South 6 miles. At the end of this run lay off *DM* the current experienced between the bearings, i.e. South 1·2 miles. Through *M* draw a line parallel to the 1st bearing; where it cuts the 2nd bearing in *X* is the ship's position on the 2nd bearing. Now since *CD* is the course steered and distance steamed and *DM* the current experienced between the bearings, *CM* is the course made good. By drawing a line parallel to *CM* through the position on the 2nd bearing we get the position on the 1st bearing at *X'*.

ANOTHER METHOD

The position at the time of taking the 1st bearing may also be found as follows. From any point on the 2nd bearing lay off the course steered and distance steamed, and current experienced between the bearings, reversed, then by drawing a line parallel to the 2nd bearing through the end of the reversed current the position on the 1st bearing is found.

Example—From a vessel steering 110° at 12 knots at 1 p.m. a lighthouse was observed to bear 056°. At 1.20 p.m. it was 4 points abaft the beam, the current was known to set S. by W. at 3 knots. Find the position of the vessel when the 1st bearing was taken.

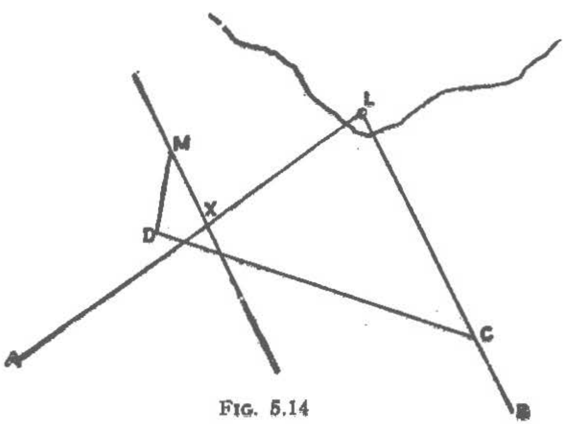


FIG. 5.14

In fig. 5.14, let *L* be the lighthouse, *AL* and *BL* the 1st and 2nd bearings, respectively.

From any point on *BL* lay off *CD* the vessel's course and distance steamed reversed, i.e. 290° 4 miles. Then from *D* lay off *DM* the current reversed, i.e. N. by E. 1 mile.

Through *M* draw a line parallel to *BL*; where this cuts the 1st bearing in *X* is the position of the vessel when this bearing was taken.

LEEWAY IN RUNNING FIXES

Frequently a wind direction and an amount of leeway is included in a running fix-type question. The notes on 'leeway' in Chapter IV should be applied. An example of a typical question follows.

A vessel steering 180° T. at 10 knots through a current setting 260° T. at 3 knots observes lighthouse 'L' to bear 240° T. Half an hour later the lighthouse bears 300° T. Allowing for 10° of leeway due to a strong W'ly wind, find the course and speed made good and the position of the vessel from the lighthouse on the second bearing.

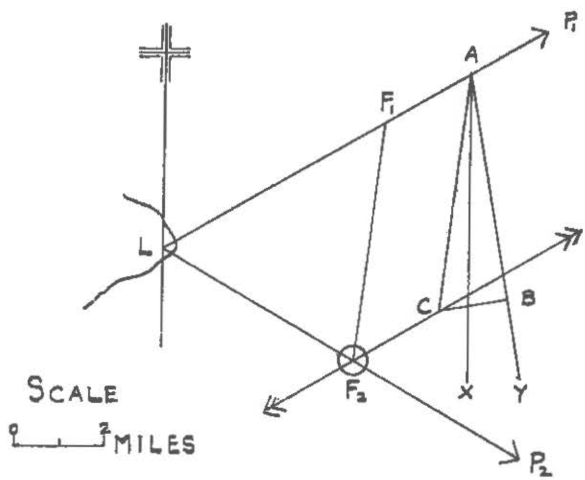


FIG. 5.15

Method:

(1) Lay off the first bearing LP_1, and on it select any point A.

(2) Draw in the course steered AX and measure from it the angle of leeway, giving the leeway course AY.

Therefore:—$AX = 180°$ T. $\angle XAY = 10°$. $AY = 170°$ T.

Sometimes the line AX is not shown on the chart, the leeway calculation being done mentally and the line AY is then laid off only.

(3) Along AY, measure AB equal to 5 miles (half an hour's steaming).

(4) From B lay off BC the current for half an hour. i.e. $BC = 260°$ T. $1\frac{1}{2}$ miles.

(5) Join A and C. The direction and length of AC give the course made good and the distance made good in half an hour.

(6) Through C transfer the first position line LP_1.

(7) Draw in the second position line $LP_2 = 300°$ T. Where LP_1 (transferred) and LP_2 cut is the position of the ship on the second bearing. (F_2).

(8) Draw $F_2\ F_1$ parallel to AC, then F_1 will be the spot where the ship really was on the first bearing.

(9) From the figure, $AC = 187°$ T.– 5·25 mls.

$$LF_2 = 120° \text{ T.—4·85 mls.}$$

Therefore course and speed made good $=187°$ T. 10·5 knots. Position of the vessel from the lighthouse on the second bearing $= 120°$ T. 4·85 miles.

PARTICULAR TYPES OF RUNNING FIX

Particular types of running fix extensively used are:—

Doubling angle on the bow.
Four-point bearing.
Distance run equals distance ship will pass off object when abeam.

DOUBLING ANGLE ON THE BOW

Note the time, or log reading, when the object is a certain number of degrees on the bow, and again when the object's angle on the bow is double the first. The distance run in the interval is the distance off the object at the instant of taking the second observation.

In fig. 5.16, let L be the object; SC the ship's course; AL the first bearing; BL the second bearing. Suppose $\angle CAL = \theta$, then $\angle CBL = 2\theta$, $\angle CBL - \angle CAL = 2\theta - \theta = \theta = \angle BLA$. $\triangle ABL$

is therefore isosceles, so that $BL = AB$, i.e. the distance off at the second bearing is equal to the distance run between the bearings.

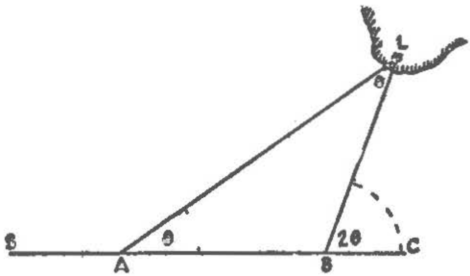


FIG. 5.16

FOUR-POINT BEARING

The reading of the log, or time, is noted when the object is four points on the bow and again when it is abeam. The distance run in the interval is the distance off the object when abeam.

DISTANCE RUN IS THE DISTANCE SHIP WILL PASS OFF THE OBJECT WHEN ABEAM

It is often desirable to know the distance a vessel will pass abeam of an object before it is bearing abeam. This is accomplished by adjusting the angle on the bow of the first and second bearings, so that the distance run between the bearings will be equal to the distance off when the object is abeam.

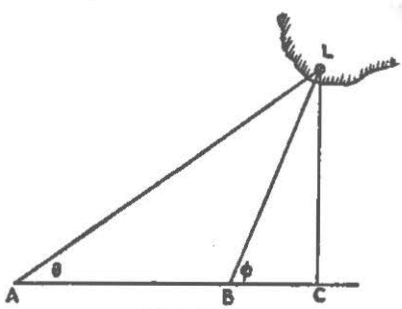


FIG. 5.17

In fig. 5.17, let L be the object, AL and BL the first and second bearings, respectively; AC the ship's course and CL the beam bearing. Let the first angle on the bow $\angle CAL = \theta$, and the second $\angle CBL = \emptyset$.

Given that $AB = CL$

In $\triangle LCA$ $\dfrac{AB+BC}{CL} = \cot\theta$

In $\triangle LCB$, $\dfrac{BC}{CL} = \cot\emptyset$

$$\therefore \frac{AB+BC}{CL} - \frac{BC}{CL} = \cot\theta - \cot\emptyset$$

$$\therefore \frac{AB}{CL} = \cot\theta - \cot\emptyset, \text{ but } AB = CL$$

$$\therefore 1 = \cot\theta - \cot\emptyset.$$

Hence, in order that the distance run between the first and second bearings will be equal to the distance off the object when abeam, the difference between the cotangents of the first and second angles on the bow must be unity.

Consulting a table of natural cotangents, many pairs of angles will be found to comply with the above equation. The most suitable are 35° and 67°, whose cotangents are 1·428 and ·425, respectively. The first angle is not too fine on the bow, and the second not too broad before the distance is known which the vessel will pass off the object when abeam. Another pair of suitable angles are 37° and 72°

Examination questions sometimes adapt the foregoing principle in reverse, so to speak. Two angles on the bow are given with a distance run in between and the candidate could never know whether these were 'special angles' unless he consulted a table of natural cotangents.

Problems of this type can always be done by assuming a course and employing the principle of the ordinary running fix, as described earlier in this chapter. This gives the position on the second bearing, from which spot the course is run up to the beam bearing and the distance off measured. It is however worth looking to see whether $\cot\theta - \cot\emptyset$ does in fact equal unity.

It is to be noted that the three methods described above can only be employed when the vessel is making good the course steered and distance made good is known.

COCKED HAT

If three or more bearings are taken of shore objects, instead of two as described up until now, the additional bearings should provide further checks on the ship's position. In practice, however, this often means that doubt is cast on the fix because the position lines do not intersect at one point. For instance, when three bearings are laid off, a small 'cocked hat' is frequently encountered.

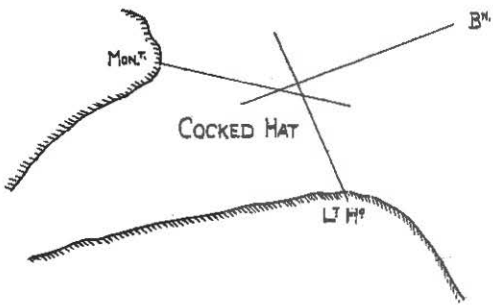


FIG. 5.18

The existence of a cocked hat may be attributed to one or more of several factors, of which perhaps the most likely to be met with in day-to-day routine is that of an incorrect compass error or a compass error wrongly applied. It need hardly be stressed that to know the compass error accurately at all times is of the greatest importance and this applies equally to magnetic and gyro-compasses.

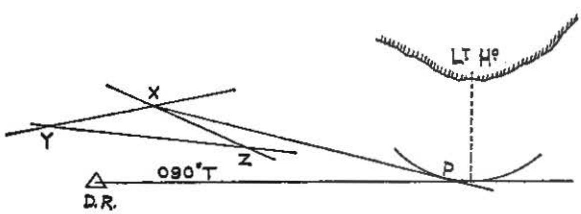


FIG. 5.19

If the cocked hat is small (as in Fig. 5.18) the ship's position is generally taken as the centre. If the cocked hat is large then the bearings should be regarded as inaccurate and unreliable and the reasons sought out. If repeated bearings still give a large cocked hat or if there is no time to check the bearings, assume the vessel to be in the part of the cocked hat which puts her in greatest danger, e.g. a vessel steering due East to round the lighthouse as shown (Fig. 5.19.)

Assume the vessel to be at *X* and alter course to head in the direction *XP*.

Many other examples could be devised and of course the position lines need not be bearings of shore objects. The principle holds good with astronomical position lines and with position lines obtained from radio aids to navigation. In the case of astronomical position lines inaccuracies in observations are the most likely cause of errors; in the case of radio aids the reasons may differ with each aid.

The notes and sketches on cocked hats should be compared with those on The Diamond of Error, in Chapter XII.

DEAD RECKONING POSITION AND ESTIMATED POSITION

In still water a vessel will *make good* the course she is steering, since the only force acting is her motive power. In coastal waters where tidal streams are experienced, or localities where currents exist, an external force acts upon the vessel and impels her to move in the direction of the moving water.

Thus the vessel has two velocities, and, depending upon the direction in which the body of water is moving, relative to her fore and aft line in which the propulsive force acts, the course made good may differ considerably from the course steered.

Fig. 5.20 shows a vessel steering in the direction *AF*, through a current, or tidal stream, setting in the direction *ab* and making good the course *BC*.

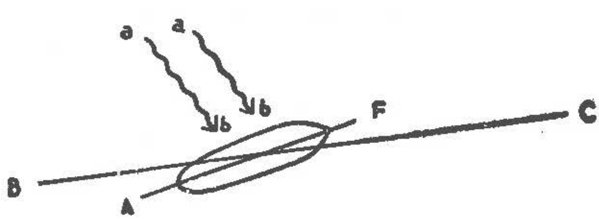


FIG. 5.20

It is necessary frequently to check the set and drift being experienced. This can be done if the departure position is known and a fix obtained some time later, the difference between the dead reckoning position and fixed position being the set and drift.

The Dead Reckoning Position (D.R.) is the position arrived at after steering any course for a number of miles by log, or by engine revolutions after allowing for slip. That is, the D.R. position is the position obtained from the course steered by the ship and her speed through the water and from no other factors.

In fig. 5.21, let A be the point of departure, AB the course steered and distance steamed by log. Then B is the dead reckoning position or D.R. position.

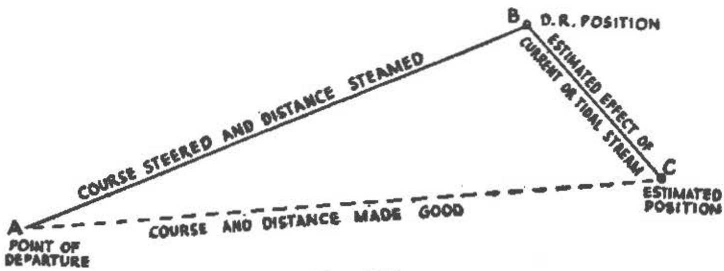


FIG. 5.21

If from the D.R. position BC is laid off as the *estimated effect* of current, tidal stream or weather conditions, then C is the estimated position, and AC the estimated course made good. Thus although the vessel left position A heading in the direction AB, it is *estimated* the vessel is at C on account of the set and drift experienced during the run.

If the vessel is making leeway then an allowance for this must be included in arriving at the estimated position.

As stated, in deducing the D.R. position it is the speed made good through the water with which we deal. In arriving at this speed, the ship's speed may be increased or decreased by the force of wind and sea but no account must be taken of leeway.

The situation in fig. 5.21 would be changed if the vessel therein depicted was steering through a strong northerly wind causing her to make leeway. Then the diagram would become as fig. 5.22.

To arrive at the estimated position the effect of leeway and drift must be taken into account.

By definition, X becomes the D.R. position.

B might be said to be the D.R. position adjusted for leewav and $AX = AB$.

C is the Estimated Position (E.P.) as before.

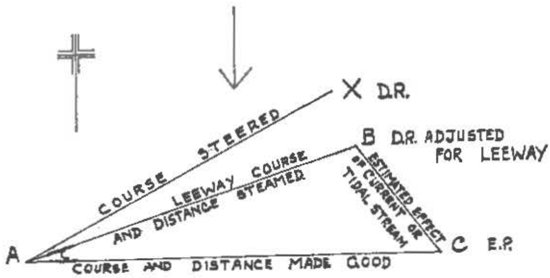


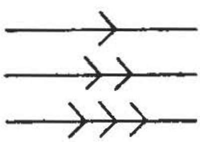
FIG. 5.22

Set is usually expressed true and denotes the direction in which the vessel has been moved by the force of current or tidal stream. Drift is given in miles.

As explained in Chapter IV, leeway is usually expressed as an angle (that is, so-many-degrees) but occasionally it may be quoted as a direction and distance in a similar manner to set and drift.

It could be noted at this point that the various courses referred to in this chapter are often marked by arrows as a means of ready identification.

The convention adopted is:—



Course steered

Course made good.

Current or tidal stream.

Fig. 5.21 laid off with these markings would appear as shown in fig. 5.23.

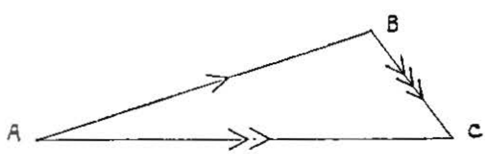


FIG. 5.23

Fig. 5.22 laid off with these markings would appear as shown in fig. 5.24.

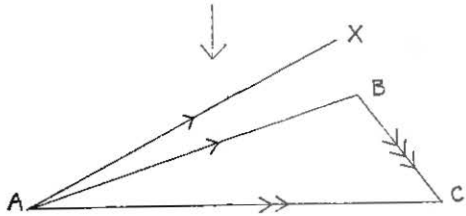


FIG. 5.24

ON FINDING THE SET AND DRIFT OF A CURRENT

It is now proposed to explain the method of finding the set and drift when the position of the vessel has already been found by cross bearings. If the position is known by observation and the dead reckoning position can be found, the difference between the latter and the former position is obviously the direction and distance the vessel has been set.

Example—A vessel left position *A*, steering 130° T. at 10 knots. After she had continued on this course for 1 hour and 24 minutes cross bearings were taken and the position of the vessel found.

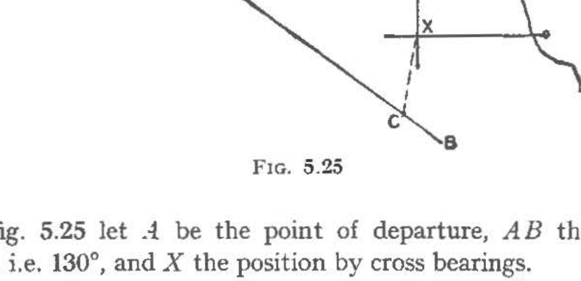


FIG. 5.25

In fig. 5.25 let *A* be the point of departure, *AB* the course steered, i.e. 130°, and *X* the position by cross bearings.

Now, since the vessel has been on the course for 1 hour and 24 minutes, measure on AB, AC equal to 14 miles, then C is the dead reckoning position of the vessel. And since X is the position by observation then CX is the set and drift experienced during the run.

TO FIND THE SET AND DRIFT WHEN A VESSEL IS STEERING A COURSE TO COUNTERACT AN ESTIMATED CURRENT AFTER HER POSITION HAS BEEN FOUND BY OBSERVATION

Example—A vessel steaming 10 knots left a position A to make position B, steering a course to counteract a current estimated to set 310° T. at 2 knots. When the log showed 15½ miles her position was found by cross bearings to be at X. Find the actual set and drift of the current.

In fig. 5.26, let A be the point of departure and B her destination From A lay off AC equal to one hour's current, then with a distance of 10 miles in the dividers and with centre C cut AB in D, then CD is the course to steer to counteract the *estimated current.*

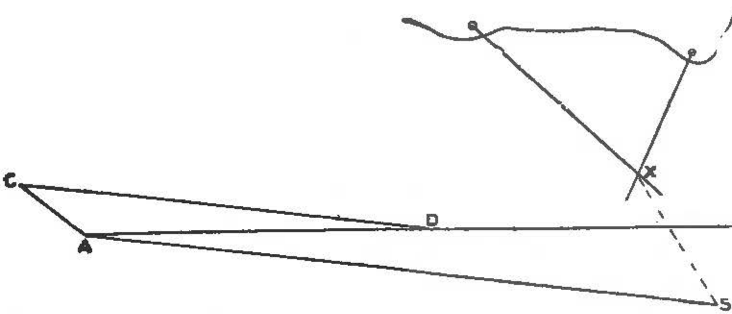


FIG. 5.26

X being the position of the vessel by observation, it is clear that the vessel has not experienced the current which was estimated, otherwise her position would have been on the line AB. In order, therefore, to find the actual current experienced find the vessel's position by dead reckoning. The difference between this position and the observed position is the set and drift experienced. From A, the point of departure, lay off the course the vessel is steering, which is AS, parallel to CD, and measure along this line the distance she has steamed by log, i.e. AS equal to 15½ miles.

Then S is the dead reckoning position of the vessel. Since X is the position by observation, then SX is the actual set and drift experienced during the time the vessel has taken to run 15½ miles by log.

Let us now repeat the foregoing example—the vessel now steering a course to counteract an estimated current and also leeway.

Repeating the example illustrated in fig. 5.26 but the vessel is also steering to counteract 5° of leeway due to a strong northerly wind.

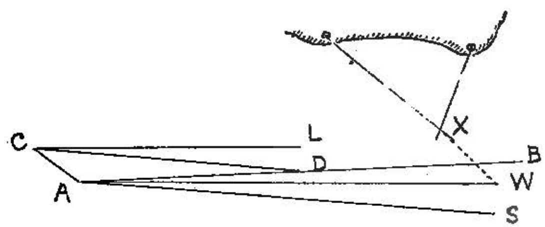


FIG. 5.27

W is the D.R. position.

S is the D.R. position adjusted for leeway.

Example—A vessel steaming 10 knots left a position A to make position B, steering a course to counteract a current estimated to set 310° T. at 2 knots and allowing for 5° leeway due to a strong northerly wind. When the log showed 15½ miles her position was found by cross bearings to be at X. Find the actual set and drift of the current.

The vessel must head up into the wind to counteract the leeway.

Here the vessel hopes to go along the line AB (fig. 5.27) heading in the direction CL and if current and leeway allowed are both correct this is what she will do. However, the course the vessel actually did make good was AX so the estimate of one or both of current and leeway must have been inaccurate.

By definition the D.R. position is W— and the D.R. position adjusted for leeway is S.

In the question we are clearly asked for the set and drift only and so in the absence of any other information it must be assumed that the allowance for leeway is correct and that had there been no set and drift the vessel would have been at *S*.

The line *SX* therefore remains the measure of the set and drift and so the solution to that part of the question is unchanged. The course to steer, however, is now along *CL* instead of *CD*.

Had the current and leeway both been wrongly estimated then it is interesting to note that the best we could have made of the question would have been to say that *WX* represents the displacement of the vessel's position due to the combined effects of current and leeway.

ABEAM AND NEAREST APPROACH

When a vessel is making good the course she is steering and there is no across-course current or wind effect the position when a point of land is abeam and the position when the vessel is at her nearest approach to the point of land will coincide.

If however there is any question of the vessel being carried off the course she is steering then the two occurrences will coincide neither in position nor in time. Two examples of 'abeam' and 'nearest approach' follow. In one case a vessel is steering a course to counteract a current; in the other case a vessel is taking a running fix.

Example 1—Position *B* is due north of position *A*. Find the course to steer to proceed from *A* to *B*, allowing for a tidal stream averaging 080° T., 3 knots and allowing for 7° of leeway due to a strong westerly wind. Vessel steaming 10 knots.

What would be the bearing and distance of the vessel from lighthouse *P* (Fig. 5.28)

(i) at the time of the beam bearing of *P* ?
(ii) at the time of the nearest approach to *P*?

If the vessel left *A* at 1000 hours when would each bearing occur?

METHOD—

(1) Lay off the course to steer to counteract the current and leeway, as described in Chapter IV. This is *CE* (Fig. 5.28) and is 335½° T.

AB is the course made good. The speed made good appears as *AD*, which is 10·1 knots.

(2) Lighthouse *P* will be abeam when the vessel is at *X*. The beam bearing is 065½°, which is 90° from *CE*.

$$335\tfrac{1}{2}^\circ + 90^\circ \text{ gives } 065\tfrac{1}{2}^\circ.$$

Position of beam bearing—*X* – 245½° T., 8·8 miles from *P*.

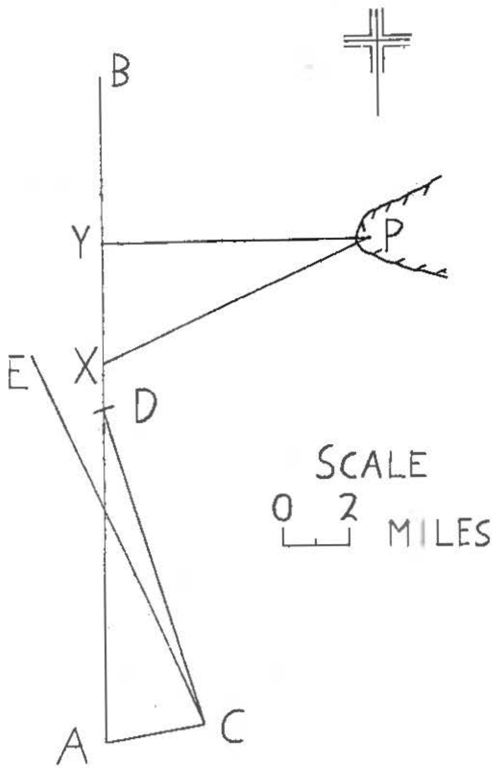


FIG. 5.28

(3) The nearest approach of the ship to lighthouse *P* will occur when the vessel is at *Y*. The bearing here is 090°, which is 90° from *AB*.

$$000^\circ + 90^\circ = 090^\circ$$

Position of nearest approach—*Y* – 270° T., 9·0 miles from *P*.

(4)

Dist. to X—11·4 miles	Dist. to Y—15 miles
Time to $X = \dfrac{\text{distance}}{\text{speed made good}}$	Time to $Y = \dfrac{\text{distance}}{\text{speed made good}}$
$= \dfrac{11{\cdot}4}{10{\cdot}1}$	$= \dfrac{15}{10{\cdot}1}$
$=$ 1·13 hours	$=$ 1·48 hours
$=$ 1 hour 8 minutes	$=$ 1 hour 29 minutes
Time of beam bearing—1108 hours	Time of nearest approach—1129 hours

Example 2—A vessel is steering 000° T. at 10 knots. Lighthouse *P* (Fig. 5·29) bore 3 points forward off the beam and after 1 hour 00 minutes it bore 3 points abaft the beam. Find the ship's position with relation to the lighthouse on the second bearing allowing for a current setting 340° T. at 4 knots and allowing for 7° of leeway due to a strong easterly wind.

What would be the bearing and distance of the vessel from lighthouse *P*

(i) at the time of the beam bearing of *P* ?

(ii) at the time of the nearest approach to *P* ?

METHOD—

(1) Lay off the two true bearings of the lighthouse.

First bearing		*Second bearing*	
True course	000° T.	True course	000° T.
Relative bearing	056°	Relative bearing	124°
True bearing	056° T.	True bearing	124° T.

(2) Select any point *C* (Fig. 5.29) on the first position line and complete a running fix as described in this chapter.

(3) The ship's position on the second bearing is at *B*, which is 304°, 13·9 miles from *P*.

The course and distance made good appear as *CD* (349½°).

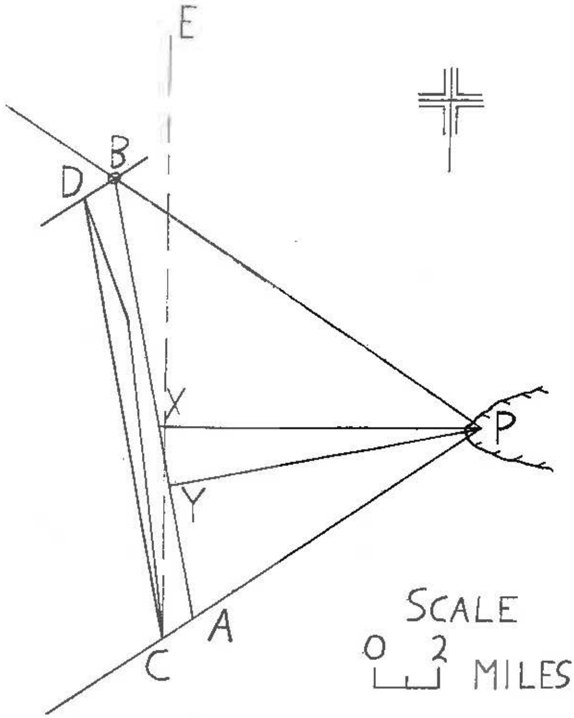


FIG. 5.29

The position on the first bearing is at *A*; *AB* being again the course and distance made good.

(4) Lighthouse *P* will be abeam when the vessel is at *X*. The beam bearing is 090°, which is 90° from *CE*, the course steered.

Position on beam bearing—*X*—270° T., 10·0 miles from *P*.

(5) The nearest approach of the ship to lighthouse *P* will occur when the vessel is at *Y*.

The bearing here is 079½°, which is 90° from *AB* (or *CD*), the course made good.

$$349\tfrac{1}{2}° + 90° \text{ gives } 079\tfrac{1}{2}°.$$

Position on nearest approach—*Y*—259½° T., 9·9 miles from *P*.

CHAPTER VI

DANGER ANGLE

CIRCUMSTANCES occasionally arise when it is necessary to pass close to a submerged danger, and certain measures which take the form of horizontal or vertical danger angles are adopted to ensure the safety of the vessel.

HORIZONTAL DANGER ANGLE

Choose two conspicuous objects on the chart, if possible equidistant from the danger, and draw a circle through these objects and the point at which the vessel requires to pass the danger.

From any point on the circumference of this circle draw lines to the conspicuous objects. The angle contained between these lines is the danger angle.

Example—Suppose a vessel requires to pass a rock *R* one mile off, find the angle to set on the sextant subtended by the objects *A* and *B* on the shore.

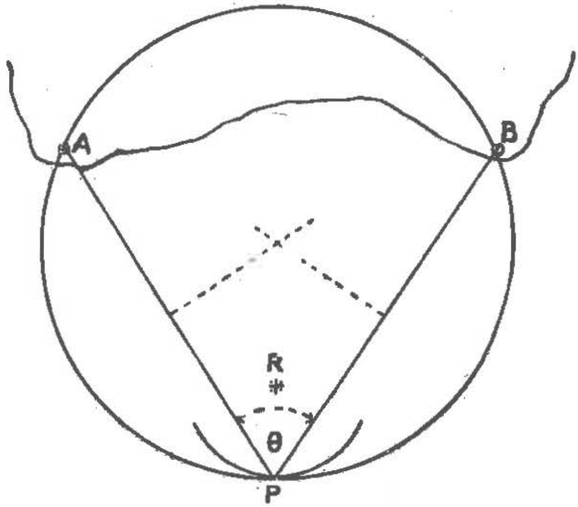


FIG. 6.1

In fig. 6.1, let A and B be the objects and R the rock. With a radius of one mile and centre R describe an arc of a circle. Now draw a circle through A and B and just touching the small arc already drawn in. From the point of contact P draw lines to the objects A and B, and the angle contained between these lines is the angle to set on the sextant and can be measured with the aid of parallel rules.

If this angle on the sextant is maintained the vessel will pass the required distance off the rock. If it becomes less she will pass further off, and if greater nearer to the danger than one mile.

VERTICAL DANGER ANGLE

In fig. 6.2, suppose a ship at position X wishes to pass rock R at a safe distance of, say, one mile. Find the vertical angle subtended by the lighthouse at the given distance off, so that the vessel may pass the rock in safety.

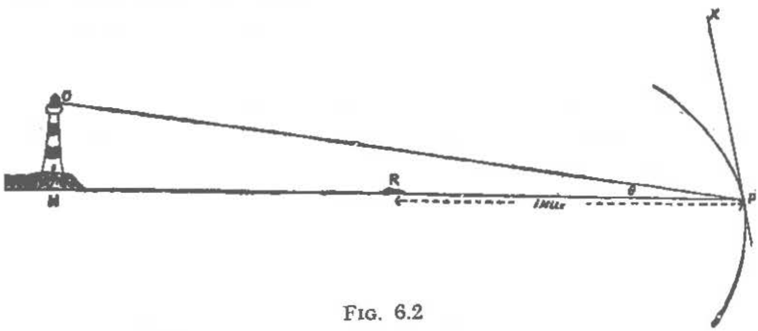


FIG. 6.2

With centre R and radius one mile describe an arc of a circle. Draw XP a tangent to this arc. Join P to H and to O, then the angle HPO is the required angle. This angle, which is the angle of elevation of the lighthouse, is given by the formula:—

$$\text{Tangent of angle} = \frac{\text{Height of lighthouse}}{\text{Distance } HP}$$

Both height and distance naturally being quoted in the same terms, that is, both in feet, both metres, both miles.

NOTE—The height of a light as listed in the Admiralty List of Lights or as printed on the chart is the height of the centre of the lantern above the level of Mean High Water Springs or Mean Higher High Water, whichever is given (for the locality) in the Admiralty Tide Tables. In places where there is no appreciable tide the height is that above sea-level.

Thus in tidal waters the charted height of a lighthouse must be corrected for the difference in the height of the tide at the time of observation and the height of Mean High Water Springs or Mean Higher High Water.

The vertical angle then measured is that between the centre of the lantern and the surface of the sea.

The following methods are very useful for finding (*a*) the distance off an object the height of which is known, the angle of elevation being found by the sextant; and (*b*) the vertical danger angle, the distance it is required to pass off the object being measured from the chart.

It is especially suited to those who do not have a copy of Nautical Tables at hand.

Example—The elevation of the top of a lighthouse 110 feet above sea-level is observed to be 40′; find the distance the observer is off the lighthouse.

In fig. 6.3, let the arc BD be equal to the radius AB then the angle BAD is a radian.

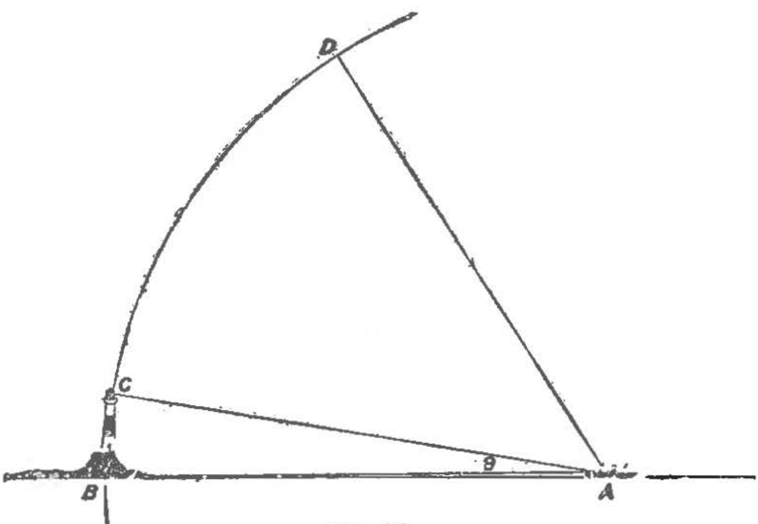


FIG. 6.3

The value of a radian in sexagesimal measure is 57° 17′ 45″ correct to the nearest second.

Radius AB = the arc BD = 57° 18′ = 3438′

$$\frac{\text{Arc } BD}{\text{Arc } BC} = \frac{\text{radius } AB}{\text{chord } BC} = \frac{\angle BAD}{\angle BAC} \quad \text{when } \theta \text{ is small}$$

$$\frac{AB}{BC} = \frac{57^\circ\ 18'}{\theta}$$

$$AB \text{ in feet} = \frac{BC \text{ in feet} \times 3438'}{\theta}$$

$$AB \text{ in miles} = \frac{BC \text{ in feet} \times 3438'}{\theta \text{ in mins.} \times 6076{\cdot}1}$$

$$AB \text{ in miles} = \frac{BC \text{ in feet}}{\theta \text{ in mins.}} \times \frac{3438}{6076{\cdot}1}$$

$$AB \text{ in miles} = \frac{\text{Height of object in feet}}{\text{Angle of elevation in mins.}} \times {\cdot}565$$

$$AB \text{ in miles} = \frac{110}{40} \times {\cdot}565$$

$$AB \text{ in miles} = 2{\cdot}75 \times {\cdot}565$$

$$AB = 1{\cdot}55 \text{ miles}$$

NOTE—See Appendix, page 352.

Conversely to the above, the vertical danger angle can be found by transposition, the distance it is required to pass off the object being measured from the chart.

$$\text{Since } AB \text{ in miles} = \frac{\text{Height of object in feet}}{\text{Angle of elevation in mins.}} \times {\cdot}565$$

$$\text{Angle of elevation in mins.} = \frac{\text{Height of object in feet}}{AB \text{ in miles}} \times {\cdot}565$$

$$\text{Angle of elevation in mins.} = \frac{110 \times {\cdot}565}{1{\cdot}55} = \frac{62{\cdot}15}{1{\cdot}55}$$

$$\text{Angle of elevation in mins.} = 40'$$

POSITION BY BEARING AND VERTICAL ANGLE

Bearing and distance is a handy method of obtaining a fix. The bearing of a suitable object is taken by compass and, at the same instant, its vertical angle is measured by the sextant.

The bearing laid off on the chart gives a position line, and the distance off the object measured along the bearing marks the position. The distance off can be calculated by either of the methods described in this chapter.

NOTE—When transferring the position from one chart to another, it should be done by bearing and distance, choosing an object common to both charts.

EFFECT OF 'HEIGHT OF EYE'

It is customary to ignore the observer's height of eye when taking vertical sextant angles, unless in exceptional circumstances.

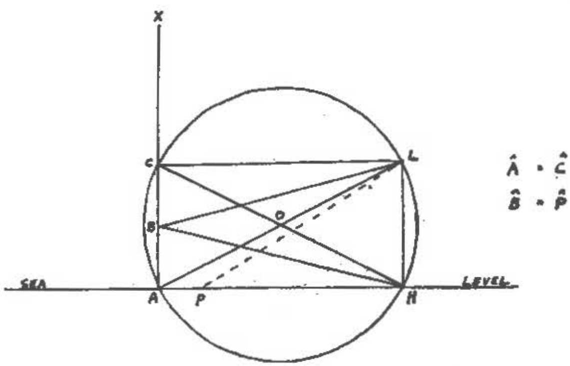


FIG. 6.4

LH is the lighthouse.
AH the distance off.
AX the line of possible positions for the observer's eye.

It will be seen from the figure that as long as the observer's eye is at a height less than that of the lantern, too large an angle is measured, the ship appears to be closer to the lighthouse than she actually is and a margin of safety is given.

In any case, unless in some craft very close inshore, the distance off will far exceed the other dimensions and the differences in the various angles will be negligible.

POSITION BY BEARING AND HORIZONTAL ANGLE

A particular case where bearing and angle form a convenient method of fixing the ship's position arises in the case of a small island whose length can be measured on the chart.

The horizontal angle subtended by the length of the island should be observed by a sextant and at the same time take the bearing of one end of the island. The distance off can be calculated by adjusting the formula given on page 114, thence the position found by plotting bearing and distance.

Example—The horizontal angle subtended by the length of an island 1·5 miles long is 17° 30′, and the east end bears N. 10° E. Find the distance off in miles.

$$\text{Distance off in miles} = \frac{1{\cdot}5 \times 3438}{1050}$$

$$= 5 \text{ miles (approx.)}$$

This gives International nautical miles or U.K. nautical miles as the case may be.

Position of vessel is S. 10° W. 5 miles, from east end of island.

TO FIND THE MAXIMUM HORIZONTAL ANGLE SUBTENDED BY TWO POINTS—SHIP MAKING HER COURSE

In fig. 6.5, let *SC* represent the ship's course as laid off on the chart; *A* and *B* two prominent objects. Join *A* to *B*. Bisect the line *AB* and through the point obtained draw *DE* perpendicular to *AB*. On *DE* find the centre of a circle passing through *A* and *B* and just touching the course line. *F* is the required point.

With centre *F* and radius *FA* describe the circle. The angle contained in the seaward segment of the circle is the required angle.

The position on the course line when the objects subtend their maximum angle may be found as follows:—

SC, the ship's course, is a tangent to the circle, and hence the point of contact is found by drawing through *F*, the centre of the circle, a line perpendicular to *SC*. It is *FG*. Angle *AGB* is the maximum horizontal angle which may be measured by a protractor.

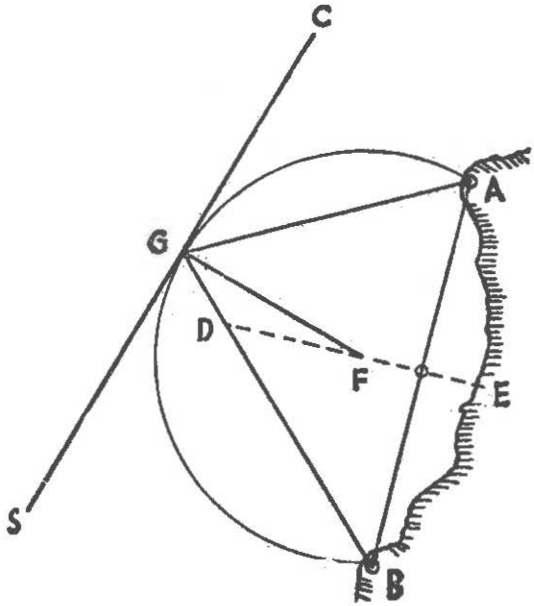


Fig. 6.5

FIXING SHIP'S POSITION BY HORIZONTAL ANGLES

A very accurate and convenient method of fixing a vessel's position is by means of horizontal angles subtended by objects on shore. Three suitable objects are chosen from the chart, the angle at the observer contained between the left-hand and middle objects is measured with a sextant, and at the same time a second observer measures the angle contained between the right-hand and middle objects.

In fig. 6.6, suppose *A*, *B* and *C* to be the objects.

Measure the angle between *A* and *B* and suppose it to be equal to 50° and the angle between *B* and *C* equal to 56°. Join *A* to *B* and *B* to *C*.

It is now necessary to draw through *A* and *B* a circle, one segment of which contains the observed angle. This is accomplished as follows:—At *A* and *B*, with the aid of a protractor, or by construction, lay off the complement of the observed angle, in this case 40°

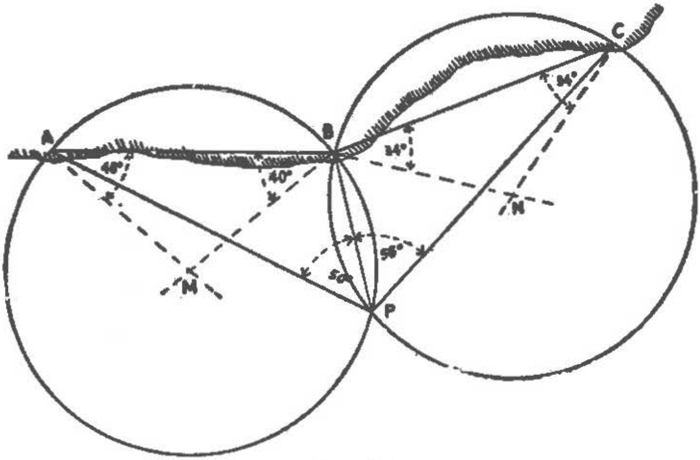


FIG. 6.6

on the same side of AB as the observer. The two lines will intersect in M. With centre M and radius MA describe a circle.

Now $\angle AMB = 180° - (40° + 40°) = 100°$, which is twice the observed angle, and bearing in mind the angle at the centre of a circle is twice the angle at the circumference when both angles stand on the same arc it follows that the observer is situated somewhere on the circle.

In a like manner a circle is drawn through B and C, whose segment on the same side of BC as the observer contains an angle of 56°. The observer must be somewhere on the circumference of this circle; therefore, in order to be on the circumference of both circles, he must be at P, their point of intersection.

It may happen that one of the observed angles exceeds 90°. In this case lay off on the opposite side to that of the observer the complement of the observed angle. Where the two lines cut will be the centre of the required circle.

The above observations would be written down in the following manner:

$$A\ 50°\ B\ 56°\ C$$

which signifies that A is to the left of B and C to the right of B; or in other words, A is the left-hand object, B the middle, and C the right-hand object. Particular note should be taken of the method of writing down and of reading these angles.

In order to avoid a bad fix, choose objects so that—

(*a*) the ship and centre object are on the same side of a line joining the other two objects; or

(*b*) the ship is inside the triangle formed by joining the positions of the objects.

No fix will be obtained if a circle passes through the three objects and the ship. (*See* fig. 6.7).

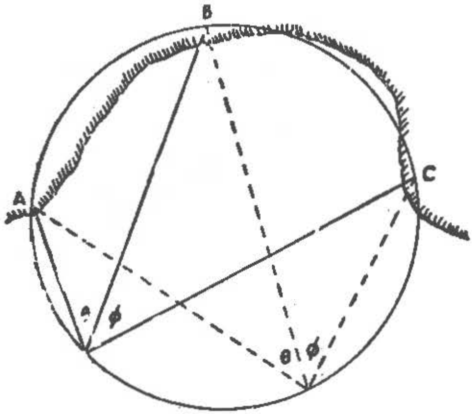


Fig. 6.7

It is, however, not usual to draw the above circles on the chart, the observed angles being laid off and the position found by means of a station pointer.

STATION POINTER

A station pointer is a circular disc graduated in degrees from zero to 180° on either side of zero and with three legs having bevelled edges radiating from the centre of the disc. One leg is fixed with its bevelled edge at the zero of the graduations and is known as the middle leg. The other two legs, called the right and left legs, are free to revolve about the centre of the disc, one on either side of the fixed leg. These movable legs can be clamped by means of a small screw at any particular degree of the graduations which will show the inclination of the bevelled edge of the movable leg to the bevelled edge of the fixed leg.

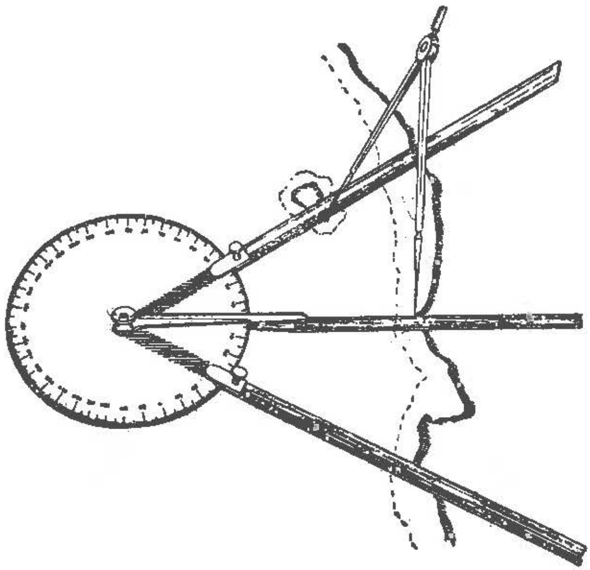


FIG. 6.8

Fig. 6.8 illustrates a station pointer and method of use.

To use the station pointer—

The fixed leg represents the middle object. Clamp the right leg at the observed angle between the middle and right-hand objects, then clamp the left leg at the observed angle between the middle and left-hand objects. Place the instrument on the chart with the bevelled edges of two legs passing through the centres of their respective objects. Then carefully move it until the bevelled edge of the third leg passes through the centre of the third object.

The centre of the disc will be the position of the observer which can be marked with a pencil. As before mentioned, the angles are measured with a sextant, the objects being assumed to be in the same horizontal plane as the observer.

The angles may, however, be observed by compass bearings of three objects. The position of the vessel can then be found by station pointer.

In fig. 6.6, suppose *A* bore by compass 315° C., *B* 005° C., and *C* 061° C. From these bearings the angle contained between *A* and B equals 50°, and that between B and C 56°, which should be written down as follows—

$$A\ 50°\ B\ 56°\ C$$

and the position found by station pointer in the manner previously explained. It will be noted that in finding the angles contained between the objects the deviation for the direction of the ship's head was not taken into account. It is not necessary to do so providing the ship's head is kept in the same direction while all the bearings are observed, because the same deviation, or error of the compass, would be applied to each of the bearings in order to turn them into magnetic or true bearings, hence the angles would be the same as those already found.

For those who cannot obtain the use of a station pointer to plot positions given by horizontal angles, it should be observed that the position can be found by construction in the manner already shown or by making use of the following device.

Procure a piece of tissue or transparent paper and on it lay off a line to represent the centre leg of a station pointer. On this line make a dot, and from the dot draw lines to the left and right of the line already drawn making angles with it equal to the given angles between the left and middle and middle and right-hand objects respectively. Place the paper on the chart and carefully move in until the lines pass through their respective objects.

The intersection of the lines will be the required position which can be pricked on the chart.

When the objects used for the angles are very near the observer the use of the transparent paper method is preferable to the use of a station pointer since the disc of the instrument to a certain extent hides the objects.

Fig. 6.8 illustrates a practical method of manoeuvring the station pointer.

The points of the dividers are placed on the left-hand and middle objects—care being taken not to pierce the chart—and held in position with the left hand. The bevelled edges of the left and middle legs of the station pointer which have already been set at the given angle are brought to bear against the legs of the dividers and the instrument manoeuvred with the right-hand until the bevelled edge of the right leg passes through the right-hand object. The centre of the disc gives the position of the vessel.

It may happen that the object selected will be covered by the disc and consequently the above method cannot be employed. The position can, however, be quickly found by placing the left and middle legs of the station pointer over their respective objects and inserting the forefinger and thumb against the bevelled edges of these legs, and carefully moving the instrument until the bevelled edge of the remaining leg passes through the object.

The use of a station pointer in finding a course to steer to make a point of land a given number of degrees on the bow and a given distance off is referred to in Chapter IV.

CHAPTER VII

TACTICAL PROBLEMS

TACTICAL problems concern the movement of one vessel in relation to another. For instance, one vessel may be required to intercept another whose course and speed are known; or an escort may be ordered to increase speed to take up a new station, and it is desired to know the course to steer and time occupied in carrying out the manoeuvre. Such problems are capable of a graphic solution involving the principle of relative velocity.

The method employed is as follows:—The positions of the vessels with respect to each other are plotted on the chart. An imaginary current is introduced, the velocity of which is equal to one vessel's speed and direction opposite to her course. This vessel is now considered stationary. The manoeuvring vessel then finds the course to steer to reach the other vessel, or take station with respect to her, counteracting the imaginary current.

It will be apparent that since the imaginary current affects both vessels to the same extent, we may, after the course has been found, disregard the current and the course found will be that required.

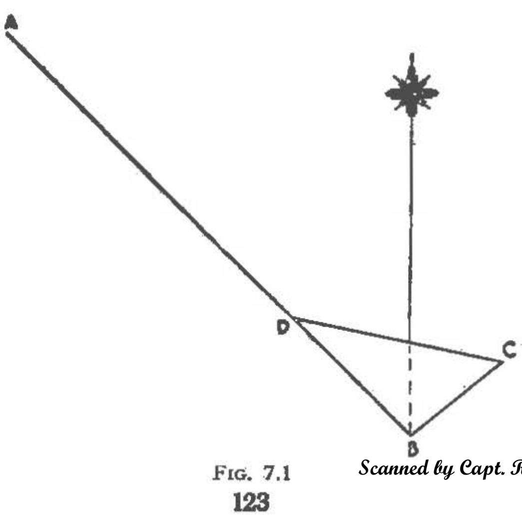


FIG. 7.1

In fig. 7.1, let *A* be a vessel steering S. 50° W. at 8 knots. Vessel *B* 40 miles S.E. of *A* has a maximum speed of 15 knots and wishes to intercept *A*. It is required to find the course for *B* to steer.

Suppose a current to set N. 50° E. at 8 knots, then *A* may be considered to be stationary and *B* merely requires to steer a course counteracting the supposed current in order to intercept *A*. Join *B* to *A*. From *B* lay *BC*, N. 50° E. 8 miles. With 15 miles in the dividers (*B*'s maximum speed) and centre *C*, cut *BA* in *D*. Join *C* to *D*. Then *CD* is the course to steer, and the distance *BD* will be made good by *B* towards *A* in one hour. It is 12 miles.

The time *B* will take to intercept *A* may now be found by proportion—

$$\frac{\text{Required time in mins.}}{60 \text{ mins.}} = \frac{40}{12}$$

$$\therefore \text{Required time} = \frac{60 \times 40}{12}$$

$$= 200 \text{ mins. or 3 hours 20 minutes}$$

Example—An escorting vessel stationed 2 miles on the starboard quarter of a convoy is instructed to increase speed to 12 knots and take station 2 miles on the convoy's port beam; convoy steaming North at 8 knots.

In fig. 7.2, let *A* represent the convoy and *B* the escorting vessel 2 miles on *A*'s starboard quarter.

Suppose a current to set South at 8 knots. Then *A*, the convoy, is stationary. *C* is a position 2 miles on *A*'s port beam. Join *B* to *C*. This is the course *B* must make good counteracting the imaginary current setting South at 8 knots. From *B* draw *BD* South 8 miles. With centre *D* and radius 12 miles, *B*'s increased speed, cut *BC* produced in *E*. *DE* is the required course. *BE* the distance made good in one hour.

To find the time taken to reach new position.

By measurement *BC* is 3·75 miles and *BE* 6·4 miles.

$$\therefore \frac{\text{Required time in mins.}}{60} = \frac{3{\cdot}75}{6{\cdot}4}$$

$$\therefore \text{Required time} = \frac{60 \times 3{\cdot}75}{6{\cdot}4} \text{ mins.}$$

$$= 35 \text{ mins.}$$

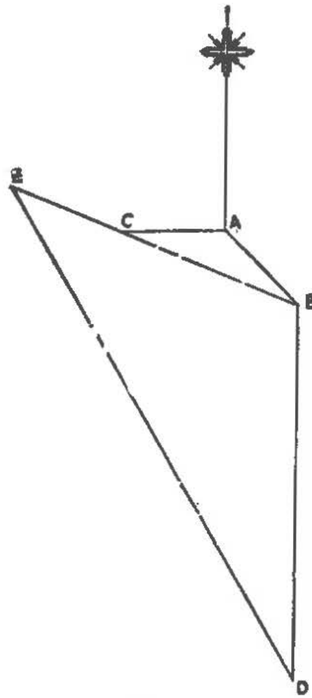


Fig. 7.2

TO FIND THE COURSE MADE GOOD FROM THREE BEARINGS OF THE SAME OBJECT—THE TIME OR DISTANCE RUN BETWEEN THE BEARINGS BEING KNOWN

In coastal navigation it is important to know the course which the vessel is *making good* over the ground.

This information may be obtained by means of the 'Three-Bearing Problem', so termed throughout this book, which presents a convenient and accurate method of obtaining the course the vessel is making good over the ground, provided the vessel is kept on one course at a uniform speed, and the various factors which contribute to the making good of a course remain constant.

It is only necessary to observe three bearings of one object and note the interval of time, or distance steamed by log, between the instants of taking the bearings.

The course may be found by calculation or by graphic method on the chart.

The principle involved is that of three parallel straight lines being cut by any two other lines.

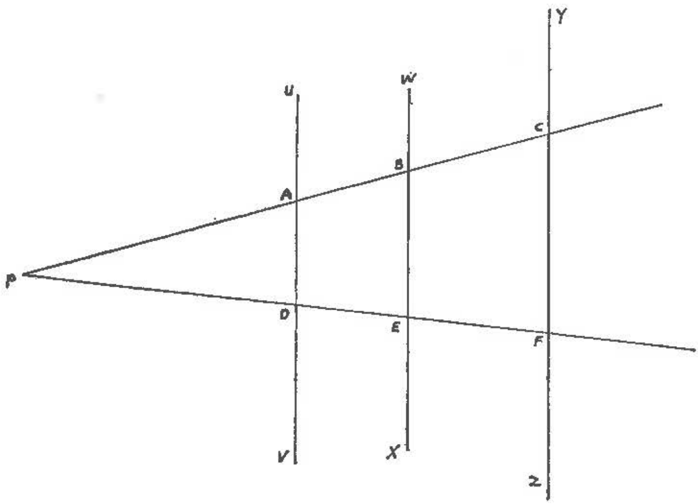


Fig. 7.3

UV, *WX* and *YZ* are three parallel straight lines cut by the other two lines in *A*, *B* and *C* and in *D*, *E* and *F*.

If the two other lines are not parallel they must meet somewhere. In this case let it be at *P*. Then by proportion in triangles we can say that $AB : BC :: DE : EF$.

$$\text{i.e. } \frac{AB}{BC} = \frac{DE}{EF}$$

The ratios thus established provide a convenient means of solving the problem.

The three bearings of the object are laid off on the chart. Through the object is drawn a line, preferably but not necessarily at right angles to the middle bearing. On this line is marked off the time interval expressed in units, using any suitable scale; the scale of longitude on the chart, being constant, provides a ready scale. Lines parallel to the middle bearing are drawn through the points obtained and extended to cut the first and third bearings. By joining the points where they cut, the course made good is obtained.

To take an example—

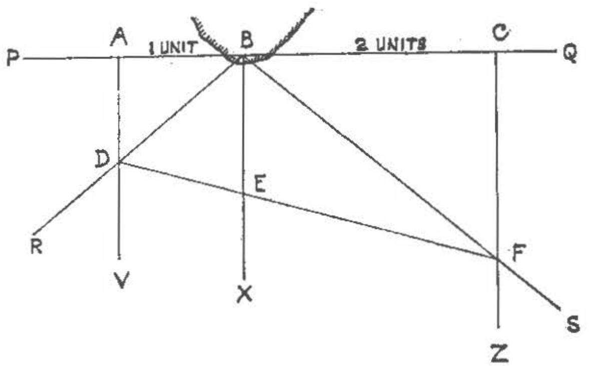


FIG. 7.4

In fig. 7.4, *B* is a shore object of which the three bearings *RB*, *XB* and *SB* are taken respectively. If the first bearing was taken at 1300 hours, the second at 1315 hours and the third at 1345 hours then the ratio of times between the bearings is 15 minutes to 30 minutes, i.e. 1 : 2.

Through *B* draw *PBQ*, preferably but not necessarily perpendicular to *XB*.

Measure off *BA* and *BC* so that *BC* is twice *BA*. For example, it might be convenient to make *BA* equal to three minutes of longitude and *BC* equal to six minutes. Notice that the latitude scale, being variable, should not be used.

Draw *AV* and *CZ* parallel to *BX*; they must be parallel to *BX* and if *PQ* was made perpendicular to *BX* then they will also be perpendicular to *PQ*.

Mark the points *D* and *F* where *AV* and *CZ* cut the 1st and 3rd bearings respectively. Join *D* and *F* and mark *E* where *DF* cuts the 2nd bearing.

The student will see that we now have a construction similar to that in fig. 7.3 which represents the basic principle. *AV*, *BX* and

CZ are the three parallel lines and the two other lines are PQ and DF.

$$\text{As} \quad \frac{DE}{EF} = \frac{AB}{BC} \quad \text{and} \quad \frac{AB}{BC} = \frac{1}{2} \quad \text{then} \quad \frac{DE}{EF} = \frac{1}{2}$$

and so the line DF must be a true representation of the direction in which the ship crossed the chart. That is, DF is the course made good.

Note that if we had doubled the scale of BA and BC, DF would have appeared elsewhere on the chart but the line would have run in the same direction.

Therefore, the 'Three Bearing Problem' on its own gives the course made good only and does not give the distance made good, a distance off or a position in any sense.

Extensions of the Three Bearing Problem will be seen in the Worked Examples and in the Exercises.

Alternative Proofs.

There follows now for reference an alternative graphical proof of the Three-Bearing Problem using similar triangles inside the framework of the construction. This in turn is followed by a mathematical proof involving a knowledge of right-angled trigonometry.

Graphical Proof.

In fig. 7.5, let L be the lighthouse, AL, BL and CL the first, second and third bearings of the object, respectively. Let AC represent the course made good over the ground, θ the angle which the course makes with the second bearing, then the ratio between AB and BC must be equal to the ratio between the unit intervals of time elapsed between the instants of taking the first and second, and second and third bearings.

AK and CP are drawn parallel to BL, and XY, drawn through L, is at right angles to BL. DE is parallel to MN. FC is parallel to BE. Now considering triangles ADB and BFC

$\angle DAB = \angle FBC = \theta$

$\angle ADB = \angle BFC$, being right angles

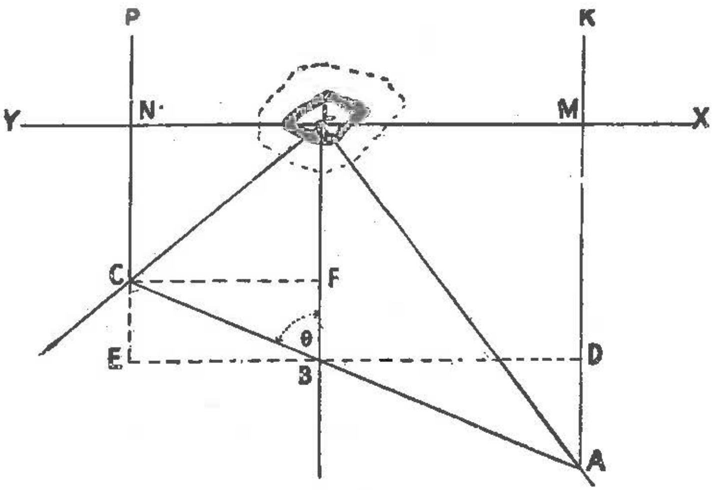


FIG. 7.5

Hence the triangles are similar.

$$\therefore \frac{AB}{DB} = \frac{BC}{FC}$$

$$\therefore \frac{AB}{BC} = \frac{DB}{FC}$$

i.e. the ratio between AB and BC is equal to that between DB and FC.

$$\therefore AB : BC = DB : FC$$

But DB and FC are, respectively, equal to ML and LN.

. . $AB : BC = ML : LN$.

Mathematical Proof.

In fig. 7.6, let L represent the position of a lighthouse, PL, QL and XL the first, second and third bearings, respectively, of the lighthouse taken at intervals of m and n minutes of time. Let α and β denote the angles at the lighthouse between the first and second and second and third bearings, respectively. Also let PQX represent the direction which the vessel is making good over the ground.

It is required to find θ, the angle which the course made good over the ground makes with the second bearing.

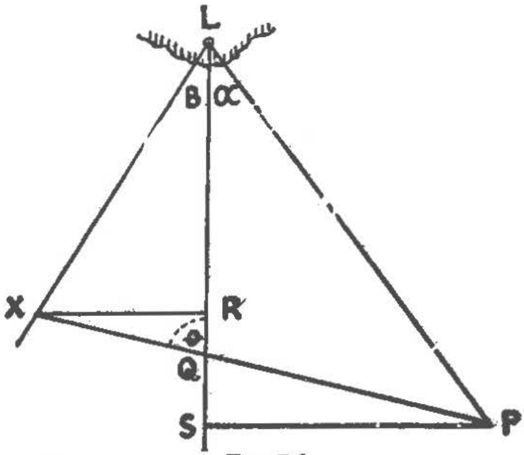


FIG. 7.6

Draw PS and XR perpendicular to LQ.
Triangles PSQ and XRQ are similar.

$$\therefore \frac{PS}{XR} = \frac{PQ}{QX} = \frac{m}{n}$$

From right angled triangle XRQ:— $RQ = RX \cot\theta$
" " " PSQ:— $QS = PS \cot\theta$

$$\therefore RX \cot\theta + PS \cot\theta = RQ + QS$$

$$\therefore (RX + PS) \cot\theta = RS$$

$$\text{" } \quad \text{" } \quad = LS - LR$$

$$\text{" } \quad \text{" } \quad = PS \cot\alpha - RX \cot\beta$$

$$\therefore \quad \cot\theta = \frac{PS \cot\alpha - RX \cot\beta}{PS + RX}$$

$$\cot\theta = \frac{\dfrac{PS}{RX}\cot\alpha - \cot\beta}{\dfrac{PS}{RX} + 1} \quad \text{(Dividing by } RX\text{)}$$

$$\cot\theta = \frac{\dfrac{m}{n}\cot\alpha - \cot\beta}{\dfrac{m}{n} + 1}$$

$$\cot\theta = \frac{m \cot\alpha - n \cot\beta}{m + n}$$

NOTE—If $n \cot \beta$ is greater than $m \cot \alpha$ the value of $\cot \theta$ taken from the tables must be subtracted from 180° to find angle θ. It is to be observed that the above formula merely gives the angle which the course made good makes with the second bearing.

The distance of the vessel from the object, on any of the bearings, cannot be obtained without additional information.

The formula is simplified when (1) the elapsed times are equal; (2) the angles at the object are equal; (3) each of the angles at the object are equal to 45°.

When the elapsed times are equal:—

Formula:— $$\cot \theta = \frac{m \cot \alpha - n \cot \beta}{m+n}, \text{ but } m = n$$

$$\therefore \quad \cot \theta = \tfrac{1}{2}(\cot \alpha - \cot \beta)$$

When the angles at the object are equal:—

Formula:— $$\cot \theta = \frac{m \cot \alpha - n \cot \beta}{m+n}, \text{ but } \alpha = \beta$$

$$\therefore \quad \cot \theta = \frac{\cot \alpha\,(m-n)}{m+n}$$

When each of the angles at the object is equal to 45°:—

Formula:— $$\cot \theta = \frac{m \cot \alpha - n \cot \beta}{m+n}$$

$$\cot \theta = \frac{m \cot 45° - n \cot 45°}{m+n}, \text{ but } \cot 45° = 1$$

$$\therefore \quad \cot \theta = \frac{m-n}{m+n}$$

In working out the formulae strict attention must be given to the signs. If the value of $\cot \theta$ is preceded by the minus sign, the angle taken from the tables must be subtracted from 180° to obtain the true value of θ.

EXAMPLES OF THREE BEARING TYPE PROBLEMS

It may be found more advantageous to describe arcs of circles, whose radii equal the time intervals, in preference to representing the intervals by linear measure, and drawing tangents to the arcs. This method is adopted in the following examples.

Example—From a vessel steaming at a uniform speed a lighthouse is observed to bear 040° After steaming 6 miles the lighthouse bore North and after steaming a further 4 miles it bore 310°. Find the course the vessel is making good.

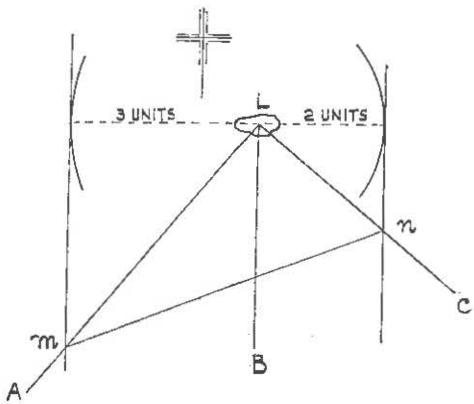


FIG. 7.7

In fig. 7.7, let *L* be the lighthouse, *AL*, *BL* and *CL* the 1st, 2nd and 3rd bearings respectively.

In this example, no times are given, only distances covered. It is immaterial whether the distances are through the water (by log) or over the ground; all that matters is that the proportion of the first part of the run is to the second part of the run as 6 is to 4, i.e. 3 : 2, and the problem is worked in exactly the same way as before.

With centre *L* and radius 3 units, draw an arc to the westward.

" " *L* " " 2 " " " " " " eastward.

Place the parallel rules along *LB* and move them so as to draw tangents to both arcs as shown.

Name the points *m* and *n* where the tangents cut *LA* and *LC* respectively.

Join *mn* and this is the course made good over the ground.

In the following examples it is shown how with the aid of additional data the distance made good and the position of the ship can be found.

Example—Given the course and speed of a vessel three bearings of an object taken at intervals and the set of the current. Required to find the ship's position when each bearing was taken, also the drift experienced between the 1st and 3rd bearings.

From a vessel steering 105° at 10 knots a lighthouse bore 023°; 20 minutes later it bore 349° and after a further interval of 30 minutes it bore 315°. Required the course made good, the position of the vessel when each of the bearings was taken, and the drift of the current which was known to be setting 335°

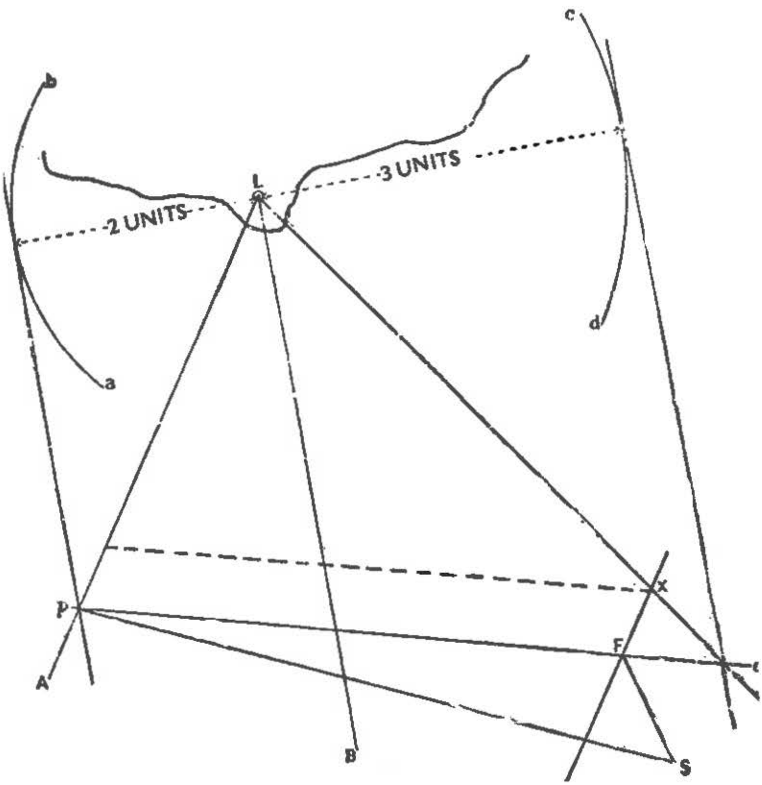


Fig. 7.8

In fig. 7.8, let L be the lighthouse, AL, BL and CL the 1st, 2nd and 3rd bearings respectively. The proportion of times in this case is 20 to 30, i.e. 2 : 3.

From any scale with 2 units as a radius and centre L describe an arc of a circle to the westward, in figure *ab*. Then with a radius of 3 units and centre as before describe an arc to the eastward, in figure *cd*.

Lay off tangents to these arcs parallel to the middle bearing and join the points where the tangents cut the 1st and 3rd bearings, i.e. *pq*. This will be the course the vessel is making good over the ground. From *p* lay off the course steered and distance the vessel has steamed between the 1st and 3rd bearings, in figure *pS*. That is, *pS* equals 50 minutes at 10 knots or 8⅓ miles. At the end of this run, i.e. at *S*, lay off the direction in which the current is setting, cutting the course made good in *F*. That is, *SF* is in the direction 335°.

Then since *pq* is the course made good, *pS* the course steered and distance steamed, and *SF* the direction of the current, the distance *SF* must be the drift of the current in 50 minutes in order that *pF* may be the actual course and distance made good. The position of the vessel on the 3rd bearing can now be found as in a running fix. Through *F* draw a line parallel to the 1st bearing; where it cuts the 3rd bearing is the ship's position when that bearing was taken, in figure *X*.

Through the position on the 3rd bearing lay off, in the reverse direction, the course made good. Where this line cuts the 2nd and 1st bearings is the position of the vessel when these bearings were taken.

Example—At 7 p.m. from a vessel steering 110° at 5 knots a lighthouse bore 50° on the starboard bow, at 7.45 p.m. it bore 75° on the starboard bow, and at 9 p.m. it bore 30° abaft the beam and at the same time a tower bore 53° on the starboard bow.

Required the course made good, the position of the vessel when each bearing was taken, and the direction and rate of the current.

In fig. 7.9, let *L* be the lighthouse and *T* the tower, *AL*, *BL* and *CL* the 1st, 2nd and 3rd bearings of the lighthouse, respectively, *RT* the bearing of the tower. Since the 3rd bearing of the lighthouse and the bearing of the tower were taken simultaneously the true position of the vessel must be where these bearings intersect.

Find the course made good as in the previous example. Through the position of the vessel (in figure *X*) lay off, in the reverse direction, the course made good by the vessel between the 1st and 3rd bearings,

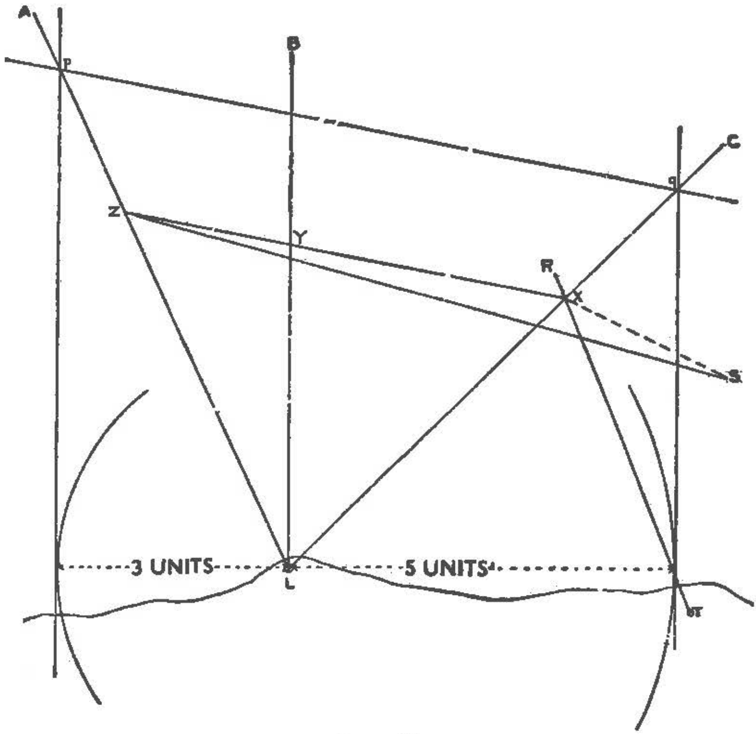


FIG. 7.9

and the position of the vessel on the 2nd and 1st bearing is found as before, i.e. in *Y* and *Z*. To find the set and drift of the current proceed as follows. Find the dead reckoning position of the vessel by laying off from *Z* the course steered and distance steamed, i.e. *ZS*, then *S* is the dead reckoning position; the difference between this position and the position by observation, i.e. cross bearings, is the set and drift of the current, in figure *SX*.

VISIBILITY OF THE SEA HORIZON

In conditions of perfect visibility the distance in nautical miles of the sea horizon from an observer whose height of eye is *h* feet above sea-level is given by the formula $1{\cdot}15\sqrt{h}$. In metric units the distance for observer's height *h* metres is $2{\cdot}09\sqrt{h}$.

Thus for height of eye h feet:

$$d = 1{\cdot}15 \sqrt{h}$$

For height of eye h metres:

$$d = 2{\cdot}09 \sqrt{h}$$

In both instances the distance given is in nautical miles, either International or U.K., the difference being negligible for present purposes over such short distances.

If an observer, whose height of eye is h feet above sea-level, can just see a light, the height of which is H feet above sea-level, the distance he is off the light will be equal to the sum of the distances of the sea horizon for each of these heights.

Example—An observer, whose height of eye is 25 feet above the sea, can just see a light, the height of which is known to be 100 feet above sea-level. How far is he from the light?

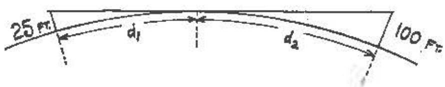


FIG. 7.10

$$\begin{aligned}
\text{Distance in miles} &= d_1 + d_2 \\
\text{,, \quad ,,} &= 1{\cdot}15\sqrt{25} + 1{\cdot}15\sqrt{100} \\
\text{,, \quad ,,} &= 1{\cdot}15\ (\sqrt{25} + \sqrt{100}) \\
\text{,, \quad ,,} &= 1{\cdot}15\ (5 + 10) \\
\text{,, \quad ,,} &= 1{\cdot}15 \times 15 \\
\text{,, \quad ,,} &= 17{\cdot}25
\end{aligned}$$

Example—At what distance could an observer whose height of eye is 9 metres expect to sight a light whose height above sea-level is 25 metres?

$$\begin{aligned}
\text{Distance in miles} &= 2{\cdot}09\sqrt{9} + 2{\cdot}09\sqrt{25} \\
&= 2{\cdot}09(3+5) \\
&= 2{\cdot}09 \times 8 \\
&= 16{\cdot}72 \text{ miles}
\end{aligned}$$

The formulae assume mean refraction. If abnormal refraction is suspected this method of obtaining a distance off should not be employed.

Most nautical tables provide a table of visibility from which can be found the distance of the sea horizon for heights up to 10,000 feet. This table will be found most useful for ascertaining the maximum distance at which an object of known height should be visible, or adjusting the range of a light, as given on the chart, when the observer's eye is higher than 15 feet (or 5 metres)—the height for which the charted range is calculated.

Example—The range of a light, as given on the chart, is 15 miles. How far will the light be seen by an observer, whose height of eye is 45 feet?

From table of visibility, 45 feet	=	7·70 miles
,, ,, ,, ,, 15 ,,	=	4·45 ,,
Difference	=	3·25
Charted range	=	15 miles
Correction for height of eye	=	3·25 miles
Distance light is visible	=	18·25 miles

Note, however, that the charted range of a light may be less than the range obtained by working out the formula using the charted height of the light. The reason for this is that the power of a light and the meteorological visibility are taken into account when stating the light's charted range.

In practice, of course, the restrictive and commonplace effect of reduced atmospheric visibility should be continually borne in mind and vessels are often far inside the charted range of a light before it is sighted.

Navigators are warned of the effect of background lighting. This would be evident in the case of a light superimposed on a brilliantly lit town or industrial plant. The effect is much greater than is generally supposed and may severely reduce the distance at which a light may be sighted.

CHAPTER VIII

POSITION FROM ASTRONOMICAL AND TERRESTRIAL POSITION LINES

An astronomical position line is really a small arc of a circle of position whose centre is the object observed and radius the angular distance of the observer's zenith from the object. The true zenith distance of an object is the distance in nautical miles of the observer from the geographical position of the object. With this geographical position as a centre and a radius equal to the zenith distance expressed in nautical miles, a circle of position can be described on some part of which the observer is situated. The position of the observer on the circle is fixed by laying off the true bearing of the object at the instant of observation.

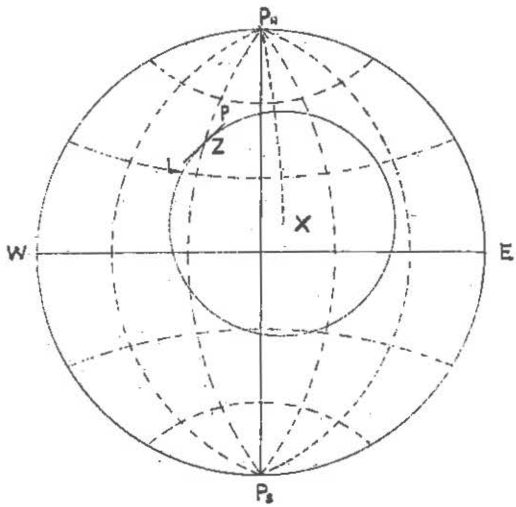


Fig. 8.1

X is the Geographical Position of the body.
Z is the position of the observer.

The Circle of Position is the circle drawn on the surface of the earth with centre X and radius XZ (the zenith distance).

PL is a small portion of the circumference of the circle of position, taken to be a straight line.

In actual practice it is not convenient to use the method of plotting the circle from its centre in order to find the position. To do so, the zenith distance must be very small; to plot the geographical position of the object a small scale chart must be used and, to avoid distortion in the radius of the circle due to variation in the scale of latitude, the latitude must be low.

The principle of the Astronomical Position Line is illustrated in fig. 8.1, part of which is adapted and enlarged as fig. 8.2.

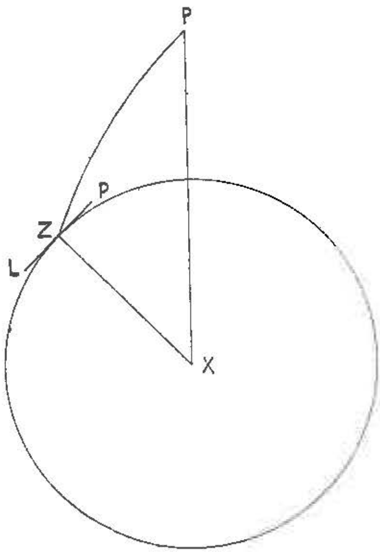


FIG. 8.2

When the position line runs due East/West, i.e. along the top or bottom of the circle, or due North/South, i.e. along the extreme sides of the circle, special conditions prevail.

When East/West the position line is part of the parallel of latitude. *See* 'Latitude by Meridian Altitude' (page 140).

When North/South the position line is part of the Meridian of

Longitude. *See* 'P.V. Sights', mentioned under 'Longitude by Chronometer' Method (page 141).

In other cases the practical application of the principle is to solve the '*PZX* triangle' illustrated and thus establish a position on the earth's surface through which the position line passes and also the direction in which the position line runs.

There are four methods in general use which achieve this end. These are described in the following text.

The triangle may be worked out mathematically from the basic formula or there may be employed one of a number of procedures which shorten the calculation by varying degrees. For details of these the student is referred to textbooks on navigation. In chartwork we are concerned with the application of the end result.

The practical method of laying down a position line is to plot a small part of the circle of position as a straight line.

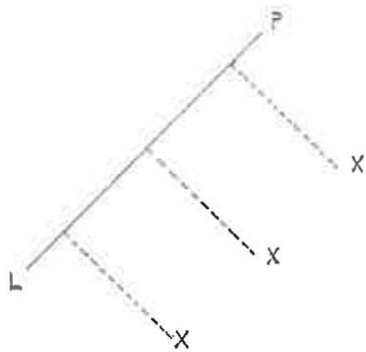


FIG. 8.3

The distance to the body '*X*' is so great that its direction from any part of the position line may be represented by parallel lines. (Fig. 8.3). That is, the bearing of the body is taken to be the same from anywhere on the position line.

Methods of Identifying the Position Line—

(1) Latitude by Meridian Altitude.

In this first method there is no triangle to solve. When the body *X* is on the observer's meridian, bearing due North or South, *P*, *Z* and *X* lie in a straight line, the position line runs due East/West and is then part of the observer's parallel of latitude.

The calculation for latitude by meridian altitude thus gives the position line in the form of a small portion of a parallel of latitude. The azimuth or bearing of the body is 000° or 180°.

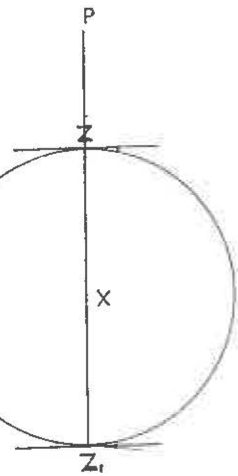


FIG. 8.4

(2) Longitude by Chronometer.

The longitude by chronometer method assumes a latitude and solves the triangle for the angle *P*. If the problem is worked several times using a different latitude on each occasion a different value for ∠*P* results and so a different longitude is given. However, the principle holds good and on each occasion the longitude given is the longitude in which the position line cuts the latitude used. The latitudes used should of course be in the proximity of the observer's approximate position.

In Fig. 8.5 (*a*):—

If latitude *aa* is used to work the triangle, ∠*XPl* is given.

If latitude *bb* is used to work the triangle, ∠*XPm* is given.

If latitude *cc* is used to work the triangle, ∠*XPn* is given.

From this it follows that the longitude which results in each case will be different.

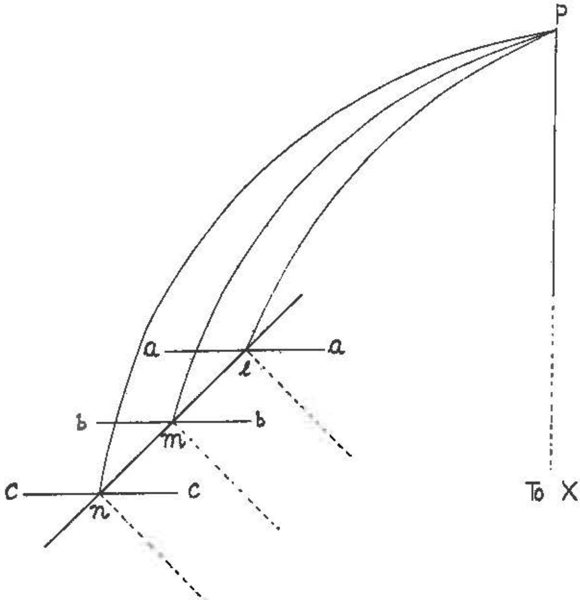


FIG. 8.5 (*a*)

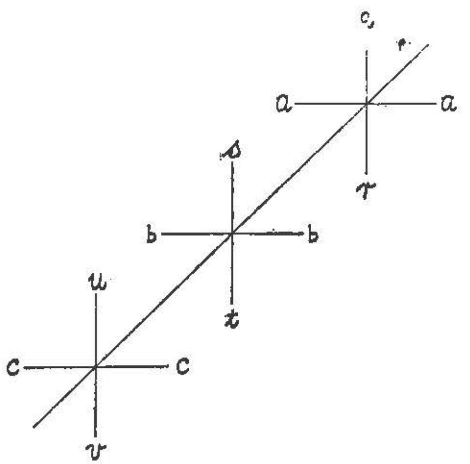


FIG. 8.5 (*b*)

That is, [in Fig. 8.5 (*b*)]:—

If latitude *aa* is used to work the sight, *qr* is the longitude given.

If latitude *bb* is used to work the sight, *st* is the longitude given.

If latitude *cc* is used to work the sight, *uv* is the longitude given.

Each latitude provides a longitude through which to draw the position line. Naturally the practice is simply to work the sight once using generally the D.R. latitude. The azimuth of the body X ($\angle PZX$ in fig. 8.2) is established usually from tables and the position line is drawn at right angles to such azimuth.

There are two occasions when the longitude by chronometer method does give the exact longitude of the ship. The first is when the latitude used to work the sight is the latitude in which the ship is actually situated and in this case the ship's position is established by the working-out of a longitude by chronometer sight. The second occasion is when the bearing of the body is due East or West. Then the position line runs North/South and this, of course, means that the position line is running along a meridian. The longitude of the ship is thus established. No indication is given of the latitude, however. This is sometimes known as a P.V. sight, the body being on the observer's Prime Vertical.

The longitude by chronometer method should not therefore normally be thought of as a calculation which gives the vessel's longitude; it merely provides a position through which to draw a position line.

(3) Ex-Meridian.

Closely allied in manner of application to the longitude by chronometer is the ex-meridian method of obtaining an astronomical position line. This is a special case which can only be used when the body is close to the meridian, that is, when the position line is close to the top or bottom of the circle (fig. 8.1), and the angle P is small.

The ex-meridian calculation assumes a longitude and either by solving the triangle PZX or by using ex-meridian tables arrives at a latitude through which to draw the position line.

If the problem were worked several times using a different longitude and therefore a different value for $\angle P$, a different latitude would result each time. Again the principle holds good and on each occasion the latitude given is the latitude in which the position line cuts the longitude used. Again the longitudes used should be in the proximity of the observer's approximate position.

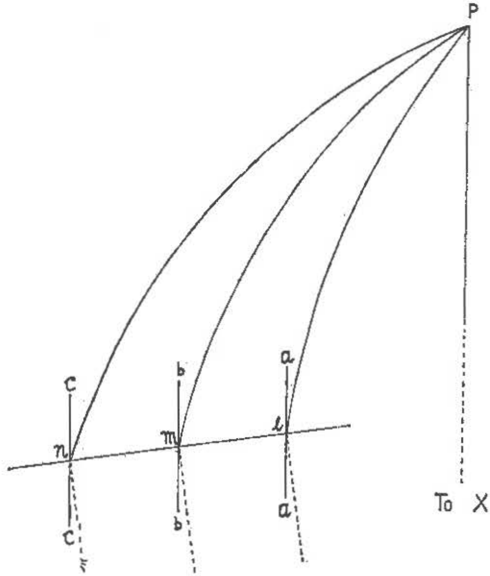


FIG. 8.6 (*a*)

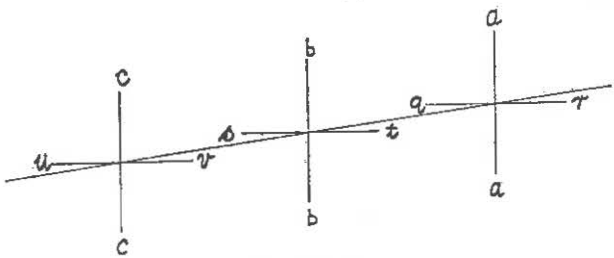


FIG. 8.6 (*b*)

In figure 8.6:—

If longitude *aa* is assumed ∠*lPX* is used in the calculation and latitude *qr* is given.

If longitude *bb* is assumed ∠*mPX* is used in the calculation and latitude *st* is given.

If longitude *cc* is assumed ∠*nPX* is used in the calculation and latitude *uv* is given.

Each longitude provides a latitude through which to draw the position line. Again the practice is to assume one longitude (usually the D.R.) and obtain one latitude. The azimuth is established as before and the position line is drawn through this point.

When the longitude in which the ship is actually situated is used, a correct latitude results. When the body is bearing due North or South the triangle disappears and the problem becomes a meridian altitude, giving the correct latitude.

(4) Marc St. Hilaire or Intercept.

The fourth method departs in a sense from the procedure set by methods (2) and (3). It compares the assumed distance of the observer from the body with the actual distance, so arriving at the error of the assumed position in relation to the position line.

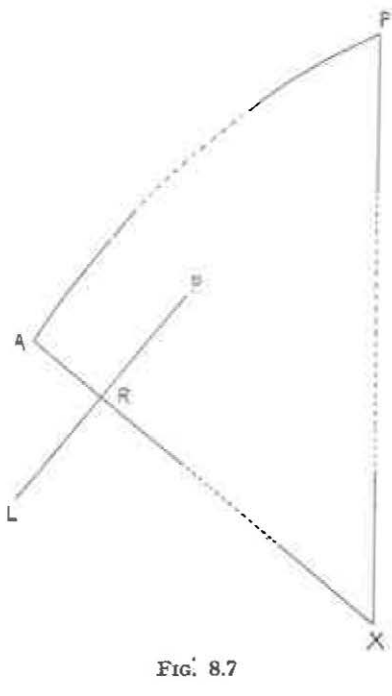


FIG. 8.7

In fig. 8.7 '*A*' is the assumed position. This is usually the D.R. or the D.R. taken to the nearest round figures.

With a sextant the navigator observes *RX*, the actual zenith distance of the body *X*. The position line on which the ship is situated is therefore at radius *XR* from *X*. For the instant of observation the triangle *APX* is solved for side *AX*. Note that had the observer really been at *A*, *AX* would have been the value of the zenith distance and the position line would have run through *A*.

The azimuth of *X* is found as before.

Therefore we can say:—

AX is what was thought to be the zenith distance.

RX is the actual zenith distance.

Therefore the error in the zenith distance is *AR*—this is called the *intercept*.

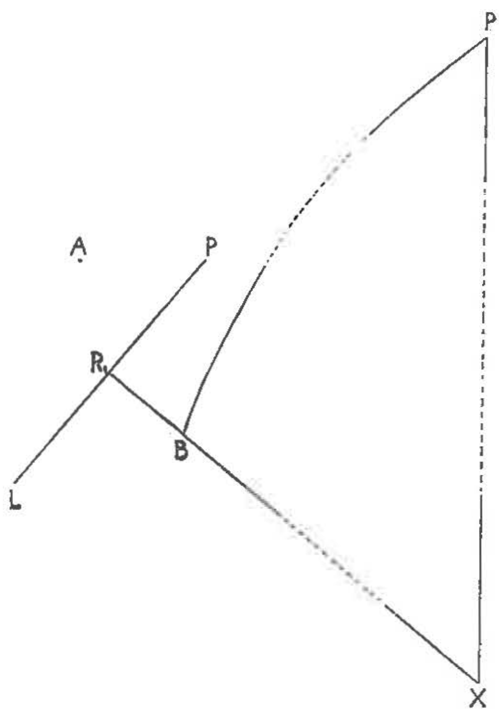


FIG. 8.8

The practical operation of plotting is as follows:—

Plot position A on the chart. Lay off the bearing of X. Along the direction AX measure AR. Through R draw the position line at right angles to AX. The vessel is somewhere on the line PL.

In this case because R is closer to the body than A the intercept, AR, is said to be *towards*. That is it is laid off from A towards X.

AX is referred to as the calculated zenith distance.

RX is referred to as the true zenith distance.

Point R is sometimes referred to as the Intercept Terminal Point (ITP).

Repeating the position line of fig. 8.7 in fig. 8.8. If position B had been taken as the assumed position then solving the triangle would have given BX as the calculated zenith distance. The true zenith distance would have been unaffected and of value R_1X.

In this case because R_1 is further from the body than B the intercept BR_1 is said to be *away*. That is it is laid off from B away from X.

To sum up briefly, the astronomical position line as illustrated in figs. 8.1 and 8.2 may be obtained and plotted by one of the four methods described.

(1) In the Meridian Altitude the body is on the observer's meridian, the position line runs due East/West and is part of the observer's parallel of latitude.

(2) In the Longitude by Chronometer a selected latitude gives a longitude through which the position line runs. This method may be especially helpful when the body bears due East or West, or nearly so.

(3) In the Ex-Meridian a selected longitude gives a latitude through which the position line runs. This method can only be used when the body is close to the meridian.

(4) In the Marc St. Hilaire a selected position (latitude and longitude) gives the perpendicular distance to the position line.

In all cases the position line is drawn at right angles to the azimuth of the body observed.

Remember that at the moment of taking the sight the position line is fixed on the surface of the earth. The object of the operation is to determine where the position line is and so plot it on the chart.

To take an example:—

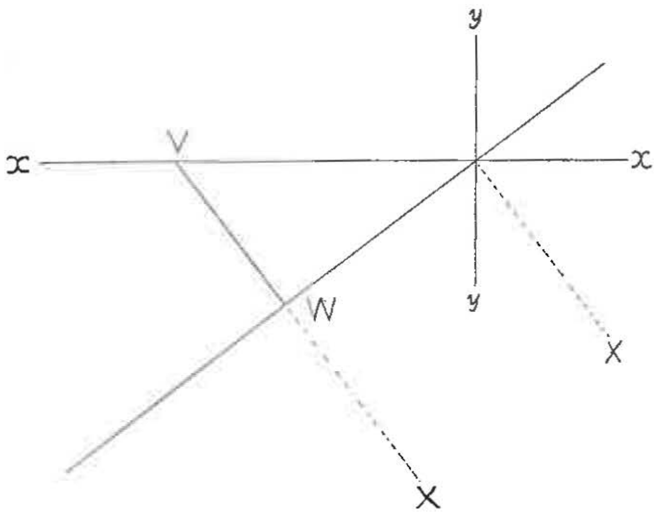


FIG. 8.9

A vessel in dead reckoning position V (Fig. 8.9) takes an observation of the sun bearing 142½° T.

(*a*) Working the sight by the Longitude by Chronometer method, she uses the D.R. latitude *xx* and obtains the longitude *yy*.

(*b*) Working the sight by the Marc St. Hilaire method, she uses the D.R. latitude and longitude and obtains the intercept *VW* (towards).

Plotting from (*a*) and also from (*b*) it will be found that the position line given is one and the same line. That is (*a*) and (*b*) are simply two separate methods of identifying the already existing position line.

As may be surmised there are occasions when it is advantageous to use one or other of the four methods.

There follows an example of each type, laid off on Plate 8.1.

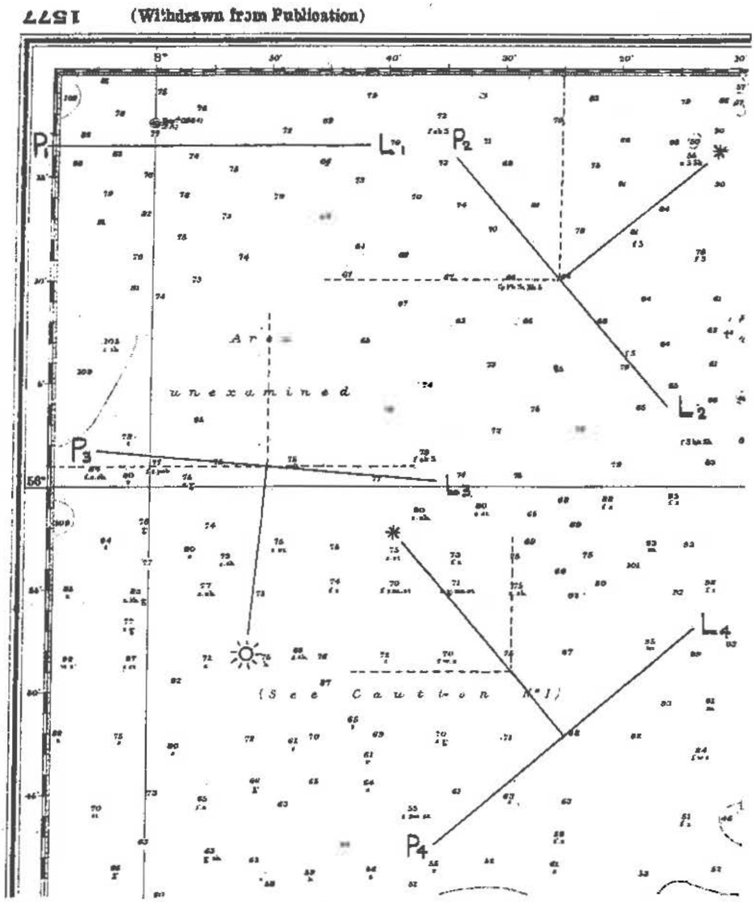


PLATE 8.1

Reproduced from British Admiralty Charts, with the permission of the Controller of H.M. Stationery Office and of the Hydrographer of the Navy.

Note that in plotting problems, unless stated otherwise, the given D.R., Estimated, or Assumed Position is taken to be the position which has been used in the working of the sight.

1. In D.R. position, Lat. 56° 15′ N., Long. 9° 00′ W., the meridian altitude of the sun gave a latitude of 56° 16·5′ N. Plot the position line.

2. In Estimated Position Lat. 56° 10′ N., Long. 8° 35′ W. an observation of a star bearing 050° T., when worked by the longitude by chronometer method, gave a longitude of 8° 25′ W. Plot the position line.
3. In D.R. position, Lat. 56° 00′ N., Long. 8° 50′ W., an observation of the sun near the meridian gave a latitude of 56° 01′ N. when worked by the ex-meridian method. If the sun was bearing 185° T. plot the position line.
4. An observation of a star bearing 320° T. when worked by the Marc St. Hilaire method gave an intercept of 4′ away. An assumed position of Lat. 55° 51′ N., Long. 8° 29′ W. was used to work the sight. Plot the position line.

Crossed Position Lines.

Although the foregoing methods provide the means of finding and plotting a position line, and while this knowledge in itself has many advantages, the position of the vessel is not found. Given additional information, however, the usefulness of the position line is considerably extended.

The astronomical position line may be crossed with one or more other position lines so as to give an actual fix of the ship.

Examples of such other position lines may be:—

Another astronomical position line.

A bearing of a shore object.

A DF bearing.

A radar range.

A hyperbolic position line established on a lattice chart.

All these position lines are discussed individually in various parts of this book. A similar list of position lines is drawn up in Chapter V (page 83).

For example, if, simultaneously with the observation of the heavenly body, a bearing of a terrestrial object is obtained, or a bearing of a D.F. station taken, the intersection of the position line and bearing will give the position of the observer.

In the case of crossed astronomical position lines it will be seen that if the basic principle of circles of position is applied, then the circles will cut in two places. These places, however, will normally be far removed from one another and this ambiguity presents no practical difficulty.

Transferring Position Lines.

An astronomical position line may be transferred in the same way as a terrestrial position line. (*See* Chapter V).

If a terrestrial bearing is taken a given time after the observation for a position line, the position of the vessel can be determined by the running fix or open bearing method. In this case the position line and terrestrial bearing are laid off on the chart. From any point on the position line lay off the course steered and distance steamed in the interval. At the end of the course line lay off the allowance, if any, for current or tidal stream and through the end of the current line draw the position line. Where it cuts the terrestrial bearing is the position of the vessel.

In connection with this form of problem in chartwork the two special cases already mentioned should be noted.

At noon, when the sun bears North or South, the position line runs East and West, i.e. a parallel of latitude. Again if an observation of a heavenly body is taken when it is on the prime vertical it bears East or West and consequently the position line will run due North and South, i.e. a meridian.

Example—From a vessel steering 080° at 10 knots the altitude of a star bearing 110° was obtained and the longitude found to be 11° 2′ W., the latitude by account being 55° 30′ N.

One and a half hours later a light was observed to bear 340°. Find the position of the vessel when the bearing of the light was taken, the current being estimated to set S.E. at 1½ knots.

On Plate 8.2, let *A* be the position obtained by plotting the latitude by account and the longitude by observation. That is, it is the position through which to draw the position line. From *A* lay off *AB* 110°, through *A* draw *CD* at right angles to *AB*, then *CD* is a position line. Now from any point on *CD* lay off *MN*, the course steered and distance steamed in 1½ hours. From *N* lay off *NP* the current experienced in 1½ hours. Now lay off *LS* the bearing of the light. Through *P* draw a line parallel to the first position line and where it cuts *LS* in *X* is the ship's position.

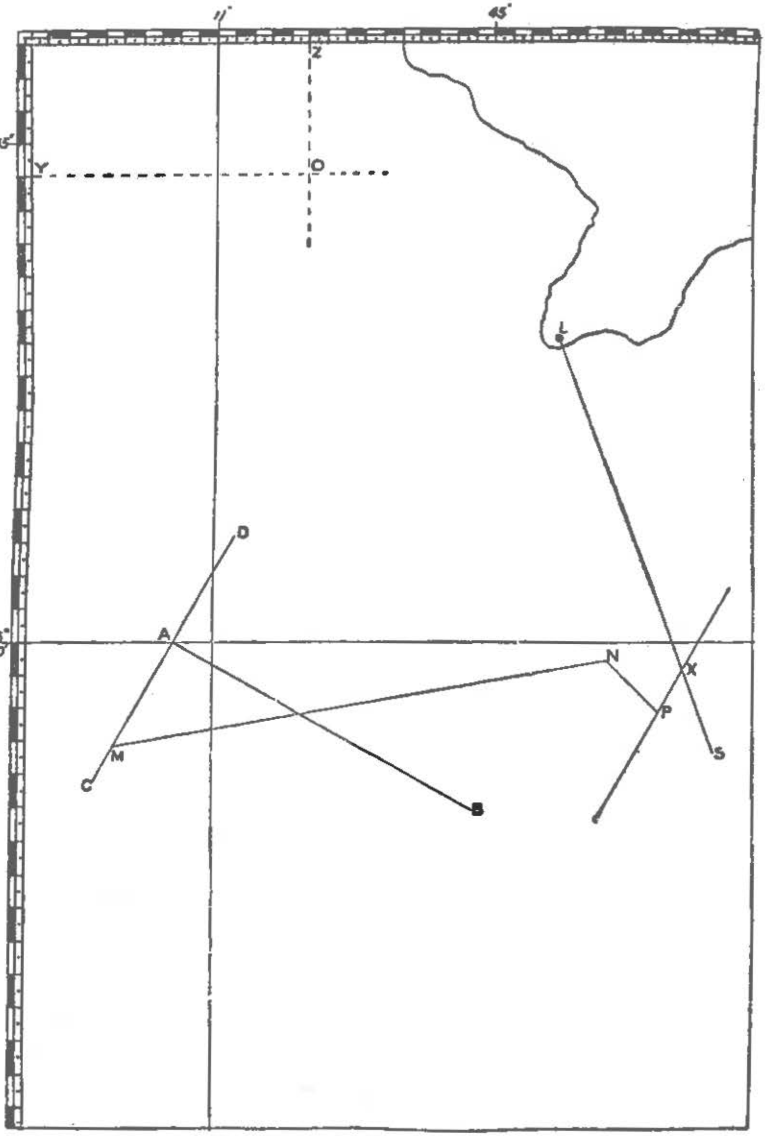


PLATE 8.2

THE USE OF A SINGLE POSITION LINE

A single position line, whether terrestrial, astronomical or any other type, when plotted, does not provide a fix, but, as already stated, merely shows a line somewhere on which the vessel is situated. It is possible, however, to elucidate from it more information than appears at a first glance. If the position line is a straight line under certain circumstances it may ensure steering a safe course.

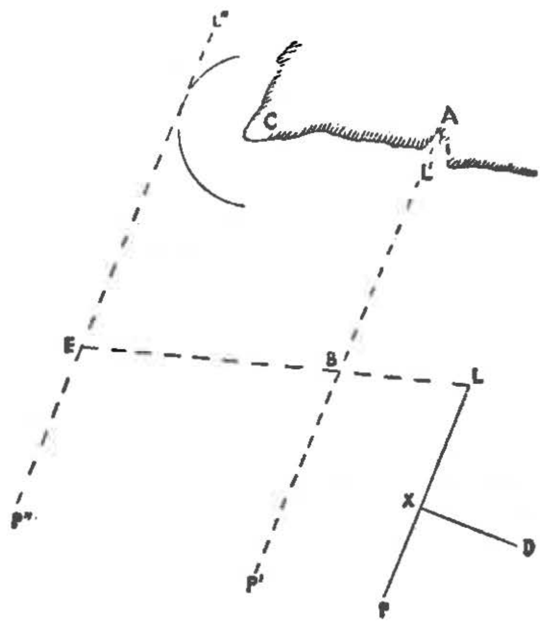


FIG. 8.10

In fig. 8.10, let *PL* represent a position line and *D* the dead reckoning position. Draw *DX* perpendicular to *PL*. Then *DX* is the least error in the D.R. position.

By the same reasoning, it follows that if an observation is taken of a heavenly body bearing directly ahead or astern a comparison between the plotted position line and D.R. position will reveal how much the vessel is ahead or astern of the D.R. position.

In the case of a meridian altitude observation, the comparison indicates the error in the D.R. latitude. When the position line is the result of an observation of a body on the prime vertical the comparison gives the error in the D.R. longitude.

In the vicinity of land, when the acquisition of a position line is succeeded by low visibility, conditions may be favourable for the adoption of the position line as a safe course to reach a certain position, to pass a headland at a safe distance, or to clear a danger.

Referring to fig. 8.10, assume PL to be a position line resulting from a reliable sight soon to be followed by poor visibility and it is desired to reach position A.

Transfer PL to pass through A, and from anywhere on PL draw LB representing a safe course from the original position line to the transferred one. If, then, the course and distance indicated by LB is made good, the vessel will arrive on $P'L'$, whence by altering course to make good this direction she will eventually arrive at A.

Suppose, however, that after acquiring the position line PL, it was required to pass point C at a distance of, say, 5 miles, weather conditions being as already mentioned. Proceed as follows:

With C as a centre and radius of 5 miles, describe an arc. Draw $P''L''$ as a tangent to the arc and also parallel to PL. Let LE represent a safe course from PL to arrive on $P''L''$, then by making good this course and distance the vessel will arrive on $P''L''$. By now proceeding so as to make good this direction, the vessel will pass 5 miles off point C.

Should the effect of a current, or tidal stream, have to be taken into account, find the course to steer to counteract the current, or tidal stream to make good LE, in fig. 8.10. Now, at the appropriate time, find the course to steer again counteracting any current, or tidal stream, to make good $P''L''$, fig. 8.10, and the vessel will pass the required distance off point C.

In the two above examples note that if the vessels head along the directions LB and LE respectively, and there is a known current or known leeway, the vessels will make good courses different from the directions LB and LE. However, each will still strike the transferred position line but at spots other than B and E. The speed made good must be found to determine the moment to alter course along the transferred position line in each case.

It will be evident that soundings taken along the transferred position line will be of material assistance in recognising the vessel's position, and particularly so if the position line crosses different depth contour lines (fathom lines).

There follows an example similar to those illustrated in fig. 8.10 but incorporating current and leeway.

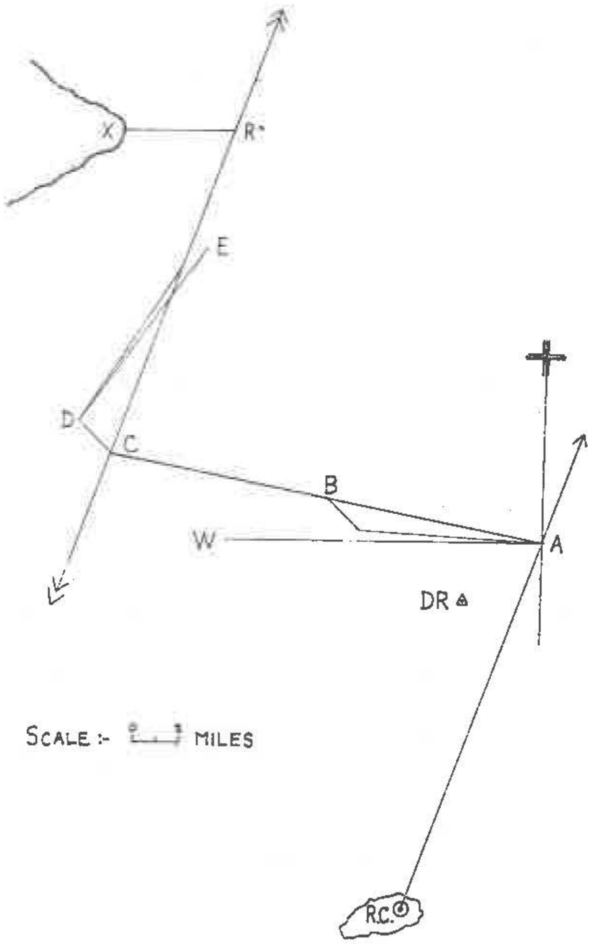


FIG. 8.11

At 0300 hours a vessel is in D.R. position as shown (Fig. 8.11). Her course is 270° T., speed 8 knots. She takes a bearing of the radiobeacon (R.C.) with her DF apparatus. The bearing when corrected is 200° T.

The ship intends to proceed to a point 5 miles due east of lighthouse *X*.

What single alteration of course should she make and when should she make it; allowing for a current setting 315° T. at 2 knots and allowing for 3° leeway due to a strong S.S.E'ly wind, both throughout the question?

From the radio beacon lay off the bearing and transfer the bearing so that the transferred position line runs through the intended destination point—*R* in fig. 8.11.

Select somewhere on the radio bearing, say point *A*. In the manner described in Chapter V lay off the leeway, course and speed through the water and current to arrive at *B*.

AB represents the course and speed made good. (By scale drawing — 281° T. 9·6 knots.)

Produce the line *AB* until it cuts the transferred position line—that is, at *C*.

$\dfrac{AC}{AB}$ is the time taken to the alteration point.

In this case $\dfrac{19{\cdot}2}{9{\cdot}6} = 2$ hours.

From *C* find the course to steer to counteract current and leeway so as to make good the direction *CR*. This procedure is explained in Chapter IV. *DE* is now the course to steer (036° T.).

The difference between the directions *AW* and *DE* is the alteration of course. In this case 270° to 036° gives 126°.

The values arrived at by scale drawing therefore are:
Alteration of course—126° to starboard.
Time to make the alteration—0500 hours.

Note that the position '*A*' could have been selected anywhere on the original bearing without affecting either the alteration in course or the time at which to make it. Thus it is impossible to state a time of arrival. All that the problem achieves is to put the vessel on a course which will carry her safely to her destination.

CHAPTER IX

PICKING UP A LINE OF SOUNDINGS

DURING thick weather when the position of the vessel is uncertain, on account of the lack of opportunity of taking observations, the position may be found with a fair degree of accuracy, if the vessel is 'in soundings', by running a 'line of soundings'.

A series of soundings is taken and compared with the soundings printed on the chart. If they agree it may be reasonably assumed the position is as denoted, but such position should be used with caution. The procedure is as follows:—

The vessel is kept at a uniform speed on her course and a cast of the lead or echo sounder readings taken at short intervals. The depths recorded are corrected for the height of the tide at the time of the cast to reduce them to chart datum—that is, the depth as marked on the chart when the sounding was taken.

It is only required to mark on the edge of the parallel ruler, or piece of paper attached to the edge of the ruler, the relative distances between the soundings. Keeping the ruler in the direction of the *course made good*, work the rulers over the chart in the vicinity of the soundings until the soundings marked on the ruler, or paper, coincide with those marked on the chart.

Unless in the case of echo-soundings the nature of the bottom at each cast should be noted as this knowledge is of considerable value in recognising the chart soundings.

The finding of the position is comparatively simple if the line of soundings is run at slack water. Such, however, will not always be the case, and the effect of current or tidal stream must be taken into account.

When the current or tidal stream is not acting end on to the vessel's fore-and-aft line, the true course made good will differ from the true course steered. As the soundings are taken along the course made good it will be necessary to find this course and mark thereon the relative distances between the soundings.

Various types of line-of-soundings problems are encountered. They are generally:—

(1) Given the course steered and speed steamed and the current. Find the course made good.

(2) Given the speed steamed, the current and the course required to make good. Find the course to steer.

(3) Given the course steered and speed steamed and an approximate current. The soundings give the course and speed made good.

To explain these further:—

(1)

A vessel steering N. 70° E. (true) at 6 knots, through a current setting 320° at 2 knots, takes the following soundings, all reduced to datum:

At	0700 hrs.;	0720 hrs.;	0740 hrs.;	0750 hrs.;	0805 hrs.;	0820 hrs
Soundings	40 fms.	38 fms.	38 fms.	37 fms.	37 fms.	36 fms.

Between the first and last soundings an interval of 1 hour and 20 minutes has elapsed. The vessel has therefore steamed a distance of 8 miles with a current drift of $2\frac{2}{3}$ miles.

To find the course and distance made good.

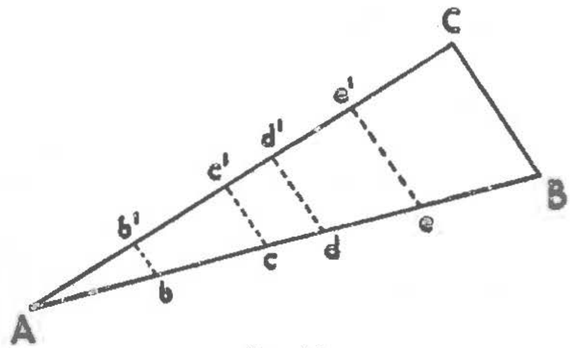


FIG. 9.1

Referring to fig. 9.1, AB is the course steered and distance steamed, i.e. N. 70° E. (true) 8 miles. BC represents the set and drift of the current, i.e. 320° $2\frac{2}{3}$ miles. Then AC is the course and distance made good between the first and last soundings. Ab, bc, *cd*, *de* and *eB* represent respectively, 2, 2, 1, 1½ and 1½ miles, i.e. the distance steamed between the respective soundings. From the points *b*, *c*, *d* and *e*, lines are drawn parallel to *BC*, the direction of the current, to cut *AC*, the course made good, in *b'*, *c'*, *d'* and *e'*. Thus *Ab'*, *b'c'*, *c'd'*, *d'e'* and *e'C* are the relative distances apart of the soundings when taken. It is to be noted that triangles *ABC*, *abb'*, *acc'*, etc., are similar and hence *Ab*: *AB* : : *bb'* : *BC*. Thus it is unnecessary to work out the amount of current experienced up to, or between, each sounding. The parallel rulers are now placed along *AC* and the points *A*, *b'*, *c'*, etc., transferred to the edge of the ruler, or strip of paper, laid along the edge, held in position, and the ruler moved until the soundings as marked agree with those printed on the chart. Obviously in moving the rulers their direction must not be altered. The D.R. position, nature of the bottom as found by the casts, and the contour lines will be of great assistance in determining the position.

The following example illustrates the method to be employed. In foggy weather in order to verify the position by D.R. which was Latitude 50° 30′ 00″ N., Longitude 6° 00′ 00″ W., a vessel steering 078° at 6 knots through a current estimated to set 032° at 2 knots took a cast of the lead at noon and obtained 46 fms.; 25 mins. later another cast gave 44 fms.; 30 mins. later sounded in 39 fms.; 20 mins. later a depth of 39 fms. was recorded, and after a further interval of 30 mins. a depth of 37 fms., shells, was found. Find the position of the vessel when each of the soundings was taken; soundings reduced to datum.

Referring to Plate 'Cornish Coast', *AB* represents the course steered and distance steamed between the first and last soundings, *BC* the current experienced during that time and *AC* the course and distance made good over the ground. *Aa*, *ab*, *bc* and *cB* indicate the respective distances which the vessel has steamed between each of the soundings, and *Aa'*. *a'b'*. *b'c'* and *c'C* indicate the respective distances made good over the ground between each sounding.

The soundings as they occur on the course made good were transferred to a strip of paper as before explained, and with the aid of the parallel rulers carefully moved about the locality in which they were taken until the soundings marked on the paper were found to fit in with those on the chart.

It will be noted that the preparation up to the utilising of the strip of paper was done clear of the locality the vessel was known to be in, in order to obviate any unnecessary lines being drawn there, as numerous lines only lead to confusion.

(2) In this case the vessel must steer a course to counteract a given current (*see* Chapter VI) and the line of soundings is marked off along the course made good.

For instance, vessel D.R. position *A* wishes to make point *B*. Course is set to counteract a known current as shown and soundings are taken as she progresses.

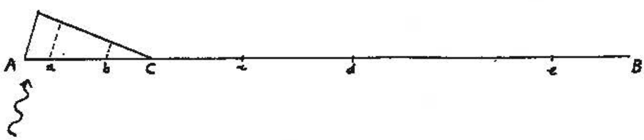


FIG. 9.2

AC is the speed made good and using this speed the positions of the various soundings are marked along *AB* and then transferred to parallel rulers or a piece of paper as in type (1). Comparison is then made with the chart on lines parallel to *AB*.

At 10 a.m., in thick weather, a vessel is in D.R. Position Lat. 50° 20′ N., Long. 8° 20′ W. She sets course for a position with Lundy Island North Light bearing 180° T. distant 10 miles making due allowance for a current setting 015° T. at 2·5 kts. vessel steaming 10 kts.

The following soundings are obtained:—

10.09 hrs.	50 fms.	
10.39 hrs.	45 fms.	Sand.
11.14 hrs.	60 fms.	Fine sand.
12.00 hrs.	57 fms.	

Find the true course steered and the position at noon.

The example is worked out on Plate 9.1, English Channel, and the student should follow the various steps.

(1) Lay off the D.R. position at 10 a.m. (*A*) and the position off Lundy Island (*B*). Join *AB*.

(2) In order to avoid a concentration of lines it is better to take parallel rules and draw a line (*XY*) parallel to *AB* somewhere else on the chart before proceeding further.

(3) Select a point (*P*) on this line and lay off the current 015°, say for two hours, that is 5 miles. Mark the end of the current *Q*.

(4) With centre *Q* and radius the ship's speed doubled, i.e. 20 miles, draw an arc to cut *XY* in *R*.

PR is twice the speed made good.

i.e. the speed made good is $\frac{23}{2}$ kts = 11½ kts.

(5) Now take the times between the soundings.

9 mins. at 11·5 kts. = 1·70 mls.
30 mins. at 11·5 kts. = 5·75 mls.
35 mins. at 11·5 kts. = 6·70 mls.
46 mins. at 11·5 kts. = 8·8 mls.

(6) Lay these distances off from *A* along *AB*. Transfer the positions *c*, *d*, *e* and *f* to parallel rules or a piece of paper and find the area on the chart where the soundings 'come in'.

This will normally be found in the region of the D.R.

(7) Mark the spots $c_{,}$, $d_{,}$, $e_{,}$ and $f_{,}$.

(8) Now the direction of the line *QR* gives the course to steer and spot '$f_{,}$', is the position at noon.

From the Chart the true course steered = 077° T.

Noon Position Lat. 50° 44·5′ N.

Long. 7° 40·0′ W.

(3) The third type is perhaps the most practical example, where the soundings obtained, compared with those shown on the chart along an approximate course made good, give the actual course and speed made good. The ship's course *or* speed is known and the set *or* rate of the current is known. The problem normally is to find the items not given and to find the ship's position at the end of, or at some other part of the run.

An example explained step by step will illustrate the sort of working involved.

At 6.45 a.m. in poor visibility and steaming 9 knots, a vessel in D.R. Lat. 49° 23′ N., Long. 8° 15′ W. sets a course to reach a position 180° T., 10 miles from Lizard Head Light House. Allowance is made for a current known to set 3 knots in some S.-E'ly direction and as the morning progresses the following soundings are obtained:—

7.00 a.m.	66 fms.	Grey sand and shell
7.38 a.m.	75 fms.	Coarse sand
8.01 a.m.	70 fms.	
8.45 a.m.	73 fms.	
9.25 a.m.	69 fms.	
10.12 a.m.	70 fms.	
11.01 a.m.	70 fms.	

Find the compass course steered, the direction of the current and the position of the vessel at noon. Variation 9° W., Dev. 3° E.

The example is worked out on Plate 9.2, English Channel, and the student should follow the various steps.

(1) Lay off the D.R. position at 6.45 a.m. (*A*) and the position off the Lizard (*B*). Join *AB*.

(2) *AB* is the line the vessel wishes to make good and as allowance is made for a current which is known, at least approximately, *AB* can be taken to be an approximate course made good.

(3) With parallel rulers or piece of paper as described previously find the actual line (XY) the vessel has moved along. XY will be expected to be roughly parallel to AB.

In the example $AB = 078°$
$XY = 080\frac{1}{2}°$

(4) Measure the distances between the soundings along XY. These come to:

pq	6·9 miles
pr	11·2 miles
ps	19·3 miles
pt	26·6 miles
pu	35·2 miles
pv	44·2 miles

A comparison of one or more of these against the times will give the speed made good, e.g. *p* to *v* is 44·2 miles.

Time taken *p* to *v* is 4 hrs. 01 m.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} = \frac{44{\cdot}2}{4{\cdot}02} = 11 \text{ kts.}$$ (almost exactly)

(5) Continue the course made good on from *v* for a further 59 minutes at 11 kts. and this gives the position at noon.

(6) Now, as before, in order to avoid a concentration of lines, draw MN somewhere else parallel to XY.
Mark off $JK = 22$ miles (2 hrs. at 11 kts.)

(7) With centre K and radius 18 miles (2 hrs. at 9 kts.) draw an arc to the S.W.
With centre J and radius 6 miles (2 hrs. at 3 kts.) draw an arc to the S.E. to cut the first arc in L.

(8) Now in triangle JKL.

- JK represents the course and speed made good.
- KL represents the true course the vessel must have been steering and the speed steamed.
- JL represents the actual direction of the set of the current and its rate.

(9) Thus from the chart:—True Course steered = 068° T.
Error = 6° W.

Compass Course steered = 074° C.

True Set 122° T.

Noon Position Lat. 49° 22′ N.

Long. 6° 59′ W.

NOTE—With regard to step (2) above, with the information given it would have been possible to construct a triangle similar to *JKL* somewhere on *AB* and so find an approximate 'speed made good'. This would facilitate step (3) further but it is generally an unnecessary operation. Normally little difficulty is experienced in identifying the soundings.

The reader will appreciate that with metric charts the methods of working a 'line of soundings' are unchanged, the depths merely being in metres instead of fathoms.

CHAPTER X

THE CORRECTION OF COURSES

In the preceding chapters of this book explanations and examples have generally dealt with true directions of the ship's head.

True, Magnetic and Compass directions are described in Chapter III.

It is not good practice to attempt to put magnetic and compass courses and bearings on the chart; indeed it would usually be meaningless to do so. True directions only are laid off on the chart.

As ships may steer true, magnetic or compass courses and may take true, magnetic or compass bearings, it is of fundamental importance to be familiar with the conversion of one form into the other.

The procedures of changing through True, Magnetic and Compass Courses and Bearings and applying Variation, Deviation and Error may collectively be entitled the Correction of Courses.

GYRO COMPASS

Most ocean-going ships and many coastal vessels have a gyro compass and repeater system aboard. Modern gyro compasses are designed to indicate true north, the adjustment of any inherent errors being accomplished mechanically or electrically. This has the great advantage of enabling true courses to be steered on the compass card and enabling true courses and bearings to be read directly from the compass or repeater card.

A great many craft do not have a gyro compass and in any case such a compass is not infallible. It is essential, therefore, that all navigators should be familiar with the use of a magnetic compass. This chapter attempts to describe the practical manipulations of courses and bearings with regard to a magnetic compass.

If, through a fault, a gyro compass develops a steady error causing its north point to indicate a direction a few degrees away from true north, such an error may be applied in the same way as a magnetic compass error. The application of compass error is described in the following pages.

MAGNETIC COMPASS

The directive power of the ship's magnetic compass is provided by the magnetic force inherent in the earth. The instrument, however, is subject to disturbance, or deflection, by the magnetic character of the ship—the deflection varies in different ships—hence the course to steer by compass cannot be taken directly from the chart.

To obtain the compass course, a true course must first be converted into a magnetic course which, in turn, is changed to a compass course. To enable the first conversion to be carried out the variation must be known; and to perform the second change the deviation is required. Those two quantities will now be described and, subsequently, it will be explained how a course expressed in one form can be converted into another form.

VARIATION

Variation is the horizontal angle which the magnetic needle makes with the true meridian.

The magnetic needle aligns itself parallel to the Earth's magnetic lines of force, which force emanates from the magnetic poles of the Earth.

The positions of the magnetic poles do not coincide with the geographical poles, the North magnetic pole, to which the north point of the needle is attracted, being situated in the islands of Northern Canada, and the South magnetic pole in Antarctica, below Tasmania. Such physical circumstances cause a magnetic needle in the Atlantic to be drawn in a varying degree to the left of the true meridian and thus produce westerly variation, while in the Pacific the needle is drawn to the right of the true meridian and the variation is easterly.

In the British Isles, the variation is approximately 9° West; in the Davis Strait, between 40° and 60° West; while off Vancouver

Island it is 25° East. It is of interest to note that off the East Coast of Australia the variation is about 10° East, and off the West Coast about 4° West.

The positions of the magnetic poles are not fixed, but are constantly moving in unknown paths, apparently completing a revolution around the geographic poles in a period of many hundreds of years.

The earth's magnetism is irregular and the magnetic poles are not diametrically opposed. On account of this the lines of force do not flow directly from South magnetic pole to North magnetic pole but their direction is locally variable.

The magnetic meridians, therefore, are not perfect semi-great circles joining their poles in a similar manner to the geographic or true meridians. Thus it is not true to say that a compass needle will point to the magnetic north pole when under the influence of the earth's field alone. That is, when the compass needle is lying along the magnetic meridian it will not necessarily point to the magnetic north pole.

The magnetic meridian is thus defined as the direction a compass needle will take up when under the influence of the earth's magnetic field alone.

As previously stated the variation is the angle between the magnetic meridian and the true meridian at any place.

The movement of the magnetic poles causes the variation to increase or decrease a few minutes yearly. This amount by which the variation changes annually is called the secular change.

On coastal charts the compass roses are drawn at points quite close together, and herein the value of the variation for the locality is given for a stated year along with the yearly increase or decrease.

The Admiralty also publish a chart entitled *Curves of Equal Magnetic Variation*. The curves, or lines, are drawn through places having the same variation, and are known as *isogonic lines*. Secular changes are also shown. The correct variation for any position can be obtained from this chart.

Should the variation obtained from the compass rose not agree with that shown on the variation chart, the latter should be considered more accurate.

DEVIATION

Steel ships inevitably have some magnetism contained within their structures. Details of the distribution and effect of this are involved but the result from the sailor's point of view is that his compass needle is drawn away from the magnetic meridian.

The amount of deflection, or horizontal angle between the compass needle and magnetic meridian, is termed the deviation. If the compass needle is drawn to the right of the magnetic meridian the deviation is easterly; if the compass needle is drawn to the left of the magnetic meridian the deviation is westerly.

As the ship's head is turned in azimuth the disturbing magnetic forces of the ship alter their position in relation to the compass needle and so produce a change in the value, and in certain cases the name, of the deviation. Thus it is important to remember that a change of compass course may, and generally does, involve an alteration in the amount, and maybe name, of the deviation.

Another aspect is that, left to itself, the effect of the ship's magnetism on the compass needle will change as the vessel changes position on the earth's surface. This would mean that different deviations would appear on the same heading in different parts of the world.

Thus it seems that the navigator is faced with a disturbing force which will promote deviations which vary with change of course and with change of position. It is in fact possible to compensate a compass against the ship's magnetism using correctors so that the disruptions are largely eliminated. It is seldom, if ever, possible to achieve zero deviation in all circumstances but a properly compensated compass can be relied upon to have greatly reduced deviations. Generally these deviations will not exceed 3° or 4° and furthermore the correction should hold good for all changes of position on the earth's surface.

The actual operation of compensating a compass is popularly called 'adjusting the compass' and after this procedure has been gone through a table of 'residual deviations' is drawn up showing the remaining deviation on each point or ten degrees of the compass. Often this table or 'deviation card' is reproduced in the form of a graph when it is referred to as a 'deviation curve'.

By and large these deviations should be a close approximation to the actual deviations experienced at any place within the succeeding months. Compasses are usually adjusted at intervals of about one year.

The object of compensating a compass is to reduce the deviations to manageable and, above all, *known* levels.

Inside of cover are shown two 'Deviation Cards'. They are for different compasses. Observe that No. 1 shows the deviation for the ship's head on each compass point, while No. 2 gives the deviation for the ship's head on each 10° change of course.

It is to be here remarked that the deviations shown on the cards are large, much larger than those remaining on a properly adjusted compass whose residual deviations should not exceed 3° or 4°. The object of introducing such large deviations is to ensure a good working deviation in the subsequent examples, and thus more clearly illustrate the methods to be adopted in finding the deviation for a magnetic course.

ASCERTAINING THE DEVIATION

It is common practice and a wise precaution to keep a check on the deviations as obtained on adjusting compasses.

In the day to day sailing of a vessel many opportunities occur to find the deviation for the particular heading of the moment.

Azimuths.

Probably the most popular method of finding the deviation is to compare true and compass bearings or azimuths of a heavenly body.

The bearing of the body for example, the sun, is taken from the ship's compass. For the time of observation the true bearing or azimuth is worked out or obtained from tables. The difference between the figure the bearing should be, that is, the true bearing, and the actual value of the bearing observed, that is, the compass bearing, is the compass error. On applying the variation the balance of the error is the deviation which may be compared with the deviation given from the card for that heading.

Amplitudes.

When an astronomical body is rising or setting the azimuth becomes a special case. The operation is now to compare the true and observed amplitudes of the body. The calculation or table used is simpler than that for the azimuth.

Particulars of Azimuths and Amplitudes are found in text-books on navigation.

Transit Bearings.

If two fixed, charted objects are in transit the error may be found by comparing the true and compass bearings of the transit.

The transit bearing is taken on the ship's compass and the true direction of the line of transit noted from the chart. The difference is the compass error.

Other Methods.

The magnetic compass may be compared with a gyro compass. This, however, should only be used when no other method is practicable since the accuracy of the deviation obtained depends on the accuracy of the gyro compass.

Reciprocal bearings may be taken. This entails setting up a compass ashore or in a wooden or other non-metal boat. The outlying compass and the ship's compass take bearings of one another simultaneously on a pre-arranged signal. The ship's bearing is the 'compass bearing' and the outlying compass bearing reversed is the 'magnetic bearing'. Perhaps even a ship with a recently corrected compass could be used to take the reciprocals.

Reciprocal bearings are accurate but are not often used because of the inconvenience.

Thus, finding the deviation entails firstly finding the compass error. The application of the variation to the error gives the magnetic bearing and the difference between the magnetic bearing and the compass bearing is the deviation. Practical examples follow in this chapter.

ERROR OF THE COMPASS

The error of the compass is the horizontal angle which the compass needle makes with the true meridian. That is, it is the angle at the compass between the true meridian and the direction taken up by the compass needle.

As previously stated the variation and the deviation combine to form the error. Therefore its value is the sum or difference of the variation and deviation, according to whether they are of the same or opposite names. The causes of the existence of these quantities have already been explained.

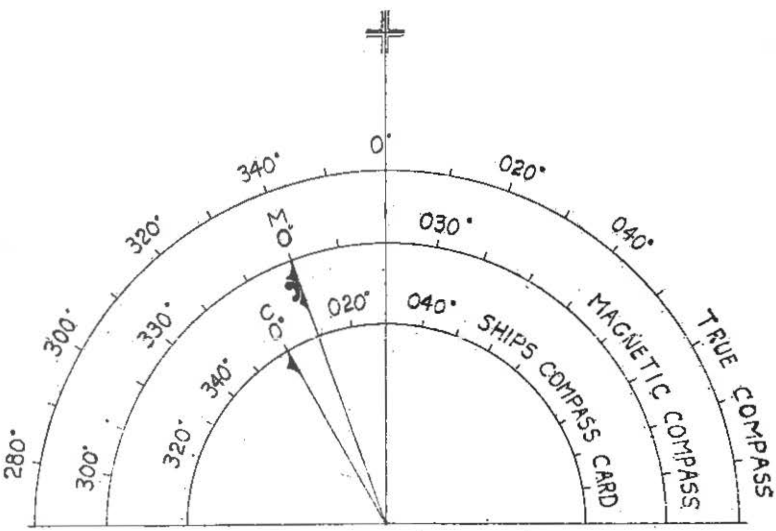


FIG. 10.1

Referring to fig. 10.1, the error of the compass is 30° West, the compass needle having been drawn to the westward of the true meridian 20° by the variation and 10° by the deviation.

The true course is 000°.
The magnetic course is 020°.
The compass course is 030°.

As the ship's head is turned in azimuth no change takes place in the value of the variation. Like circumstances, however, do not apply to the deviation; its value depends upon the direction in which the vessel is heading. Thus it follows that the error of the compass will vary as the ship's head is altered.

Suppose the variation to be 16° West and the deviation for the direction of the ship's head 4° East, the error of the compass will be 12° West. Due to the variation the North seeking end of the compass needle is drawn 16° to the westward of the true meridian and, now, from this position, on account of the deviation, it is drawn 4° to the eastward. The result is, therefore, the North point of the needle is drawn 12° to the West of the true North.

To obtain the error of the compass we have the following rule:—

Variation and deviation same names .. add.
Variation and deviation different names .. subtract.
Name the result the same as the greater.

Further Examples:—

Var. 10° E.	: Dev. 5° E.	*Therefore* Error = 15° E.
Var. 10° E.	: Dev. 5° W.	*Therefore* Error = 5° E.
Var. 2° E.	: Dev. 5° W.	*Therefore* Error = 3° W.
Var. nil	: Dev. 2° W.	*Therefore* Error = 2° W.

APPLICATION OF VARIATION, DEVIATION AND ERROR

Possibly the most common experience in chartwork is to be in possession of a true (or compass) course, values for variation and deviation and be required to find the compass (or true) course.

It is necessary to be able to change through compass, magnetic, true and through variation, deviation and error with the utmost agility.

It will be obvious to the student that he could draw a sketch similar to that in fig. 10.1 on each occasion but to do so would be cumbersome and time consuming. Instead, a much simpler 'rule of thumb', devised from the principle of fig. 10.1, is employed.

We can write down:—

True Magnetic Compass
Variation Deviation

and True Compass
Error

From this we can restate the fundamentals already enunciated in this chapter.

The difference between True and Magnetic is the Variation
The difference between Magnetic and Compass is the Deviation
The difference between True and Compass is the Error

The important rule is always to work in three-figure notation.

If the courses are given in quadrantal notation or in points of the compass the first thing to do is to turn them into three-figure notation and then work the calculation. If the courses are required in quadrantal notation or in points the calculation must first be worked in three-figure notation and then as a last step the courses changed to quadrantal or points.

The methods of work set out in this chapter will not hold good if this rule is not adhered to.

Fig. 10.2 shows a vessel heading up the true meridian. Her compass error is 10° W.

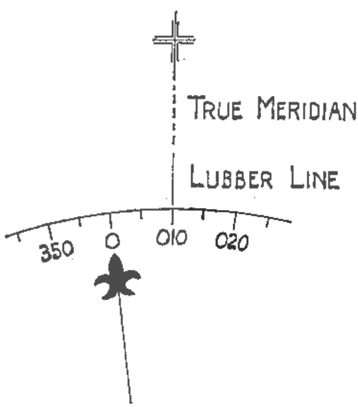


FIG. 10.2

From the diagram we can see that the compass course is 010°—and we are told that the true course is 000°.

Thus for a Westerly error the true course lies *numerically* to the left of the compass course and therefore lies to the left of it as plotted on the chart.

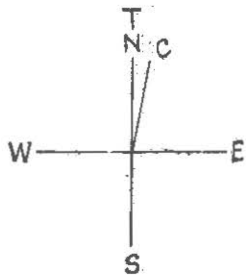


FIG. 10.3

If the above situation is illustrated with a small sketch as in fig. 10.3, then the direction 000° can be marked T. and 010° marked C.

This leads us to the 'rule of thumb' above-mentioned.

If the True is on the Left, the error is West.

It is hoped to show that this is all the reader will have to memorise in order to become adept at course correction.

Plainly if the True is on the Right, the error will be East.

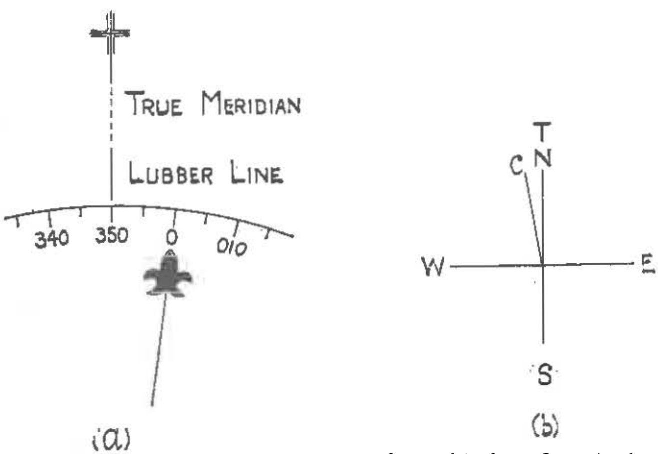


FIG. 10.4

Vessel steering up the true meridian, compass error 10° E., gives diagrams as shown in fig. 10.4 (*a*) and (*b*).

True course 000°. Compass course 350°. The true is on the right and the error is east.

Further Examples:—

1. Vessel steering 130° T. Error 15° W. What is her compass course?

The practical operation is for the reader to imagine himself standing at the centre of the figure. That is at the intersection of the NS/EW lines (Fig. 10.5). He looks out in the directions of the bearings.

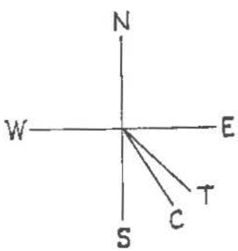


FIG. 10.5

'*T*' is laid off on 130° approximately. The error is West so the true must be on the left. Therefore the line indicating compass (*C*) must be on the right and so it can be seen that we must add the error.

True course	130° T.
Error	15° W.
Compass course	145° C.

2. Vessel steering 255° C. Error 5° E. What is the true course?

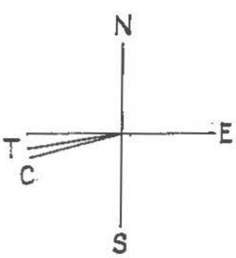


FIG. 10.6

Lay off '*C*', 255° approximately. (Fig. 10.6). The error is East so the true is on the right. Therefore the line indicating true (*T*) must be on the right and the error must be added.

Compass course	255° C.
Error	5° E.
True course	260° T.

3. Vessel steering 300° T. Her compass course is 290° C. What is the compass error?

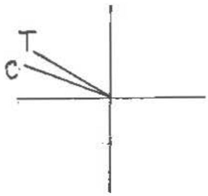


FIG. 10.7

From the diagram (Fig. 10.7) we can see that the true lies on the right and the error must be East.

True course	300° T.
Compass course	290° C.
Error	10° E.

True Magnetic Compass

Variation Deviation

The constituents of the compass error can be similarly dealt with if the True, Magnetic and Compass courses are thought of in 'degrees of trueness' or 'degrees approaching true'.

For instance, True is 'more true' than Magnetic
but Magnetic is 'nearer to true' than Compass.

Thus to apply the rule,

If the variation is West the true is on the left—
and the magnetic is on the right.

If the deviation is West the magnetic is on the left—
and the compass is on the right.

From which it follows that,

If the variation is East the true is on the right—
and the magnetic is on the left.

If the deviation is East the magnetic is on the right—
and the compass is on the left.

But if the reader memorises the rule 'If the True is on the Left, the Error is West' and thinks of the 'degrees approaching true' then all the others fall into place.

Some examples follow:—

1. Vessel steering 045° T. Her magnetic course is 050° M. What is the variation?

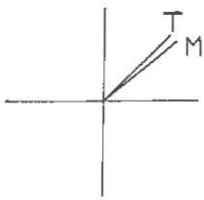


FIG. 10.8

The true lies along 045°: the magnetic along 050°.

The true is on the left so the variation must be west.

True course	045° T.
Magnetic course	050° M.
Variation	5° W.

2. Vessel steering 200° T. Variation 15° E. What is her magnetic course?

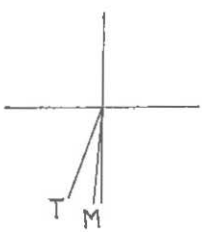


FIG. 10.9

The true lies along 200°. The variation is east so the true must be to the right. Therefore the line *M* is drawn in to the left of the line *T*.

True course	200° T.
Variation	15° E.
Magnetic course	185° M.

3. Vessel steering 030° M. Her compass course is 035° C. What is the deviation?

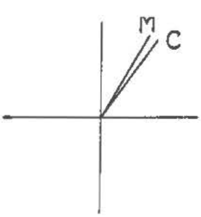


FIG. 10.10

The magnetic lies along 030°; the compass along 035°. Magnetic is 'nearer to true' than compass. The 'true' is on the left, so the 'error', in this case the deviation, must be west.

Magnetic course	030° M.
Compass course	035° C.
Deviation	5° W.

4. Vessel steering 320° M. Deviation 10° W. What is her compass course?

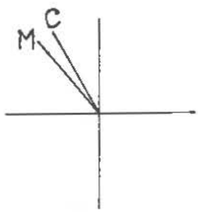


Fig. 10.11

The magnetic lies along 320°. The deviation is west so the 'true', in this case the magnetic, must be on the left. Therefore the line *C* is drawn to the right of the line *M*.

Magnetic course	320° M.
Deviation	10° W.
Compass course	330° C.

5. Vessel steering S. 20° E. by compass. Deviation 7° E. What is the magnetic course?

Compass course S. 20° E. = 160° C.

Compass lies along 160°. The deviation is east so the 'true', in this case the magnetic, must be on the right. Therefore the line *M* is drawn to the right of the line *C*.

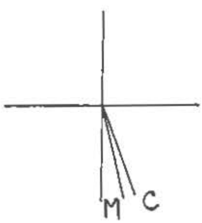


Fig. 10.12

Compass course	160° C.
Deviation	7° E.
Magnetic course	167° M.

—or S. 13° E. magnetic.

If the variation and deviation are both given they may be applied together as the compass error.

For Example:—

6. Vessel steering W.S.W. 'true'. Variation 13° E. Deviation 2° W. What is her compass course to the nearest point?

W.S.W. $= 270° - 22\frac{1}{2}°$
$= 247\frac{1}{2}°$ T.

Var.	13° E.
Dev.	2° W.
Error	11° E.

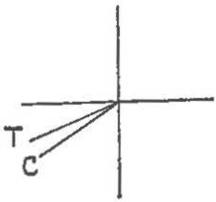


FIG. 10.13

True course	$247\frac{1}{2}°$ T.
Error	11° E.
Compass course	$236\frac{1}{2}°$ C.

—$236\frac{1}{2}°$ to the nearest point is S.W. × W.

True lies along $247\frac{1}{2}°$. The error is east so the true must be to the right. Therefore the line *C* is drawn to the left of *T*.

The greatest care is to be exercised in applying variation, deviation and error. It will be plain that should these be named wrongly, or applied the wrong way, serious consequences may result.

It is interesting to note that one of the advantages claimed of a properly compensated compass is that deviations on all headings will be small. Therefore it is possible for a deviation to be applied the wrong way and the ship still not stray far from her projected course, giving a chance for the matter to be rectified before mishap. However, this only applies to the deviation and it is possible, of course, for the variation to be a much larger quantity, thereby making the compass error substantial. This reduces the above-mentioned advantage to one of limited value.

True courses are normally taken off the chart either by using a compass rose or by matching the parallel rules on a meridian or parallel. These operations are described in Chapter IV.

Magnetic courses may also be taken off the chart by using the 'magnetic' compass rose. The reader is referred to fig. 4.1 and accompanying text.

If, however, the variation stated on the chart is for a year different from that in which the chart is in use, the magnetic course read off the chart must be adjusted for the change in variation which has occurred in the interval.

Example:—

The course read off the chart is 279° T. and the variation printed on the chart is 11° 10′ East (1964) increasing 10′ annually. Find the magnetic course for the year chart is in use, 1968.

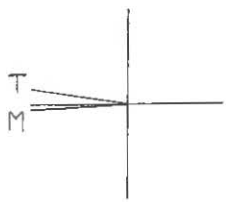


Fig. 10.14

To Correct Variation.

Given variation	11° 10′ E.
Increase = 10′×4 =	+ 40′
Correct variation	11° 50′ E.

To Find Magnetic Course.

True course	279° T.
Variation	12° E.
Magnetic course	267° M.

It is, however, important to realise that by far the most usual practice is for the magnetic course to be obtained arithmetically; that is simply by applying the variation to the true course in the manner previously described. The true course is taken directly from the chart and the variation is taken preferably from an Admiralty Variation Chart.

BEARINGS

The variation depends upon the locality and the year. The deviation, within the reservations already described in this chapter, depends upon the ship's head.

The variation is taken from the chart, preferably the Admiralty Variation Chart.

The deviation is taken from the deviation card and preferably verified with a recent check.

The two together give the error of the compass.

Now this error must be applied to bearings taken with the compass in the same way as it is applied to courses steered.

The rules described in this chapter for applying variation, deviation and error, hold good in the same way when correcting bearings as when correcting courses.

Remember that the compass error at any moment depends upon the ship's head. Thus the error to be applied to a bearing is the error derived from the present course. A common mistake when learning chartwork is to work out a separate deviation for each bearing. This with the variation applied gives a separate compass error for each bearing. A moment's thought will show that this is a grave error of principle.

Two examples will illustrate the procedure:—

1. From a vessel steering 030° by compass, a lighthouse was observed to bear 080° by compass. Find the true bearing of the lighthouse, assuming the variation to be 8° West and deviation for the direction of the ship's head 6° West.

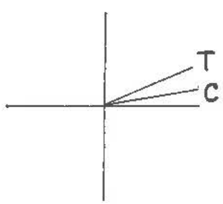


FIG. 10.15

Var.	8° W.
Dev.	6° W.
Error	14° W.

Compass bearing	080° C.
Error	14° W.
True bearing	066°T.

2. From a vessel steering 140° C. a beacon bore 100° C. and at the same time a lighthouse bore 176° C. Find the true bearings of the objects assuming the variation to be 12° E. and the deviation for the direction of the ship's head 4° W.

Var.	12° E.
Dev.	4° W.
Error	8° E.

Bearings

Beacon

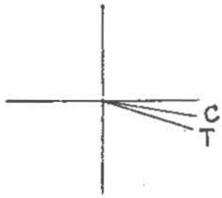


FIG. 10.16 (*a*)

Compass bearing	100° C.
Error	8° E.
True bearing	108° T.

Lighthouse

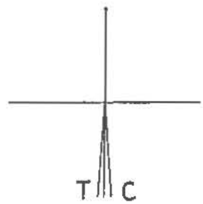


FIG 10.16 (*b*)

Compass bearing	176° C.
Error	8° E.
True bearing	184° T.

Magnetic bearings can, of course, be obtained by applying the variation to the true bearing or the deviation to the compass bearing.

Examples:—

1. From a vessel steering 200° C. a light bears 275° C. If the deviation for the direction of the ship's head is 10° W. find the magnetic bearing of the light.

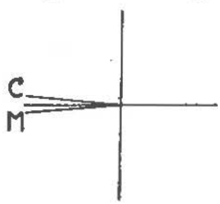


FIG. 10.17

Compass bearing	275° C.
Deviation	10° W.
Magnetic bearing	265° M.

2. An object bears 130° T. If the variation is 15° W.; find the magnetic bearing.

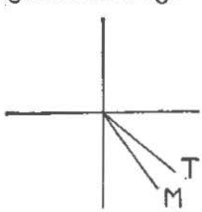


FIG. 10.18

True bearing	130° T.
Variation	15° W.
Magnetic bearing	145° M.

Similarly true and compass bearings can be obtained from magnetic bearings.

It will be appreciated that Relative Bearings, as described in Chapter XI (page 198) are not affected by compass error and 20° on the bow measured by a compass with no error is the same as 20° on the bow measured by a compass with a large error.

The pelorus or dumb compass card mentioned in Chapter III (page 64) is particularly useful in measuring relative bearings.

For practice in the application of variation, deviation and error the reader should now attempt Exercises 10.1 (*a*) and 10.1 (*b*) which appear on p. 184. Fill in the blank spaces in each line.

THE DEVIATION CARD

As stated earlier in this chapter most navigators will be in possession of a deviation card or curve drawn up for their particular vessels on adjusting compasses. The reader has now had practice in correcting courses and bearings. The next step is to demonstrate the uses of a deviation card.

Deviation cards are drawn up for Ship's Head by Compass. This leads to two possible uses of the card:—

(i) Finding the deviation for a given compass heading. This is sometimes referred to as 'using the deviation card directly'.

(ii) Finding the deviation for a given magnetic heading. This is less straight forward and is sometimes referred to as 'using the deviation card in reverse'.

Examples of each use follow and it is hoped will make the methods clear.

Note that it is usual to work to an accuracy of the nearest half degree.

Exercise 10.1 (*a*)

	Compass Course or Bearing	*Deviation*	*Magnetic Course or Bearing*	*Variation*	*True Course or Bearing*
1.	060°		065°		045°
2.		4° E.	300°		305°
3.		2° W.	200°	10° W.	
4.	133°			7° E.	135°
5.		2° E.	000°	2° E.	
6.		2° E.	000°	2° W.	
7.	002°		358°		007°
8.		6° W.	153°		153°
9.	268°			4° E.	272°
10.	182°		180°		178°
11.	090°	3° W.		15° E.	
12.	260°	Nil			260°

Exercise 10.1 (*b*)

	Compass Course or Bearing	*Variation*	*Deviation*	*Error*	*True Course or Bearing*
1.	N. 45° E.	10° W.	5° W.		
2.	S. 20° W.	20° E.			S. 45° W.
3.			2° E.	10° W.	S. 20° E.
4.	N. 22° W.	8° E.			N. 14° W.
5.	S. 55° E.	Nil	3° W.		
6.			7° E.	Nil	N. 04° W.

TO FIND FROM THE DEVIATION CARD THE DEVIATION FOR A GIVEN COMPASS COURSE

This is the direct use of the deviation card.

On many occasions it will be necessary to know the deviation for a direction of the ship's head not given on the deviation card in order that the course, or compass bearings taken on the course, can be laid down on the chart.

The method to be adopted is merely one of interpolation.

It is assumed that as the ship's head turns in azimuth the deviation changes in proportion to the alteration of course. Thus if an alteration of course of, say, 10° involves a change of, say, 3° in the deviation it is assumed the deviation changes $\frac{3°}{10}$ for each 1° change of ship's course.

When the deviations are small the deviation for any compass course can be taken out by inspection. To begin with, however, the method shown in the two following examples should be adopted.

Example 1:—

Using Deviation Card No. 1, find the deviation when the ship's head is 049° by compass.

Take from the card two compass courses which lie one on each side of the given compass course and as near to it as possible; these are N.E. (045°) and N.E. by E. (056° approx.), the deviations on these courses being 18° E. and 21° E. respectively.

Write down the courses and deviations in two columns as illustrated below.

	Compass Course	*Deviation*	
	045°	18° E.	
049°			19° E.
	056°	21° E.	
4°	11°	3°	

The difference between the two courses from the deviation card is 11°.

The difference between the two deviations from the deviation card is 3°.

The difference between the given compass course (049°) and one of the courses from the card, say the lower number (045°), is 4°.

Now treat the process of interpolation as a proportion sum, i.e.:—

Change of 11° in the compass course gives a change of 3° in the dev.

Change of 1° in the compass course gives a change of $\frac{3}{11}$ in the dev.

Change of 4° in the compass course gives a change of $\frac{4\times 3}{11}$ in the dev.

$=1°$ (approx.)

Now apply the change of deviation to the deviation on the selected compass course (in this case 045°), adding if increasing and subtracting if decreasing. The result is the deviation for the given compass course.

In this case the deviation is increasing, therefore the change (1°) is added and the deviation is found to be 19° E.

An alternative is simply to say that the required deviation is

$\frac{4}{11}$ ths of the way from 18° to 21°

and $\frac{4}{11}$ ths of 3° = 1° (approx.)

adding this 1° to the 18° gives us the deviation of 19°E.

Example 2:—

Using Deviation Card No. 2, find the deviation when the ship's head is S. 22° E. by compass.

Following the method described in Example 1:—

S. 22° E. is 158°

	Compass Course	*Deviation*	
	150°	2° E.	
158°			½° W.
	160°	1° W.	
8°	10°	3°	

The difference between the two courses from the deviation card is 10°. The difference between the two deviations from the deviation card is 3°. The difference between the given compass course (158°) and 150° is 8°.

Change of 10° in the compass co. gives a change of 3° in the dev.

Change of 1° in the compass course gives a change of $\frac{3}{10}$ in the dev.

Change of 8° in the compass course gives a change of $\frac{8\times3}{10}$ in the dev.

$= 2\frac{1}{2}°$ (approx.).

In this case the deviation changes from 2° E. to 1° W., i.e. 3°. The easterly deviation decreases to NIL, and thence the deviation becomes westerly, increasing.

Applying the change of 2½° to 2° E. the resulting deviation is ½° W. Thus the deviation on 158° (S. 22° E.) is ½° W.

Using the alternative method stated in Example 1:—

$\frac{8}{10}$ths of the way from 2° E. to 1° W. is ½° W.

$\frac{8}{10}$ths of 3 is 2½ (approx.)

2½° applied from 2° E. towards 1° W. gives ½° W.

Exercise 10.2

Using Deviation Card No. 1, find the deviation for the following compass courses.

1. N. 26° E..	4. S. 3° W.
2. 082°	5. 216°
3. S. 40° E.	6. N. 18° W.

TO FIND FROM THE DEVIATION CARD THE DEVIATION FOR A GIVEN MAGNETIC COURSE

This is the second and indirect use of the deviation card.

It has already been remarked that the deviation card shows the deviation for compass directions of the ship's head; moreover it has been illustrated how to find the deviation for compass courses other than those shown on the card.

Compass courses, however, cannot be taken directly off the chart. It is the true course or occasionally the magnetic course which is obtained therefrom. To set or head this course the corresponding compass course must be computed. This is accomplished in the case of a true course by first applying the variation and then finding the deviation for the magnetic course, thereby converting it into a compass course.

Deviations for magnetic courses are not found from the deviation card by direct interpolation. The procedure is best explained by going through an example.

Example 1:—

Using Deviation Card No. 1, find the deviation for a course of 054° magnetic and thence the compass course.

	Compass Course (*C*)	*Dev.* (*D*)	*Magnetic Course* (*M*)	
line 1	034°	15° E.	049°	049°
line 2	038°	16° E.	054°	054°
line 3	045°	18° E.	063°	
		3°	14°	5°

(i) Write down three columns, entitled Compass Course, Deviation and Magnetic Course. These are usually abbreviated to C, D and M.

Save three lines for each column.

(ii) In the middle line (line 2) of the third column (M), write down the given magnetic course, in this case 054°.

(iii) In the top and bottom lines (lines 1 and 3) select from the deviation card two adjacent compass courses, which with the deviations applied, will give two magnetic courses which straddle the given magnetic course, one above it and one below it. In this case the compass courses are 034° and 045° giving magnetic courses of 049° and 063° respectively.
Note that the two compass courses selected must be adjacent to each other. It will not do to miss one.

(iv) Take the difference between the top and bottom lines (lines 1 and 3) in columns D and M. In this case we get $18° - 15° = 3°$ and $063° - 049° = 14°$.

Also take the difference between the given magnetic course (i.e. 054°) and one of the calculated magnetic courses (i.e. 049° or 063°). Taking the lower number for this example we have $054° - 049° = 5°$.

(v) Now do a proportion sum similar to that explained in the preceding text for direct reading of the deviation card. In this case:—

A change of 14° in the mag. co. gives a change of 3° in the dev.

A change of 1° in the mag. co. gives a change of $\frac{3}{14}$ in the dev.

A change of 5° in the mag. co. gives a change of $\frac{5 \times 3}{14}$ in the dev.

$= 1°$ (approx.).

(vi) Now apply this change of deviation to the deviation associated with the calculated magnetic course which was selected. In this case 15° E. is the deviation associated with 049° M.

Add or subtract the change of deviation, as ascertained by inspection. In this case 1° is applied to 15° E. in the direction of 18° E.

That is, 1° is added to 15° E., giving 16° E., and this is the deviation for the given magnetic course.

As in the working for direct reading of the deviation card, it is again possible as an alternative to say that the required deviation is

$\frac{5}{14}$ths of the way from 15° to 18°

and $\frac{5}{14}$ ths of 3° = 1° (approx.)

adding this 1° to 15° gives us the deviation of 16° E.

(vii) The last step is to apply this deviation and obtain the required compass course. In this case 054° M. and deviation 16° E. gives 038° C.

Example 2:—

Using Deviation Card No. 1, find the compass course to steer to make N. 19° W. magnetic.

N. 19° W. magnetic is 341° M.

C.	*D.*	*M.*	
337½°	1° W.	336½°	
341°	0°	341°	341°
349°	2° E.	351°	351°
	3°	14½°	10°

(i) Write down the given magnetic course (341°) in the middle line of the third column as before.

(ii) Select two adjacent compass courses which with the deviations applied will straddle the given magnetic course, one above it, one below it. In this case 337½° (N.N.W.) and 349° (N.×W.)

are the compass courses giving magnetic courses of $336\frac{1}{2}°$ and $351°$ respectively.

(iii) Taking the differences as before we get $3°$, $14\frac{1}{2}°$, and $10°$. This time, for practice, the difference between the given magnetic course and the higher of the two calculated magnetic courses has been taken, i.e. $351° - 341° = 10°$.

(iv) Now by proportion:—

A change of $14\frac{1}{2}°$ in the mag. co. gives a change of $3°$ in the dev.

A change of $1°$ in the mag. co. gives a change of $\frac{3}{14\frac{1}{2}}$ in the dev.

A change of $10°$ in the mag. co. gives a change of $\frac{10 \times 3}{14\frac{1}{2}}$ in the dev.

$= 2°$ (approx.)

(v) Applying this $2°$ change in deviation to $2°$ E. in the direction of $1°$ W. gives $0°$ as the deviation for the given magnetic course. Note that in this example we are working from line 3 upwards.

Using the alternative method:—

The required deviation is $\frac{10}{14\frac{1}{2}}$ths of the way from $2°$ E. to $1°$ W.

and $\frac{10}{14\frac{1}{2}}$ths of $3°$ is $2°$ (approx.)

applying this $2°$ to the $2°$ E. gives us a deviation of $0°$.

(vi) As before the last step is to obtain the required compass course. In this case, <u>341° C.</u>

Hence the compass course to steer is the same as the magnetic course in this instance.

Example 3:—

Using Deviation Card No. 2, find the deviation for a magnetic course of N. 39° W. and thence the compass course.

Following the method described in the two previous examples:—

N. 39° W. magnetic is 321° M.

C.	*D.*	*M.*	
320°	10°W.	310°	
	7° W.	321°	321°
330°	6° W.	324°	324°
	4°	14°	3°

A change of 14° in the mag. course gives a change of 4° in the dev.

A change of 1° in the mag. course gives a change of $\frac{4}{14}$ in the dev.

A change of 3° in the mag. course gives a change of $\frac{3 \times 4}{14}$ in the dev.

$= 1°$ (approx.).

Applying 1° to 6° W. in the direction of 10° W., the required deviation comes to 7° W.

Alternatively:—

The required deviation is $\frac{3}{14}$ths of the way from 6° to 10°.

and $\frac{3}{14}$ths of 4° is 1° (approx.)

The deviation therefore is 7° W. and the compass course is 328° C.

Exercise 10.3 (*a*)

Using Deviation Card No. 1, find the compass course to steer in order to make the following magnetic courses:—

1. N. 39° E. Magnetic
2. N. 80° E. ,,
3. S. 73° E. ,,
4. S. 39° E. Magnetic
5. S. 5° E. ,,
6. S. 10° W. ,,

Exercise 10.3 (*b*)

Using Deviation Card No. 1, find the compass course to steer in order to make the following true courses:—

	True Course	*Var.*		*True Course*	*Var.*
1.	220°	10° W.	4.	317°	3° W.
2.	277°	10° E.	5.	001°	15° E.
3.	290°	2° E.	6.	345°	5° W.

LEEWAY IN THE CORRECTION OF COURSES

The application of leeway is described earlier in this book; initially in Chapter IV and also in Chapter V. Types of problems dealt with incorporating leeway are, Course to Steer to Counteract a Current; Running Fix; Set and Drift.

Often when correcting courses it will be found that account must be taken of leeway. An alteration of the ship's head probably means an alteration in the deviation and thence the error.

The manner in which leeway affects the correction of courses may be illustrated in two examples.

Example 1:—

Vessel steering 050° C., Var. 10° W. Dev. 5° W., making 7° of leeway due to a strong S.E.'ly wind. Find the true course steered and the course made good.

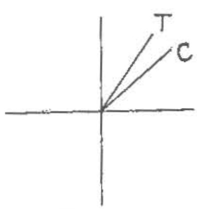


FIG. 10.19 (*a*)

Var.	10° W.
Dev.	5° W.
Error	15° W.

Compass course	050° C.
Error	15° W.
True course	035° T.

The vessel is therefore heading 035° T. but she is being blown 7° down-wind by the S.E.'ly breeze.

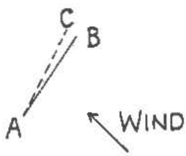


FIG. 10.19 (*b*)

Thus in fig. 10.19 (*b*) the ship is heading in the direction *AB* (035° T.) but is actually proceeding along the line *AC*, which as can be seen must be 028° T.

True course	035° T.
Leeway	7°
Leeway course	028° T.

Therefore 028° T. is the course made good,

and 035° T. is the true course steered.

Example 2:—

Place *B* lies due North-East of place *A*. A ship wishes to proceed from *A* to *B*. Using Deviation Card No. 2 and allowing for 7° of leeway due to a strong S.E.'ly wind, find the compass course to steer in order to make good the course. Var. 10° W.

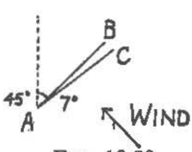


FIG. 10.20

Vessel wishes to make good *AB*. Therefore she must head up into the wind by the amount of the leeway so that she will proceed along *AB* while actually heading in the direction *AC*.

T. course to make good	045° T.
Leeway	7°
Course to steer to counteract leeway	052° T.

052° is the direction the ship must head. Therefore the deviation which must be obtained from the card is the deviation which corresponds with that true course.

		C.	*D.*	*M.*
True course to steer	052° T.			
Var.	10° W.	040°	13° E.	053°
		048°	14° E.	062°
Magnetic course to steer	062° M.	050°	14° E.	064°

In this case it can be seen by inspection that the required deviation is 14° E. (to the nearest half degree) and the compass course is therefore 048° C.

Magnetic course	062° M.
Dev.	14° E.
Compass course	048° C.

Therefore the required compass course to steer is 048° C.

Exercise 10.4 (*a*)

Given the following information, find the True Courses made good:—

	Compass Course	*Var.*	*Dev.*	*Direction of Wind*	*Leeway*
1.	022°	8° E.	2° E.	E.	5°
2.	247°	9° W.	3° E.	S.	4°
3.	331°	15° E.	4° W.	W.N.W.	8°
4.	156°	Nil	2° W.	S.W.	10°
5.	S. 80° E.	5° W.	6° W.	N.N.E.	2°
6.	N.W.×N.	1° W.	3° E.	N.E.	2°
7.	N. 03° E.	8° W.	Nil	W.	6°
8.	S.×E.	17° E	2° W.	N.	Nil

Exercise 10.4 (*b*)

Using Deviation Card No. 2, find the Compass Courses to steer in order to make good the following True Courses:—

	True Course required to make good	*Direction of Wind*	*Leeway*	*Var.*
1.	070°	N.	5°	2° W.
2.	180°	W.	10°	5° E.
3.	272°	S.	3°	10° W.
4.	155°	S.W.	6°	7° E.
5.	335°	N.E.	7°	5° W.
6.	004°	W.	7°	8° W.
7.	S. 48° E.	E.	2°	Nil
8.	S.×W.	S.E.	Nil	12° E.

CHAPTER XI

RADIO BEARINGS

THE plotting of radio bearings and the subsequent use of such bearings forms an important part of chartwork. Radio bearings are particularly useful in coastal waters where in restricted visibility they may be the only means of ascertaining a position.

There are two methods of obtaining radio bearings.

(*a*) Shore-based direction finding equipment takes a bearing of the ship. This requires prior and subsequent radio communication and the ship must transmit to enable the shore station to take the bearing.

(*b*) The ship uses her own direction finding apparatus to take a bearing of a shore station or beacon.

The setting up of a world-wide system of radio beacons has made the use of shipborne DF apparatus so convenient that the practice of having shore-based equipment take the bearing has virtually been superseded and has largely disappeared from everyday use. Indeed as has been remarked in Chapter II, the service has been discontinued in the U.K., as in some other countries. However, it is worth noting that a bearing received by a shore station from a ship should be relatively error-free as compared with a bearing received by a ship from a shore station. The great advantage of shipborne equipment is the convenience which its independence gives especially when combined with automatic radio beacons ashore. As a safety feature all vessels of 1600 gross tons and over are required to be fitted with their own radio direction-finding apparatus.

Types of radio stations and beacons shown on charts are listed in Chapter II under the heading of Radio and Radar Stations. Details of these stations appear in the *Admiralty List of Radio Signals*. Most light-vessels (or their succeeding structures or buoys) operate a radiobeacon service. Ocean weather ships are equipped to do so but often the service is on request in emergency only.

ERRORS AND ADJUSTMENTS OF RADIO BEARINGS

Before attempting to plot radio bearings it is important to appreciate the errors and adjustments to which a bearing is subject. A bearing as noted by the DF operator must be corrected and adjusted before it can be plotted on the chart. For some errors no compensation is possible by the chart-user.

It is proposed to give a brief description of each error or adjustment inasmuch as it affects chartwork. The steps in the practical correction of a radio bearing will be shown in the process. As will be seen, some of the errors are due to the ship; others are inherent in the wave.

Relative Bearings.

In dealing with radio bearings it is important that the reader understands what is meant by a relative bearing.

A Relative Bearing is defined as the angle at the observer contained between the ships fore and aft line and the line of bearing through the object, measured round to starboard from the ship's head.

e.g.—In fig. 11.1 Relative Bearing of *A* is 70°
" " " *B* is 310°

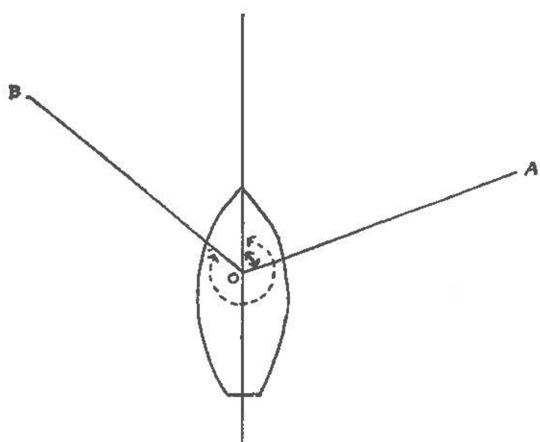


FIG. 11.1

An alternative way of expressing relative bearings sometimes used, is simply as the angle on the particular bow. For example, in fig. 11.1 the relative bearing of *A* would be referred to as Green 70 and of *B* as Red 50.

Leeway.

On considering the definition of a relative bearing it will be seen that when applying such a bearing it is immaterial whether the ship is making leeway or not.

e.g. Vessel steering 040° T., Relative Bearing 100°, Wind N.W., Leeway 10°. Find the True Bearing.

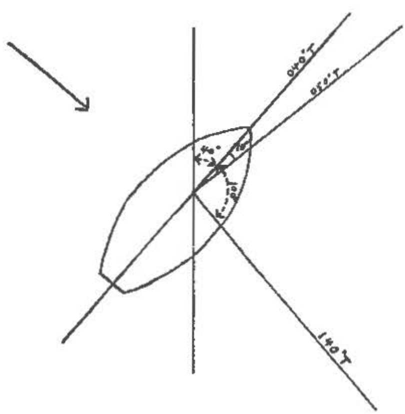


FIG. 11.2

The vessel is heading along the line of 040° but actually travelling along the line of 050°. However, as the relative bearing is measured from the ship's head the true bearing remains unaffected at 140° T.

A ship steering a course to counteract the effect of leeway would similarly apply the relative bearing only with respect to the ship's head.

Quadrantal Error.

Radio Bearings taken with shipborne apparatus are liable to read slightly in error due to the wireless wave being affected by the metal of the ship. The main error caused is quadrantal in nature it being greatest when the wave approaches the ship on the bows and quarters, least when the wave approaches the ship from ahead, astern or abeam. The error, therefore, is measureable on relative bearing and is independent of the true direction of the incoming wave. The effect is known as Error-Due-To-The-Ship or more generally, Quadrantal Error.

At intervals the ship's DF equipment is 'calibrated' for quadrantal error. That is, the ship is swung within sight of a radio station or beacon and visual bearings and DF bearings are taken simultaneously on each heading. Comparison of these will reveal the error of the DF on each point and a curve of quadrantal errors may thus be drawn up.

As quadrantal error depends upon the angle the incoming wave makes with the ship's fore and aft line, it is advantageous to have shipborne DF equipment measure the relative bearing. The value of the quadrantal error for this bearing is then taken from the calibration curve and the true bearing found.

Example:—

Ship steering 190° T. Relative Bearing 320° Quad. Error —2°

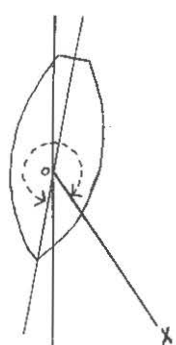


FIG. 11.3

Rel. Bearing obtained from DF equip.	320°
Q.E. obtained from Calibration Curve	−2°
∴ Correct Relative Bearing	318°

Ship's head at time of bearing	190° T.
Correct Relative Bearing	318°
	508
	360
∴ True Bearing of Station or Beacon	148° T.

Sense.

In receiving a radio bearing it is important to remember that there is a possibility of an error of 180° in the bearing. The DF apparatus measures two possible directions from which the radio wave may have arrived. These directions should be on exactly opposite points of the compass but due to the errors of the ship they may not be exactly 180° apart as measured. Plainly if the wrong bearing of the two is used results could be serious. To eliminate this 180° ambiguity a Sense Unit is incorporated in the DF set. Navigators, however, will seldom be in doubt as to which bearing should be used.

Later DF equipment is able to present automatic bearing indication on tuning into the station. The navigator is thus relieved of the obligation to select one of two possible directions, the sensing being accomplished automatically.

Great Circles.

Radio waves naturally flow out from their source in the most direct manner. Those waves which travel over the earth's surface do so along tracks which are great circles. Therefore a signal received by a ship from a station will have reached the ship along the great circle track from station to ship. The same is true of course when a wave travels from ship to shore.

In the preceding section on quadrantal error, the numerical example resulted in a true bearing. This true bearing is therefore a great circle bearing and as such is unsuitable for laying off on a Mercator's chart. Note that it is in fact a true bearing. The great circle bearing is the true bearing; but as the navigator must plot on a Mercator's chart an adjustment is necessary in order to change the bearing into a form suitable for use on such a chart.

No attempt should be made to plot radio bearings on Gnomonic charts. Although great circles appear as straight lines on these charts true directions are maintained only at the point of contact (Fig. 1.3).

A Great Circle Bearing is the angle at the observer between the observer's meridian and the great circle in question. It is usually quoted in the 360° notation.

The adjustment to apply to the great circle bearing is called the half convergency and the resulting line is called the mercatorial bearing, which is in fact a rhumb line.

On a Mercator's chart a great circle is represented by a curved line curving towards the poles. The curvature is greatest when both points are in the same latitude, and is zero when both points are in the same longitude; a meridian on a Mercator's chart is represented by a straight line. Details of great circles and Mercator's charts are among the subjects discussed in Chapter I.

On the surface of the Earth the meridians converge and meet at the poles. A great circle will, therefore, make a varying angle as it crosses each meridian, and the difference in the angle which it makes with any two meridians is called the convergency.

In fig. 11.4, great circle XY cuts meridians PQ and PR at A and B respectively. $\angle$**a** and $\angle$**b** are the angles which the great circle makes with each meridian. As can be seen the value of the angle of cut changes with each meridian. The angle will have a value of 90° at the vertex of the great circle.

The convergency between meridians PQ and PR is the difference between $\angle$**a** and $\angle$**b**.

i.e. Convergency $= \angle b - \angle a$

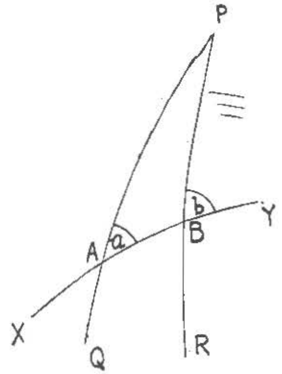


FIG. 11.4

The angle of convergency will vary depending upon the difference of latitude and the difference of longitude between the points of intersection of the great circle. Its approximate value can be calculated from the formula:—

Convergency = d. long. × sin mean lat.

It can be shown that the mean mercatorial bearing of the one point from the other differs from the true great circle bearing by half the convergency.

Fig. 11.5 represents part of a Mercator's chart.

GC is the great circle track between *A* and *B*.

M is the mercatorial line of bearing or rhumb line between *A* and *B*.

It can be shown that ∠**c** is equal to half the convergency between *A* and *B*.

i.e. True great circle bearing ± half convergency = mean mercatorial bearing.

The value of this half convergency correction may be arrived at by solving the convergency formula and taking half the answer. It is also commonly obtained from a half convergency table which is included in virtually all Nautical Tables and in many other nautical publications. A 'half-convergency diagram' and the traverse table are other sources of solution.

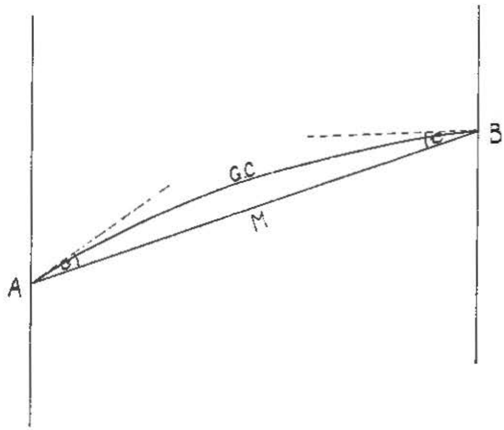


FIG. 11.5

Thus the mercatorial bearing is taken as a position line and this is accurate for practical purposes at ranges likely to be used, while taking account of the other limitations of radio bearings.

While this is adequate over short distances (up to about 100 miles in normal latitudes) it is not an advisable way of obtaining the position line over longer distances. With long distance radio bearings as described later in this chapter, when the ship takes the bearing of the station, the true position line is in the form of a line joining points of equal great circle bearing of the station; the curve of constant bearing. If a station takes a bearing of a ship the position line is part of the great circle which extends outwards from the known position of the station, along the bearing.

The application of the half convergency correction sometimes gives trouble. Many navigators memorise the rule that the half convergency correction is always applied towards the equator. Others, however, find this confusing. An infallible method is to draw out each individual case and from the drawing decide which way to apply the correction.

Remember that on a Mercator chart the mercatorial bearing is a straight line, the great circle bearing curves polewards from the mercatorial bearing and the angle between the two bearings at the ship or station is the half convergency.

Examples for each hemisphere will illustrate the manner in which great circle bearings should be corrected:—

The following convention has been adopted in the sketches comprising fig. 11.6.

SH	—	the ship.
ST	—	the radio station.
P	—	the pole.
GC	—	the great circle, joining ship and station.
M	—	line of mercatorial bearing ship/station.
←——→	—	the great circle bearing.
←- - -→	—	the mercatorial bearing.
)	—	the half convergency.

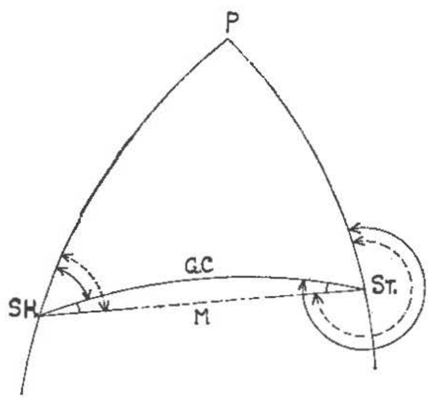


FIG. 11.6 (*a*)

Fig. 11.6 (*a*).

Northern Hemisphere—If the ship takes the bearing of the station the half convergency correction will have to be added to the great circle bearing to give the mercatorial bearing.
If the station takes the bearing of the ship the half convergency correction will have to be subtracted from the great circle bearing to give the mercatorial bearing.

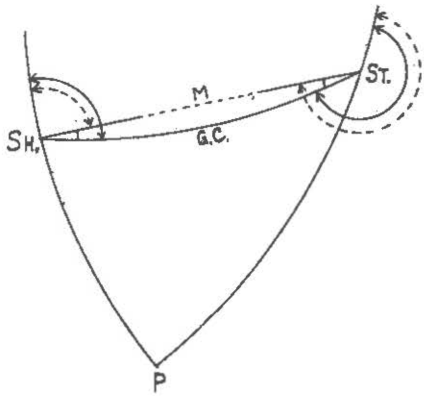


FIG. 11.6 (*b*)

Fig. 11.6 (*b*).

Southern Hemisphere—If the ship takes the bearing of the station the half convergency correction will have to be subtracted from the great circle bearing to give the mercatorial bearing. If the station takes the bearing of the ship the half convergency correction will have to be added to the great circle bearing to give the mercatorial bearing.

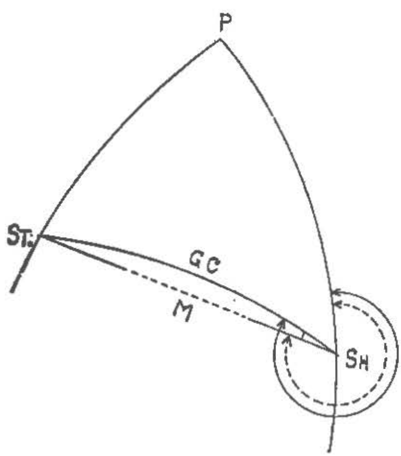


FIG. 11.6 (*c*)

Northern Hemisphere—Great circle bearing of station from ship 300°. Half convergency 1°. What is the mercatorial bearing?

[See fig. 11·6 (*c*)]

Great circle bearing of station	300°
Correction	−1°
Mercatorial bearing of station	299°

Southern Hemisphere—Great circle bearing of ship from station 303°. D. long. 1° 40′. Mean lat. 40°. What is the mercatorial bearing?

[Fig. 11·6 (*d*)]

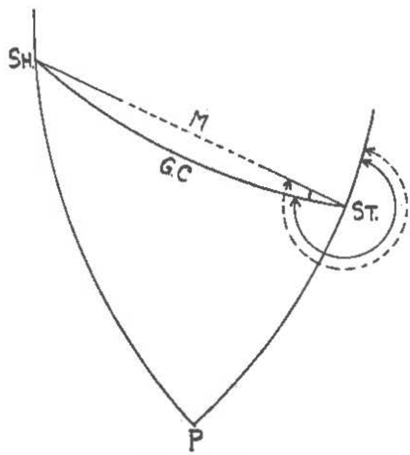


FIG. 11.6 (*d*)

Correction to apply $= \frac{1}{2}$ d.long. × sin mean. lat.

$= \frac{1}{2} \times 100' \times 0{\cdot}6$

$= 30'$

Great circle bearing of station	303° 00′
Correction	+ 30′
Mercatorial bearing of station	303° 30′

Coastal Effect.

In a similar manner to light waves entering the earth's atmosphere, radio waves suffer a refraction or bending as they cross from land to sea and vice versa. Thus stations should be sited on the coast and if a bearing is taken where the wave crosses islands or comes along a coastline it should be borne in mind that the result is likely to be in error. This is sometimes referred to as Coastal Effect.

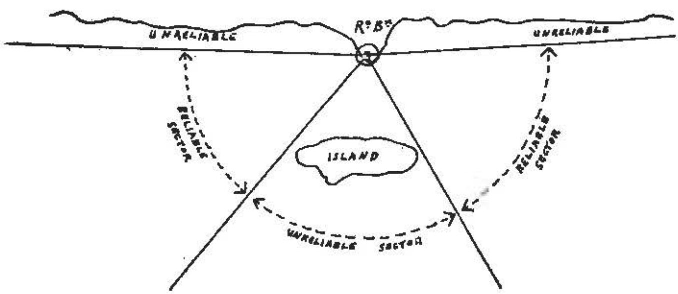


FIG. 11.7

Sky Waves.

Shipborne DF apparatus is designed to receive direct ground waves; that is radio waves which have come along the surface of the earth. It frequently happens that waves which have been reflected from layers above the earth's surface are received either in place of or together with ground waves. Such reflected energy is called a sky wave and its effect is to cause the DF set to read in error. Such an error is called 'sky wave effect'. It is occasionally called night effect, reflections being worse at night and worst around sunrise and sunset.

Sky wave effect is likely to increase with distance from the transmitting station and the errors caused are unpredictable. The effect is generally not serious up to 25 miles by night, 100 miles by day, although good bearings are often obtained up to 300 miles by day. The Admiralty List of Radio Signals gives the recommended maximum range for each radio beacon; in some cases a day and night range is given.

Long-wave signals travel furthest along the surface of the earth, providing the greatest range for ground-wave reception. Sky wave effect is also likely to be less pronounced in long wavelengths. Coastal radiobeacons, however, generally operate on medium wave (the lower wavelengths of the medium wavebands being used) since many of the vessels which will make most use of such radio beacons are fitted only with medium frequency receivers.

Classes of Bearing and Fix.

Radio direction-finding stations as mentioned in Chapter II (page 52), transmit their bearings to vessels as true bearings and in three-figure notation. For example, if a ship is due south-east of a radio direction-finding station the station on taking a bearing of the ship would transmit the bearing as 135°.

Such stations may indicate the estimated accuracy of a bearing by appending a class letter:—

Class A bearing — within ± 2°

Class B bearing — within ± 5°

Class C bearing — within ± 10°

Class D bearing — more than 10°

Thus the above-mentioned bearing may be received as 135B.

Shipborne DF operators may similarly report the class of a bearing.

When two or more radio direction-finding stations take simultaneous bearings of a vessel, one station, the control station, shall indicate the estimated accuracy of the fix by transmitting a class letter:—

Class A fix — within 5 miles of the true position.

Class B fix — within 20 miles of the true position.

Class C fix — within 50 miles of the true position.

Class D fix — not within 50 miles of the true position.

Worked Example of a Practical Radio Bearing.

A vessel approaching the Firth of Forth, steering 299° C. at 10 knots and in D.R. position Lat. 55° 50′ N., Long. 00° 30′ W. takes a bearing of Isle of May radiobeacon (Lat. 56° 11′ N., Long. 2° 33′ W.) with her DF apparatus. The relative bearing is 007°, quadrantal correction −2°, compass error 14° W., and the vessel is allowing for 5° of leeway due to a strong N'ly wind. Find the bearing of the station to lay off on the chart.

Compass course	299° C.	Relative bearing	007°
Error	14° W.	Quadrantal correction	− 2°
True course	285° T.	Corrected relative bearing	005°

True course	285° T.
Corrected relative bearing	005°
Great circle bearing	290° T.

	Station	Lat.	56° 11′ N.	Long.	2° 33′ W.
(D.R.)	Ship	Lat.	55° 50′ N.	Long.	0° 30′ W.
		D. lat.	21′	D. long.	2° 03′
		½ D. lat	10·5′	D. long.	123′
		Mean lat.	56° 00·5′ N.		

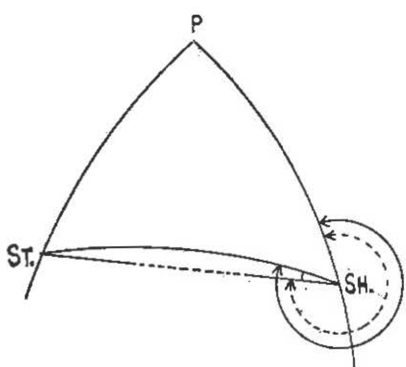


FIG. 11.8

$$
\begin{aligned}
\text{Half convergency} &= \tfrac{1}{2}\ \text{d. long. sin mean lat.}\\
&= \tfrac{1}{2}\times 123'\times \sin 56^\circ\ 00{\cdot}5'\\
&= 61{\cdot}5\times 0{\cdot}829\\
&= 51'\ (0{\cdot}8^\circ \text{ to one decimal place})
\end{aligned}
$$

Great circle bearing	290·0° T.
Half convergency	–0·8°
Mercatorial bearing	289·2° T.

Therefore the bearing of the Isle of May radiobeacon to lay off on the chart is 289·2° T.

USE OF RADIO BEARINGS

From the preceding discussion in this chapter it will be clear that radio bearings do not provide an infallible means of obtaining a position. However, the navigator will find that used within their limitations and accurately plotted on his chart, radio bearings provide an extremely useful and often accurate aid to navigation.

A radio bearing when plotted on a chart is a position line and as such may be used in conjunction with other position lines, whether terrestrial or astronomical, to give a fix.

Possible types of position lines with which a radio bearing may be crossed include a visual bearing of a shore object, an astronomical position line, a hyperbolic position line and, of course, another radio bearing. Details of these position lines appear in appropriate sections of this book.

If at least three widely divergent position lines can be employed and the resulting 'cocked hat' is small, considerable reliance may be placed on a fix. Such a fix may be comprised solely of radio bearings or may incorporate one or more radio bearing.

A radio bearing may be used in a running-fix. Another important use is as a single position line as described in Chapter VIII.

Homing.

Vessels sometimes employ the technique of 'homing' by DF. By this is meant making the relative bearing of the station zero and steaming so as to keep it that way. In other words the vessel steers straight for the station. For fairly obvious reasons this is not generally an advisable practice in poor visibility with shore stations and light vessels but homing can be used to advantage on special occasions, for instance, when proceeding to the assistance of a vessel in distress; an instance when the sense unit will also be handy.

A development in this field is a 'distress watch' device which automatically locks an unattended, automatic direction finder on to the bearing of a vessel transmitting a distress signal. The device is connected with and actuated by the auto-alarm receiver.

Practical applications of radio bearings in chartwork problems will be seen in the Examples for Exercise papers at the end of the book.

LONG DISTANCE RADIO BEARINGS

Radio stations which transmit long-wave signals and whose signals are powerful enough offer scope for the reception of long distance DF bearings.

Long-wave signals appear to bend round the surface of the earth with the result that the ground wave can be received at great distances. In addition long-wave signals are likely to be less affected by sky waves at greater distances than are the normal medium-wave radiobeacon transmissions.

This aspect, combined with the use of a cathode ray tube bearing display on receiving equipment, has enabled long-range bearings to be considered a feasibility. Cathode ray tube or visual presentation does not, of course, eliminate sky waves but the operator is in a much more favourable position for assessing sky-wave effect and the anomalous conditions are clearly indicated on the display.

Examples of stations which may be used are radio broadcast stations, Loran C stations and Consol stations.

Fig. 11.9 depicts some presentations as they may appear on the cathode ray tube display of a visual direction finder with provision for long wave/long range reception.

Fig. 11.9 (*a*)—A normal bearing. Steady while the long dash lasts.

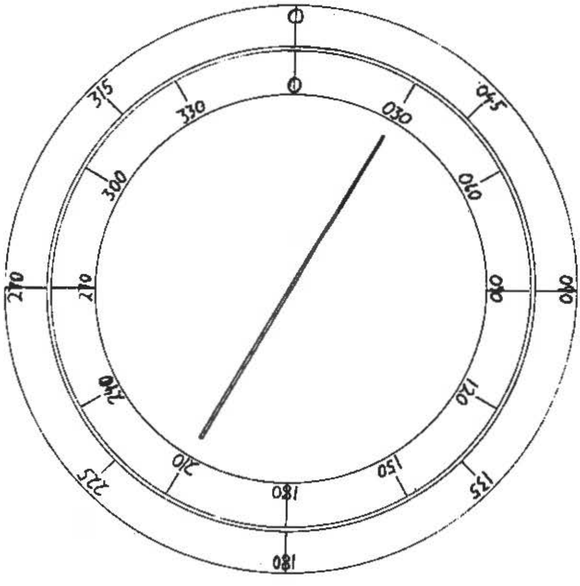


Fig. 11.9 (*a*)

Fig. 11.9 (*b*)—Interference. The required bearing is in a direction parallel to either the long sides or the short sides of the parallelogram.

Fig. 11.9 (*c*)—Reception of 'pulse' signals from stations transmitting on the same frequency. An example of this would be Loran C stations which, as mentioned in Chapter XII, all transmit on the one radio frequency. Thus all line indications will appear on the screen together. With pulse signals the length of the line varies according to the rhythm of the pulse. In the case of Consol signals

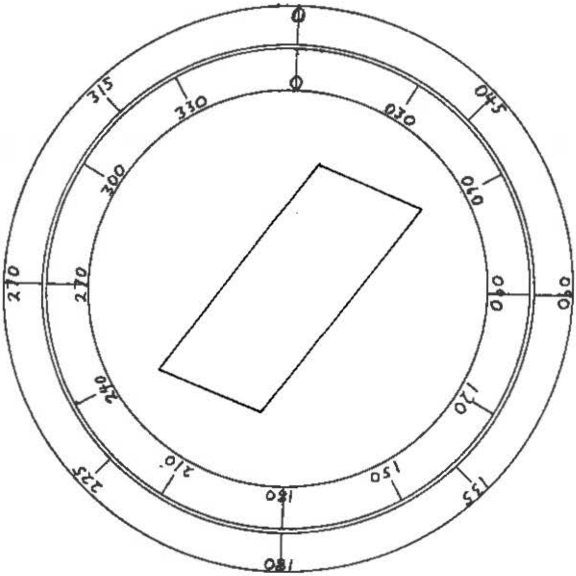


FIG. 11:9 (b)

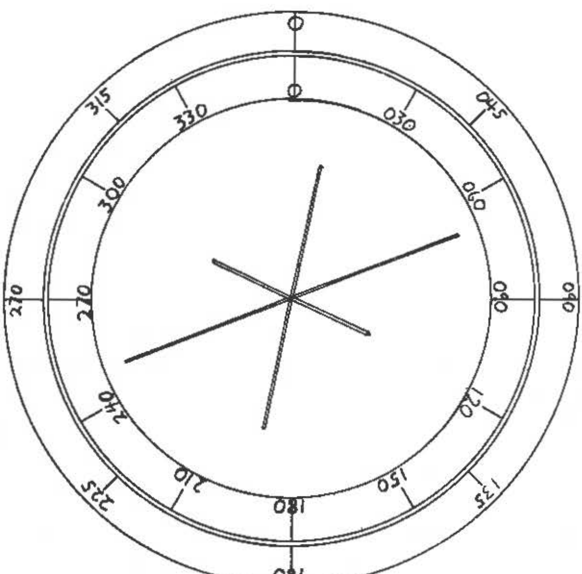


FIG. 11.9 (c)

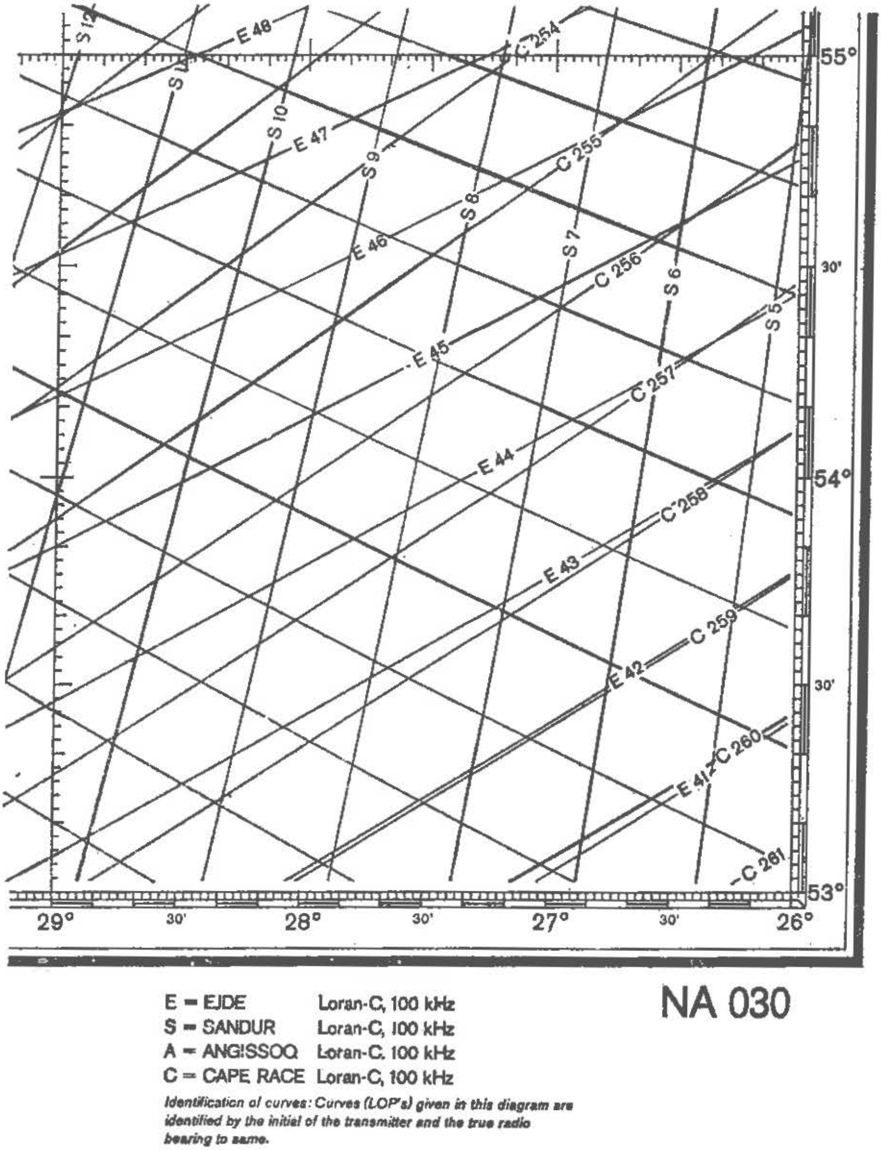


PLATE 11·1

[To face page 215

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(Chapter XII) this provides a convenient means of 'taking the count', (see page 241).

Long distance radio bearings are taken as relative bearings and quadrantal correction must be applied as described earlier in this chapter. A sensing arrangement is also still required to be fitted.

Because of the distance involved and because the ship takes the bearing of the station the position line in this instance can only be taken as, from first principles, the line joining all points on the earth's surface from which the great circle bearings of the station are the same. Such a line is often known as a Curve of Constant Bearing. While it is possible to arrive at this position line by a variety of means and to plot it on an ordinary ocean chart, position fixing is facilitated by the use of special radio plotting charts or diagrams. These charts are of relatively small areas of ocean and are on Mercator's projection. No attempt is made to show soundings. They resemble lattice charts, the lattice lines in this case are lines of equal great circle bearings of given stations; Curves of Constant Bearings.

Plate 11.1 shows a portion of a radio plotting chart of the central North Atlantic area. The stations catered for are Loran C stations. Everywhere on the line marked E 44 the great circle bearing of the station Ejde will be 044° T. Note that the lines are not great circles nor are they mercatorial bearings. They are position lines in the form of lines joining all points where the great circle bearing of a given station is a stated amount. That is, the line marked C 258 is the line joining all points where the great circle bearing of Cape Race is 258° T.

Ocean weather ships and their plotting grids are also shown on the charts. At the time of writing the North Atlantic and North Sea are the areas covered.

The reader will appreciate that with the visual display and the radio plotting chart rapid results are possible under favourable conditions. This is especially so with Loran C stations where all the bearings appear on the screen at the one time.

A further series of charts is also published, being an extension of the idea in the first series. In these 'one sight' diagrams the grid is made up of 'lines of equal difference in bearing' between two stated stations, the Loran C stations being particularly in mind.

For example, a chart may cater for three stations, *A*, *B* and *C*. From the DF equipment the navigator notes the *difference* in the corrected relative bearings of *A* and *B* and of *B* and *C*. Let us say these differences come to 120° and 95° respectively. The chart is then consulted and the intersection of position lines *A*/*B* 120 and *B*/*C* 95 gives the fix.

Exercise 11.1

1. A ship in D.R. position, Lat. 50° 00′ N., Long. 06° 20′ W. received a radio bearing from a shore station in Lat. 52° 00′ N., Long. 2° 20′ W. of 230°. What bearing must be laid off from the shore station?
2. A ship in D.R. position, Lat. 40° 20′ S., Long. 176° 00′ E, receives a radio bearing from a shore station in Lat. 42° 40′ S.. Long. 178° 00′ W. of 300°. What bearing must be laid off from the shore station?
3. A ship is steering 340° C., Var. 10° W., Dev. 5° E. and is making 10° of leeway due to a strong Westerly wind. She is in D.R. position, Lat. 52° 10′ N., Long. 12° 30′ W. and she takes a relative bearing of a shore radio station with her DF loop. The bearing taken is 085°, quad. corr.+5°. The radio station is in Lat. 54° 10′ N., Long. 05° 30′ W. What is the bearing of the radio station from the ship to lay off on the chart?
4. A ship is steering 120° C., Var. 10° E., Dev. 5° E. and is making 5° of leeway due to a strong N. E'ly wind. She is in D.R. position, Lat. 61° 20′ S., Long. 178° 40′ W. and she takes a relative bearing of a shore radio station with her DF apparatus. The bearing taken is 145°, quad. corr.−5°. The radio station is in Lat. 60° 20′ S., Long. 174° 20′ E. What is the bearing of the ship from the radio station to lay off on the chart?

CHAPTER XII

LATTICE CHARTS

THERE are a number of Electronic or Radio Aids to Navigation which give a position line of a less straightforward type to the familiar astronomical or terrestrial position line. These position lines are called hyperbolae or hyperbolic lines and the navigator under normal circumstances would be unable to draw them off on his Mercator's chart. To overcome this diffculty, in the regions covered by each radio aid, the British Admiralty supply certain of their charts superimposed with the hyperbolic position lines. Charts for systems adjoining other countries are also produced by the Hydrographic Departments of the Nations concerned.

The superimposed pattern of lines is sometimes called a grid or a lattice and a chart of this type is referred to as a lattice chart.

Sometimes, as a temporary measure, an overlay featuring a lattice may be available for an unlatticed chart.

Admiralty Lattice Charts bear the prefix *L*. At the time of writing the system adapted is as follows:—

Decca charts bear the same number as the basic chart from which they are prepared. Decca charts are issued as fully navigational and are correctible from Admiralty Notices to Mariners in the same way as the ordinary unlatticed chart. A vessel may consequently be navigated directly from a Decca lattice chart. The chart is prefixed by 'L', meaning latticed, followed by a bracket containing 'D', meaning Decca and the number of the chain.

This number may be a whole number or a whole number and a half, depending on the full chain number and letter as mentioned below. The letter is not used directly in the chart numbering system.

e.g. (1) The chart of the Orkney Islands, latticed for the North Scottish Chain (Chain 6C) is entitled L(D6) 2180.

(2) The chart of the Gulf of Bothnia, latticed for the North Bothnian Chain (Chain 5F) is entitled L(D5½) 2252.

Along the left-hand bottom border of a Decca chart appears the full chain designation showing the frequency group number of the chain, its sub-group letter and the type of Decca transmission used, whether Multipulse or Mark V.

e.g. (1) Chart 2615—Portland to Christchurch, latticed for the South-West British Chain (Chain 1B), bears the designation:—

DECCA CHART — CHAIN 1B/MP (S.W. — BRITISH).

(2) Chart 1268—Khor Musa latticed for the North Persian Gulf Chain (Chain 5C), bears the designation:—

DECCA CHART—CHAIN 5C/V (N. PERSIAN GULF.)

The code letters of the Master/Slave pairs whose lattices appear on the chart are printed on the bottom left-hand corner in appropriate colours.

Normally the coding used is:—A—Master.
B—Red Slave.
C—Green Slave.
D—Purple Slave.

Thus on a chart where the red and green lattice lines are shown, the inscription (AB.AC) appears in the bottom left-hand corner; the 'AB' in red and the 'AC' in green.

Details of chart numbering and chain designations appear in Decca Data Sheets.

A chart may have more than one Decca latticed edition, e.g. the chart of the North Sea, Southern Sheet, is latticed for the English Chain (Chain 5B) and also for the Frisian Islands Chain (Chain 9B). It may then appear numbered either L(D5) 2182a or L(D9) 2182a.

On the outskirts of chain coverage areas where fixing from a single chain becomes inadequate, fixing from two chains is possible in some instances. Inter-chain fixing charts are published for those areas but inter or cross-chain fixing facilities can only be provided successfully by transmitters of the multipulse type.

Interchain fixing charts are identified by the addition of the letters (IC) after the L(D) prefix to the chart number.

For example a chart of the central North Sea area, **2182b**, latticed for interchain fixing is numbered L(D) (IC)2182b. The full chain designation for such a chart is:—

(AC. {Chain 3 (N. British) / Chain 7 (Danish)} AD. {Chain 3 (N. British) / Chain 7 (Danish)})

DECCA INTERCHAIN FIXING CHART (3B/MP N. British & 7B/MP Danish CHAINS.)

That is lattice lines from four separate master/slave pairs appear on this chart. The four sets of position-lines appear in two different colours. The appropriate chain number is marked at spaced intervals against each set of position-lines to avoid confusion.

Interchain fixing editions of a chart may be published in addition to single chain fixing editions of the same number.

Special charts, such as the Fisheries Charts and Decca Plotting Sheets, mentioned in Chapter I, may also be overprinted with a Decca lattice.

Unlatticed Charts which have one or more Decca latticed editions bear a small printed letter 'L', in the bottom right-hand corner, just inside the outside border.

Consol and Loran lattice charts are not issued as navigational and a position fixed upon one of those charts should be transferred to an ordinary navigational chart of the area. These charts bear the letter 'L', followed by the number, followed by the name of the aid to navigation in brackets.

e.g. The Consol chart of the North Sea is entitled L2339 (Consol). The Loran chart Labrador to Miquelon is entitled L5316 (Loran).

Consol charts bear the same number as the basic chart from which they are prepared. The number of a British Loran chart may or may not be the number of an unlatticed chart.

British Admiralty Charts are published for most of the Atlantic coverage of Loran A. The U.S. Naval Oceanographic Office publish charts for the full coverage of Loran A and Loran C.

Omega charts are published by the U.S. Naval Oceanographic Office and are issued as non-navigational.

Thus the radio aid tells the navigator on which hyperbola he is situated and the lattice chart tells him through which points on the earth's surface that hyperbola runs.

It is proposed to give a brief description of the hyperbolic aids which are most likely to be met with at sea, with particular reference to their application to chartwork.

DECCA

In the Decca Navigator System, pairs of stations transmit signals, there is a shipborne display peculiar to Decca and a lattice chart is required to identify the position lines.

The system operates on the principle of comparing the phase of signals which arrive at the ship from the stations. The lattice in this case is made up of lines of constant phase difference.

The stations are grouped in the form, a Master and three Slaves; the Master making up a pair with each Slave. That is, there are three pairs of stations in each chain. Plate 12.1 shows the layout of the English Chain.

Occasionally a Master and only two Slave stations may make up a chain. This depends upon the lie of the land and upon the sea area required to be covered. In such cases red and green are usually used, the purple slave being dropped.

The properties of the Decca System allow the pattern as shown to be split naturally into numerous divisions. Each division is called a *lane*, the commencement of each lane being a line of zero phase difference.

The lanes are numbered from the master outwards and grouped into *zones*.

The number of lanes per zone varies.

The zones are lettered from the master outwards; from *A* to *J*, and then start again at *A*.

The lanes themselves are sub-divided into $\frac{1}{100}$th parts.

The position on the lattice chart is thus read to zone, lane and $\frac{1}{100}$th of a lane.

Figs. 12.1 (*a*) and (*b*) will make this clear.

On an Admiralty chart the number and spread of lanes shown depend on the scale of the chart. Decca lanes are spaced so that they are never closer together than a $\frac{1}{4}''$ or $\frac{1}{2}''$. The system adopted is to chart every 1, 2, 3, or 6 lanes or full zones, according to chart scale. As these divisions are common to the number of lanes per zone (18, 24 and 30) for each colour, the same system can be kept for each colour on the chart.

From this it will be appreciated that in order to make an accurate fix interpolation is necessary.

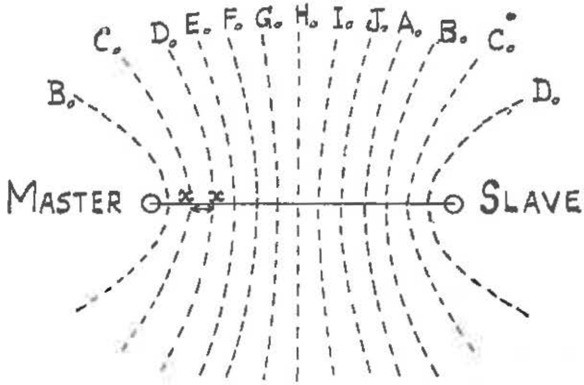


FIG. 12.1 (*a*)

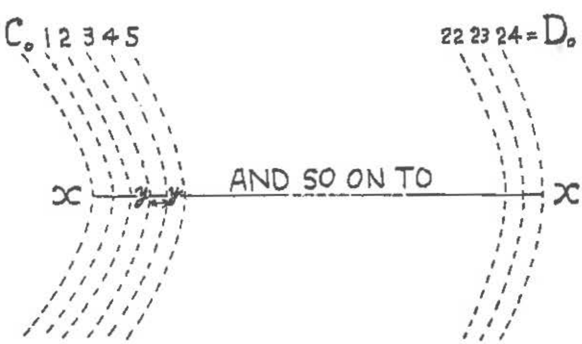


FIG. 12.1 (*b*)
'*yy*' is further subdivided into hundredths

On later Admiralty Decca charts the lattices are drawn by a computer controlled Automatic Drafting System. On such charts breaks in the position lines are left to a minimum. For example the lane numbers are offset above the appropriate lattice line, instead of the lattice line being broken for the lane number as was the former practice (Plate 12.8). In addition more use is made of pecked lines, representing half lanes, where required.

The Hydrographic Department recommends that the most suitable type of artificial lighting for use with current Decca charts is lighting with variable intensity control and fitted with an amber filter, the filter being to the specification Amber 300.

Plate 12.2 shows a complete Decca Lattice Chart. The grid is for the South-West British Chain. The Master Station appears in South Devon with Slaves in Jersey, Scilly and South Wales.

A special adaption of the Decca system, using mobile transmitters and lightweight display equipment is available. Having a comparatively short range and high accuracy this version is primarily intended for use in hydrographic work such as surveys or explorations. It may also be used in port approaches. Individual lattices must, of course, be drawn upon the charts or overlays provided, for each siting of the transmitters; alternatively the position-line at any point could be calculated.

Receivers and Displays.

For general shipboard use three forms of Decca Receivers are current. These are the Marks V, 12 and 21. The display units in the case of the first two are similar, the Mark 12 display being a development of the Mark V. Mark 12 receiving equipment caters for Decca transmissions of both multipulse and original (Mark V) types. The Mark 21 multipulse receiver is transistorised and houses receiving equipment and display in one cabinet.

Display Unit—Mark 12.

The Mark 12 and Mark V displays consist of a cabinet, the decometer bowl, with four dials, three decometer dials and one lane identification dial. Also there are knobs to effect various adjustments. Plate 12.3 illustrates a Decca Mark 12 Display Unit.

The Decometer:—

A decometer dial from the Mark 12 display is shown enlarged as Plate 12.4.

The decometer indicates Zone, Lane and $\frac{1}{100}$th Lane and there is one for each Master and Slave combination. To avoid confusion the lanes are numbered differently for different slaves. In Plate 12.4 the reading is Red G 16.28.

Lane Identification:—

The lane identification dial from the Mark 12 display appears enlarged as Plate 12.5. ·

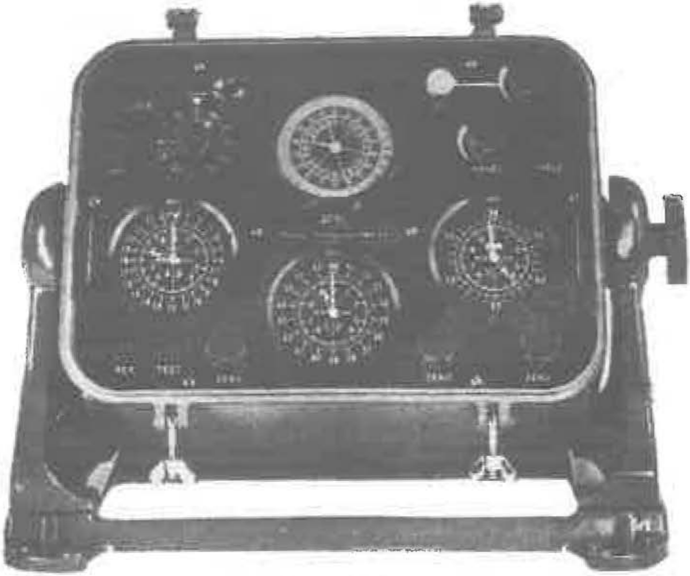


PLATE 12.3

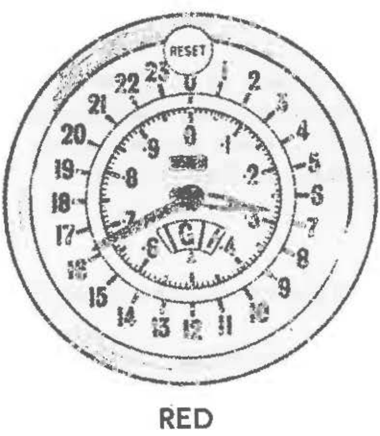


PLATE 12.4

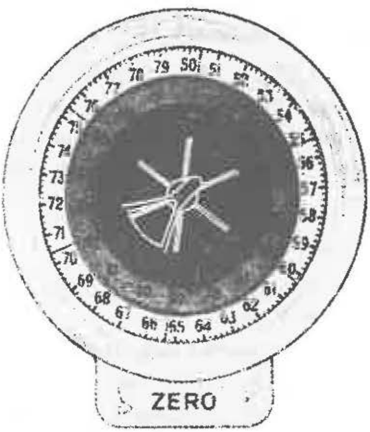


PLATE 12.5

Lane Identification enables the navigator to set up the decometers on entering the coverage of a Decca System and the readings as shown on the lane identification meter provide a check on each decometer in turn at any time within the system.

Multipulse Lane Identification gives increased accuracy and reliability in the fringes of the coverage area, maintains accuracy in sky-wave regions and extends range. The lane identification meter in this case has the precision to give a fix, and multipulse lane identification meter readings may even be more accurate than the decometer readings under sky-wave conditions at longer ranges. Inter-chain or cross-chain fixing, as mentioned earlier in this Chapter, is also facilitated.

Receiver/Display Unit—Mark 21.

In the Mark 21 receiver multipulse transmission is specially catered for and the lane identification display is the main presentation. The complete display has an altered appearance from the earlier 'bowls' and the actual receiver is of an improved and more efficient type.

Plate 12.6 illustrates a Decca Mark 21 Receiver.

The lane identification display is in the form of a digital readout giving lane and tenth of lane for each master/slave pair in turn.

The decometers show Zone and Lane in windows and indicate decimals of a lane on a dial by means of one pointer (Plate 12.7).

Knobs, similar to those on the Mark 12, effect various adjustments. Most controls are on the lower front panel.

Warning symptoms appear if there is a reduction in the quality of reception of the Decca signals.

Remote decometer displays may be added and provision is made for output of the readings to an integrated navigation system, as mentioned in Chapter XIII.

Part of the display frontage of the Mark 21 is shown enlarged as Plate 12.7.

The Decca Track Plotter, as mentioned later in this Chapter and as described in Chapter XIII, is sometimes quoted as another form of Decca display. It could be referred to as a pictorial display.

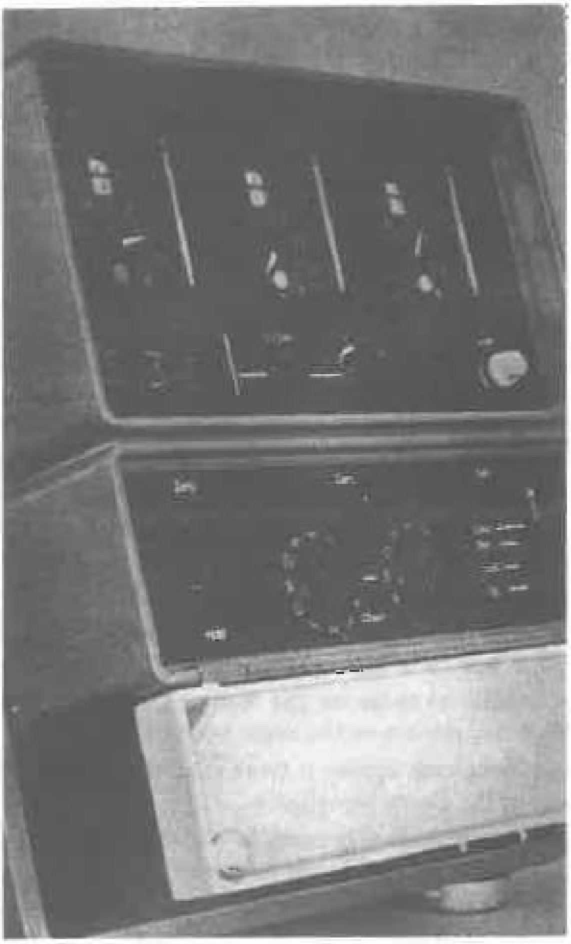


PLATE 12.6

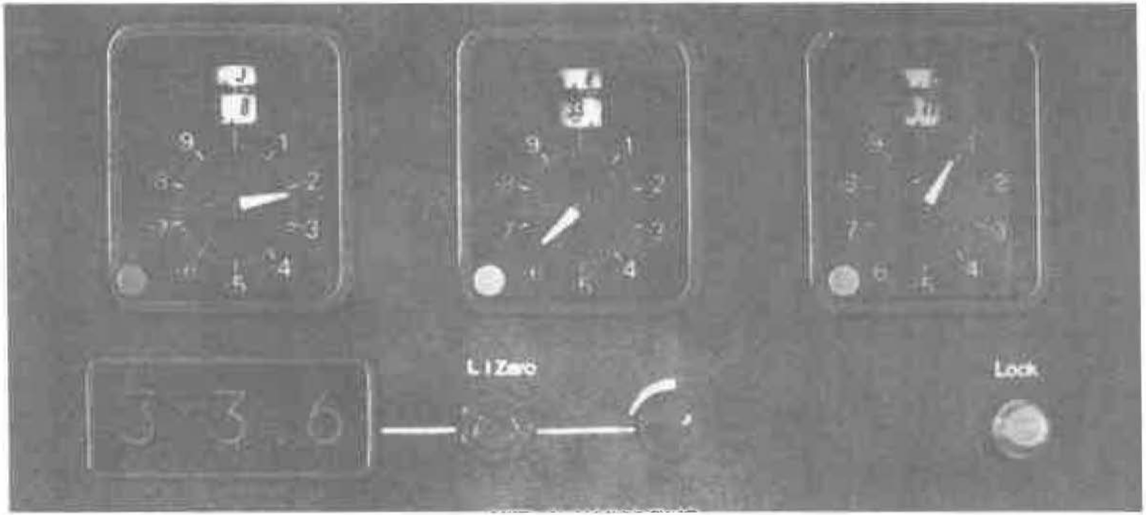


PLATE 12.7

The red decometer reads J 8·22 The green decometer reads E 33·63

The lane identification readout is indicating the comparison for the master and the green slave.

A considerable advantage of Decca is that little skill is required to take the readings from the display. Simplicity and speed are two important characteristics of the system where all position-line information is shown continuously and automatically.

Readings.

An example of taking readings from a Decca chart, and of plotting a position on a Decca chart follow and are illustrated in Plate 12.8. Corrected readings are assumed for simplicity at this stage. Remarks on possible Decca errors follow. English Chain errors in the Thames Estuary are negligible in any case.

An observer at Barrow Deep Light Vessel would read on his decometers: Red F 10·28; Green E 32·19.

Conversely, to plot the ship's position on a lattice chart from decometer readings, the position line must be interpolated at two or more points and drawn in, unless in the case where a reading falls on a marked hyperbola.

e.g. Readings Red G 1·65; Green D 45·43.

Find the ship's position.

The Red Reading:—

At *X* interpolate 1·65 between the marked hyperbolae of G0 and G2.

At *Y* interpolate 1·65 between the marked hyperbolae of G0 and G2.

At *Z* interpolate 1·65 between the marked hyperbolae of G0 and G2.

Join up *X*, *Y* and *Z* and this is the P/L of the Master and Red Slave.

The Green Reading:—

At *P* interpolate 0·43 between the marked hyperbolae of D45 and D46.

At *Q* interpolate 0·43 between the marked hyperbolae of D45 and D46.

At *R* interpolate 0·43 between the marked hyperbolae of D45 and D46.

Join up *P*, *Q* and *R* and this is the P/L of the Master and Green Slave.

Where the two position lines cut in *F* is the position of the ship.

Since the distance between the marked hyperbolae alters continually along their lengths a variable scale of some description is advantageous for quick interpolation in the plotting. The Decca Navigator Company issue such a scale in the form of a small ruler (Plate 12.9).

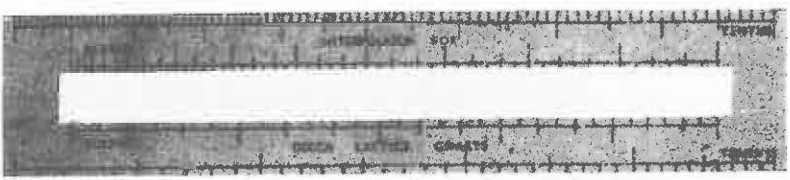


PLATE 12.9

Similarly, from readings of other electronic aids the ship's position may be plotted on their appropriate lattice charts.

Propagation Errors.

These are sometimes referred to as Pattern Errors because they produce the effect of a distortion of the lattice lines in the chart. They can be subdivided into systematic and random errors.

The hyperbolic lattices shown on Decca charts are the calculated patterns.

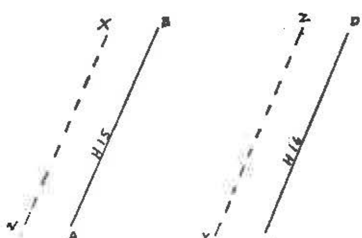


FIG. 12.2

At certain times and places an incorrect wave may be received at the ship and thus an erroneous position line indicated on the decometer.

In fig. 12.2, *AB* is the position line of H 15·00 as marked on the chart. However, due to propagation error the decometer indicates H 15·00 when the ship is on line *WX*.

Similarly with H 16·00 and *CD* and *YZ*.

Thus the pattern is distorted.

Systematic Errors.

In certain areas a pattern distortion may occur which is stable in nature. This is due mainly to the radio wave being affected by the terrain over which it passes. Such departure from the theoretical positions of the lattice lines is called Systematic Error or Fixed Error.

Systematic errors are likely to be greatest where the chain extends over mountainous land or islands as in the North Scottish Chain.

Systematic errors have been found to be constant for each locality and need therefore only be ascertained once for any position.

Where reliable data has been obtained the results are published in Decca Data Sheets on 'Fixed Errors'. Extracts from such data sheets appear in Plate 12.10.

FIXED ERRORS
PATTERN CORRECTIONS—ENGLISH CHAIN
DECCA NAVIGATOR DATA SHEET
NOVEMBER, 1954. No. 2A

AREA	RED *Class*		GREEN *Class*		PURPLE *Class*	
ENGLISH COAST						
Flamborough Head ..	0	*A*	N/A		0	*A*
Humber	+0·05	*A*	N/A		+0·10	*A*
Cromer	+0·05	*A*	N/A		−0·10	*B*
Yarmouth	+0·10	*A*	−0·05	*A*	−0·05	*A*
Lowestoft	+0·10	*A*	−0·05	*A*	N/A	
Orfordness	+0·10	*A*	−0·15	*A*	N/A	
Harwich	+0·15	*A*	−0·10	*A*	N/A	
Thames Estuary ..	+0·10	*A*	0	*A*	N/A	
North Foreland ..	0	*A*	+0·05	*A*	N/A	

PLATE 12.10 (a)

FIXED ERRORS

PATTERN CORRECTIONS—NORTH SCOTTISH CHAIN

DECCA NAVIGATOR DATA SHEET

MARCH, 1957. No. 2F

AREA	**RED** *Class*		**GREEN** *Class*		**PURPLE** *Class*	
SCOTLAND, WEST COAST						
Oban	−0·27	*A*	−0·12	*A*	−0·52	*A*
Sound of Mull (East)	−0·54	*B*	N/A		−0·22	*B*
Sound of Mull (Middle)	−0·75	*B*	N/A		+0·06	*B*
Sound of Mull (West)	−0·67	*B*	N/A		−0·01	*B*
Ardnamurchan Point	−0·39	*B*	N/A		+0·41	*B*
West of Eigg	−0·22	*B*	N/A		+0·16	*B*
East of Rhum ..	−0·31	*B*	N/A		+0·14	*B*
Loch Eynort	−0·86	*B*	N/A		+0·12	*B*
Talisker Bay	−0·30	*B*	N/A		+0·19	*B*

PLATE 12.10 (*b*)

The Data Sheet shows the amount to be added or subtracted from the decometer reading. Corrections may be classed *A* or *B* depending on the degree of reliability likely in the resulting position line. N/A means the slave in question is not used in the position in question.

Example:—

Thus in the Thames Estuary (Plate 12.8) an observer would add 0·10 to all readings of the red decometer. There would be no correction for green readings.

Computing the expected readings at Barrow Deep Light Vessel, the red correction should be applied in reverse giving:—

Red F 10·18 and Green E 32·19 as the expected readings.

Where possible pattern corrections are measured in areas where greatest accuracy is likely to be required. It must not be assumed that no distortion exists in areas where no correction is quoted. An approximate correction may be found in some cases by interpolation from listed places near by. Otherwise the charted lattice should be used with caution, especially near the coast.

Random Errors.

Random Errors in the Decca system are generally caused by interference from sky waves on the direct radio signal. The system is designed to receive ground waves and if sky waves, as mentioned in Chapter XI, are received the decometers may read in error.

Random errors can very largely depend on the range, the season and the time of day, that is, whether it is daylight or darkness. They can be expected to be greater at night and worse in winter. They are normally only significant on the fringe of the coverage area where the system should be used with caution anyway.

While random errors cannot be corrected outright it is possible to regard the error as variable within limits at individual places. Estimate is made of the error likely to occur at various places and the results published in Decca Data Sheets on 'Variable Errors'. Extracts from such data sheets appear in Plate 12:11. Note that the errors are quoted in magnitude and direction.

VARIABLE ERRORS
ALLOWANCE TABLE—ENGLISH CHAIN
DECCA NAVIGATOR DATA SHEET

MARCH, 1953. No. 3A

Coast of England

Location	*Most Accurate Direction*			*Least Accurate Direction*		
	Bearing (°True)	*Cables* *Day*	*Cables* *Night*	*Bearing* (°True)	*Cables* *Day*	*Cables* *Night*
Blyth	075°	½	1½	165°	4	20
Newcastle ..	075°	½	1½	165°	3	15
Middlesbrough ..	075°	½	1	165°	2½	10
Flamborough Head	090°	½	1	180°	2	5
Spurn Point ..	090°	½	1	180°	1	2½
Cromer	110°	½	1	020°	1	2
Yarmouth ..	180°	½	½	090°	½	1½
Thames Estuary ..	025°	¼	¼	115°	¼	½
North Foreland ..	030°	¼	¼	120°	½	1

PLATE 12.11 (*a*)

VARIABLE ERRORS

ALLOWANCE TABLE—NORTH SCOTTISH CHAIN

DECCA NAVIGATOR DATA SHEET

DECEMBER, 1959. No. 3F

Coast of Scottish Mainland

Location	*Most Accurate Direction*			*Least Accurate Direction*		
	Bearing (°True)	*Cables* *Day*	*Night*	*Bearing* (°True)	*Cables* *Day*	*Night*
Tiree	125°	½	1½	035°	2	10
Canna Island ..	126°	½	1	036°	1½	5
Little Minch ..	137°	½	1	047°	1½	6
North Minch ..	105°	¼	½	015°	½	1½
Cape Wrath ..	065°	¼	¼	155°	¼	½
Pentland Firth ..	171°	¼	¼	081°	¼	½

PLATE 12.11 (*b*)

The Diamond of Error.

The method of presentation of the allowances in the Variable Error Data Sheets is based on the arrangement of position lines known as the Diamond of Error.

If for any reason whatever the position lines obtained in a fix are inaccurate to plus or minus a certain amount, an error will result as shown.

In fig. 12.3, (*a*) illustrates part of the lattice.

X is a point where the P/L's cut at about right angles.

Y is a point where the P/L's cut at an acute angle.

The position line becomes a position lane and instead of two lines cutting in a point, two lanes cut to form a diamond or square. The ship can only be said to lie somewhere within the shaded parts of the figures.

Around *X* the area in which the ship may lie is almost a square (*b*).

Around *Y* the area in which the ship may lie is almost a diamond (*c*).

Note that at great distances (*d*) the diamond becomes long and narrow but accuracy across the lattice is still good, although along the lattice it is very poor.

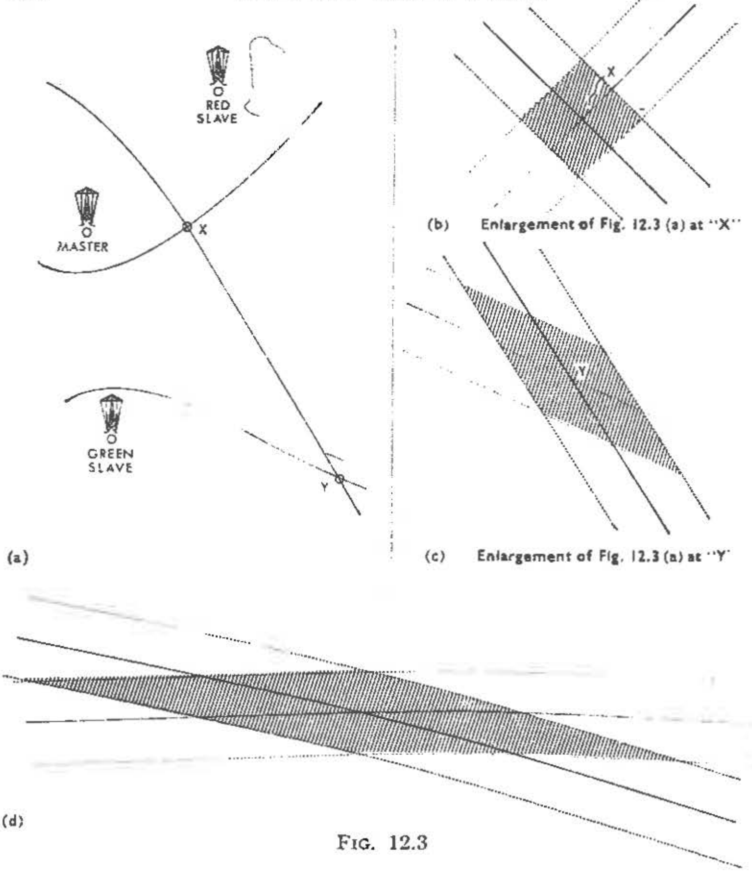


Fig. 12.3

However, a feature often overlooked is that even if the fixing accuracy is low the long access of the diamond [in (*d*)] provides quite a reasonable position line.

It should be remembered that the possibility of the above error is inherent in all hyperbolic systems.

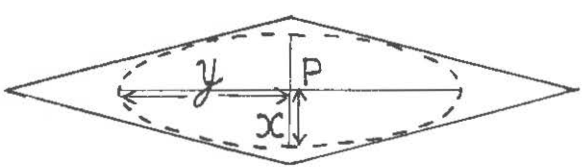


Fig. 12.4

A fuller study shows that the observer's probable position is within an oval-shaped figure contained within the diamond.

In fig. 12.4, *P* is the plotted position.

The arm *x* is the direction and distance quoted under 'Most Accurate Direction' in the data sheets on variable errors.

The arm *y* is that quoted under 'Least Accurate Direction'.

Application of Fixed and Variable Errors.

Example:—

Off the West Coast of Scotland in the space of sea between Canna Island and Loch Eynort (Skye), about midnight, local time, a vessel takes Decca readings from the North Scottish Chain as follows:—

Red F 3·63. Purple J 57·20.

Plot the Decca Fix.

Apply the fixed error corrections for Loch Eynort [Plate 12.10 (*b*)].

	Red	*Purple*
Meter Reading	F 3·63	J 57·20
Fixed Error Correction	—0·86	+ 0·12
Value to be plotted	F 2·77	J 57·32

The position lines, Red F 2·77 and Purple J 57·32, are now plotted on the chart in a similar manner to that described for the Example on Plate 12.8 under the heading 'Readings'.

Point *P* (fig. 12.5) is at the intersection of the position lines.

The error diagram is now drawn around position *P*, in this case using the variable error allowances for Canna Island [Plate 12.11 (*b*)].

Each allowance is laid off from *P* in the quoted direction and in the reciprocal direction. The fairest oval figure is then drawn.

Note that fixed error corrections are given in decometer units. Variable errors are given in degrees true and cables.

The vessel should assume she is situated in the part of the figure which places her in greatest danger and steer accordingly.

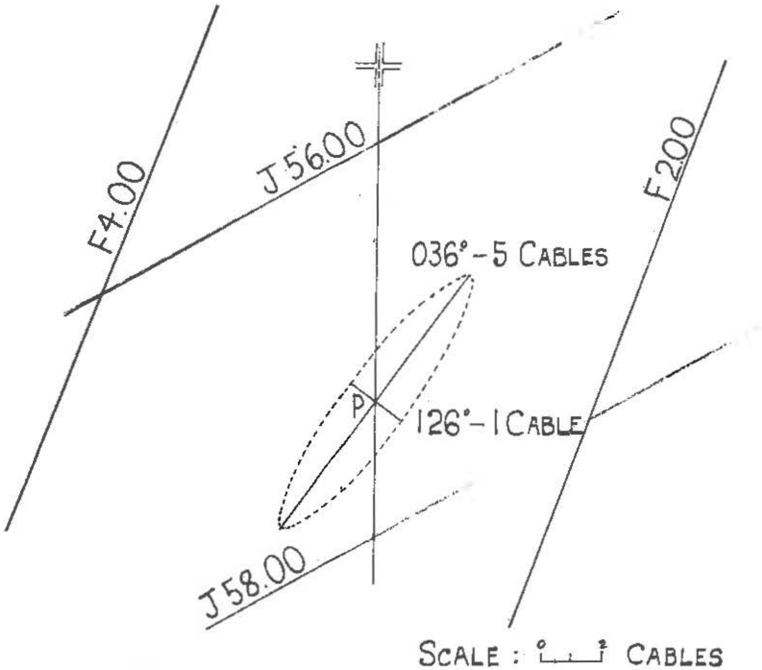


FIG. 12.5

The Decca Error Figure is analagous to the 'Cocked hat' (*see* Chapter V and fig. 5.19).

Data Sheets should always be consulted when using a chain.

While the values quoted in the data sheets are as accurate as can be ascertained, mariners are warned that the application of fixed and/or variable errors does not necessarily mean the elimination of all errors.

However, by using the data sheets, more accurate fixes should normally be obtained.

The value of Decca as a navigation aid in fringe areas by night is greatly increased if frequent fixes are taken. It is then possible to eliminate the effect of random errors to a considerable extent by drawing a mean track through the fixes. This is largely true of all hyperbolic aids.

Variable errors restrict the scale on which Decca charts are issued. That is, large scale Decca lattice charts are only issued for areas in which the variable errors are known to be small. This minimises the chance of a navigator placing undue confidence on a Decca reading at a time when it would not be justified.

Data Sheets.

Decca Data Sheets are issued covering many aspects of the Decca System and its use. In addition to the description and tabulation of errors, Decca charts are described and lists are given of Decca charts available. Other sheets deal with operating instructions, use of the system and layout of chains.

Information on Decca is also given in the *Admiralty List of Radio Signals*.

Homing.

Homing is the reverse of fixing. Compute the readings desired to show on the decometer and steer accordingly.

Lattice Homing.

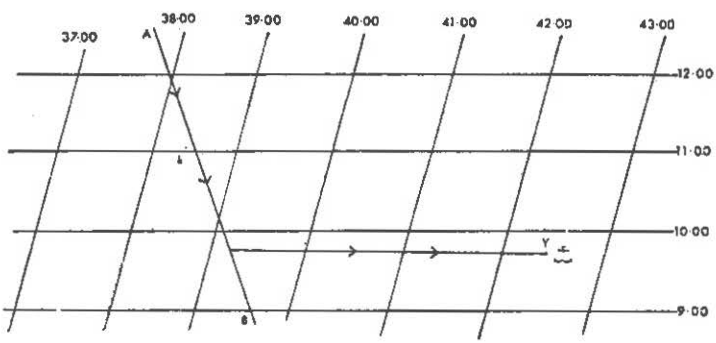


FIG. 12.6

Vessel on course *AB* wishes to make the anchorage at *Y*. When red decometer shows 9·70 alter course t… course parallel to the red lattice lines. Adjust the course as necessary from time to time to keep the red reading at 9·70.

It is important to note that if this type of homing is used in thick weather to make a port or point, great care should be exercised as other craft may be navigating in a similar manner on the same or reciprocal course.

The fixed Decca reading should always be checked with frequent and regular Decca readings of another colour and the positions plotted on the chart. Alternatively fixes should be maintained by other navigational methods.

A General Type of Homing.

Vessel wishes to go from A to B. The red lines make an angle closer to 90° with the course than the green ones. Therefore note the green readings where the course intersects each red line.

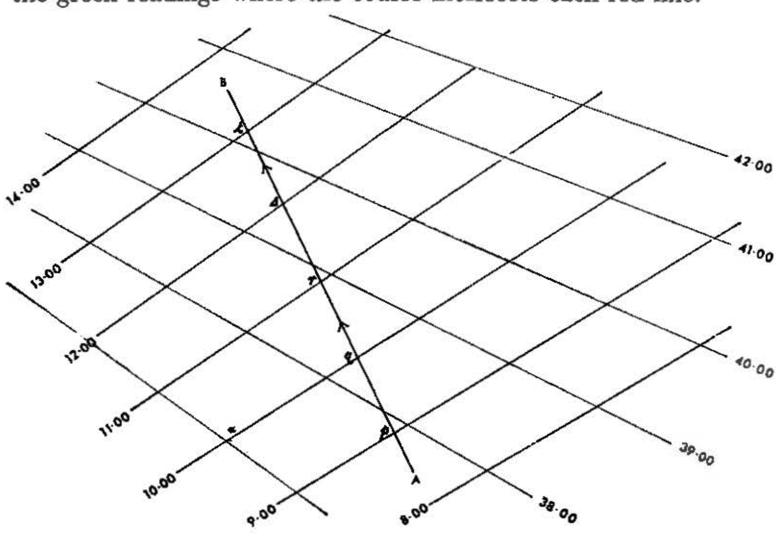


FIG. 12·7

Construct a table which in the example shown in fig. 12.7 would be as shown on opposite page.

Steer the course AB and make any required correction to the course each time the ship reaches an intersection point, e.g. if when the red decometer reads 11·00 the green one reads 38·95 the vessel is to starboard of the required line and course should be altered a little to port to bring the ship back on the line by the next intersection point.

Point	Red	Green
A	8·43	37·70
p	9·00	37·87
q	10·00	38·36
r	11·00	38·87
s	12·00	39·52
t	13·00	40·22
B	13·54	40·56

Track Plotter.

A useful extension to the Decca Navigator with regard to plotting and homing is the Marine Automatic Track Plotter. This instrument is described in Chapter XIII.

Approximate Ranges and Accuracy.

Decca Fixing Accuracy Diagrams or Coverage Diagrams appear in the *Admiralty List of Radio Signals* and these, together with the Data Sheets for Fixed and Variable Errors, should always be consulted when using the Decca.

Broadly the accuracy of a fix from a system can be considered to depend upon:—

(1) Instrumental Errors.
(2) Propagation Errors.
(3) Lane Width.
(4) Angle of cut of the hyperbolae.

It should be borne in mind that the angle of cut of the hyperbolic position lines decreases rapidly towards the and outwards and great position accuracy can therefore not be expected in those localities from position lines of a single chain.

The co-relation of range and accuracy should further be studied in the light of what has been said about the systematic and random errors.

As in all hyperbolic systems, the accuracy improves as the centre of the system is approached.

On some charts for areas on the fringe of the Decca coverage there is a break in the position lines at a range of 240 miles from the Master Station and a warning that readings may be unreliable at points beyond this break. The practice of marking such a break and caution is being discontinued however, as a gradual process, as charts come up for correction in the normal way.

In places where there is a change over from one chain to another, a chart will be available for both chains; or, where cross-chain fixing is applicable, there will be an inter-chain fixing chart.

Inter-chain fixing charts can considerably increase the coverage area since a pair of position lines from adjacent chains generally cut at a much better angle at long ranges than the position lines from either individual chain.

It might be interesting to note at this point that many users, such as fishermen, are as much concerned with the relative accuracy or repeatability of the system as with the absolute precision of a fix provided. Fishermen may wish to regain time and again a locality where fishing conditions have proved favourable for catches and may come to recognise such a locality by its hyperbolic co-ordinates.

Decca Broadcast Warnings.

If a fault occurs in the transmission of a Decca Chain, warning W/T and R/T broadcasts are sent out. These broadcasts are made from particular radio stations at particular times and when using the Decca, especially, if for any reason, without Lane Identification, navigators should listen in at the appropriate times. Details of stations and times appear in Decca Data Sheets, in Admiralty *Notices to Mariners* and in the *Admiralty List of Radio Signals*.

CONSOL

Consol is a long range navigational aid. The layout ashore is of three stations placed quite close to each other and the pattern produced is as shown in Plate 12.12.

Plate 12.12 shows a reproduction of Admiralty Chart No. L13 (Consol). Lattice lines appear from Bushmills, Northern Ireland; Ploneis, Brittany and from Stavanger, Norway. A different colour is used for each station.

The position lines obtained are called 'shallow hyperbolae' which for practical purposes at the ranges involved may be considered as Great Circles passing through the centre station. Consol may be used with or without a lattice chart.

The Consol signal can be received through any medium frequency receiver. A DF receiver will do.

Transmission is continuous and the operation of taking a bearing is to count the number of dots and dashes transmitted in a certain cycle, that cycle usually consisting of:—(1) Call sign; (2) Long, continuous signal; (3) Dot/Dash pattern. The number of characters counted determines the position line.

In taking the count, 60 characters should be heard. In practice this is rarely possible since the exact change from dots to dashes is masked by the 'twilight zone', a merging of the two types of characters. The actual count heard must be corrected by making it up to 60.

Subtract the sum of the dots and dashes from 60 and add half the difference to each. This gives the true number of dots and dashes, it being assumed that equal numbers of dots and dashes have been lost.

e.g. Observed Count 48 dashes, 4 dots

$$48 + 4 = 52$$
$$60 - 52 = 8$$

$$\therefore \text{Add} \quad \frac{8}{2} = 4 \text{ to each.}$$

$\therefore$ True Count = 52 dashes, 8 dots = 60 characters.

Several counts should normally be taken and if there are large discrepancies between successive counts the bearing is unreliable.

The procedure for taking a count may be conducted visually instead of aurally in some instances. For example, in the case of certain DF equipment by observing the 'flicks' of a meter hand; in the case of a visual DF display (Chapter XI) by observing the variations in the length of the line indicating the bearing.

The lines of the lattice are marked with the number and type of the character which occurs first in the cycle, i.e. the one which follows the long continuous signal. In the example the navigator should take '52 dashes' as the position line to seek on the chart or the argument with which to enter the tables.

Plate 12.13 illustrates a portion of the Consol Chart of the North Sea, showing lattice lines from Stavanger and from Bushmills. An observer at '*A*' would find himself to be on the position line of 7 dots from Stavanger (Blue) and 59 dashes from Bushmills (Red). That is, his corrected counts would be Stavanger 7 dots 53 dashes; Bushmills 59 dashes 1 dot. These position lines may be obtained by consulting a lattice chart of the type illustrated or they may be deduced by means of special tables.

Conversely, a ship's position may be plotted on a Consol Chart from Consol readings in a similar manner to that previously described for the Decca system.

The tables referred to are published officially for seafarers in the *Admiralty List of Radio Signals* but have also been reproduced commercially.

The tables give the great circle bearing of the ship from the station and there is added a ½-convergency table to convert the great circle bearing to a mercatorial bearing. The mercatorial bearing is then laid off on an ordinary chart.

Since the result of such a reckoning will often be in decimals of a degree it may be found expedient at long ranges to lay off as bearings the two adjacent whole numbers. Interpolation is then made in the vicinity of the D.R. making due allowance for the probable error mentioned below. For example, mercatorial bearing arrived at is 263·2°. Lay off 263° and 264° from the Consol station.

Note that the system is ambiguous inasmuch as the P/L for any number of dots or dashes is repeated at intervals. A rough D.R. position is therefore required to start with. A DF bearing of the Consul station may be taken for this purpose.

Accuracy of Consol is not high and the system should not be used for making a landfall or for coastal navigation.

Accuracy is maximum on the perpendicular bisector to the base line of the three aerials (the normal) and falls off as the base line extension is approached.

The unreliable sectors are left blank on the chart. Examples may be seen in Plates 12.12 and 12.13.

Approximate ranges over the sea for Consol are 1000 miles by day and 1,200 to 1,500 miles by night. The use of sky waves at night extends the coverage.

A major source of error is due to variation in radio propagation conditions. A table of probable position line errors is listed in the *Admiralty List of Radio Signals* and elsewhere. Errors are listed for range from the station and bearing at the station from the normal and are quoted in miles. It is prudent to assume the presence of such errors when using Consol.

A Consol coverage and accuracy diagram is included in the *Admiralty List of Radio Signals*.

A similar system to Consol, known as Consolan, is operated in the United States.

LORAN

Loran is a long-range navigation aid and once again a Master and Slave Stations arrangement is made use of ashore. The system is made up of Loran chains; pairs of stations make up a chain. Each pair gives one hyperbolic position line to a user. A Loran fix is obtained by crossing two or more position lines.

Two versions of Loran are operational. Loran A is the original; Loran C the more modern type. A third type, Loran D, is a tactical military system with mobile transmitters. This, of course, requires special charts, overlays or alternatively the position lines must be calculated. Such calculations would normally be done by means of a computer.

A common arrangement in a Loran A chain is a master and two slave stations. For example, a Loran A chain which gives coverage in U.K. waters has the master station situated in the Faeroes, one slave in Iceland and one in the Hebrides.

Plate 12.14 shows a complete Loran lattice chart and shows part of the Loran A chain above-mentioned. The stations are lettered *U*, *A* and *K* in this instance. The master station *U* is in the Faeroes, slave station *A* in Lewis and slave *K* in Iceland. Colours again are used for the grid.

Loran C is a refined version of the standard Loran system and operates on a lower frequency than Loran A. The master and slave stations can be situated further apart and this gives extended range and greater geographical coverage. Increased accuracy is also obtained by the nature of the transmitted signal and by the arrangements for taking a reading in the receiver. Each Loran C master station has at least two and up to four slave stations. For example, the Loran C chain for the North Atlantic has the master station in Greenland with slave stations in Iceland, Faeroes and Newfoundland.

Pattern.

Loran gives a hyperbolic pattern similar to that already described. Loran measures the time difference between the arrival of pulse type signals from master and slave in each pair. The lattice pattern is drawn up on lines of equal time difference, the time differences being quoted in micro-seconds (millionths of a second). For example, everywhere on a line marked 4,000 the measured time difference for the pair in question should be 4,000 micro-seconds.

Position lines are drawn for convenient divisions. Often 10, 20 or multiples of 20 micro-seconds.

Plate 12·15 shows part of a British Admiralty Loran Chart for use with the Loran A chains in the Newfoundland area. On this portion of the chart appear grids from stations in Greenland (*N*), Labrador (*L*) and Bonavista, Newfoundland (*V*).

Plate 12·16 reproduces part of a Loran C chart as issued by the U.S. Naval Oceanographic Office. The master station for the North Pacific (Alaska–Aleutian) Chain is shown. Details of slaves and of grids shown on this portion of the chart are appended.

Rates.

Each pair of Loran stations is given a character identification symbol known as the 'rate'.

In the case af Loran A the characters refer to the radio frequency channel and the pulse repetition (recurrence) rates.

In the case of Loran C, there being only one radio frequency channel, the characters refer to the pulse repetition rates and the station designation.

These symbols are used in Loran charts and in Loran tables. The word 'rate' has thus come to stand for the pair of transmitters and their transmissions.

For example:—

In Plate 12.15 are shown 1L3, 1L2 and 1H1. These are examples of Loran A rates.

In Plate 12.16 are shown SL2-X, SL2-Y and SL2-Z. These are examples of Loran C rates.

Note that in U.S. charts most position lines bear the time difference number and the rate for the pair in question, all being shown in the appropriate colour. British Admiralty charts have a slightly different appearance and do not have the rates inserted against individual position lines.

Display.

The shipborne equipment consists of a special Loran receiver/display unit which incorporates a special cathode ray tube. Signals are received through a long aerial.

Plate 12.17 shows a D-X Navigator suitable for receiving Loran A and Loran C signals.

Readings.

Station selection is by means of the characters of the Loran rate. The procedure for taking a reading is to match certain blips as seen on the cathode ray tube. A blip from the master station is matched with a blip from the slave station. A number of adjustments are made with receiver controls in order to match the blips. Each stage in the process is registered and on completion the measured time difference or delay is presented.

In the D-X Navigator the 'Delay in Microseconds' numbers indicate the position line. In Plate 12.17 the reading is 1662, set for rate 1L5.

The procedure for taking a reading varies slightly for each of Loran A and Loran C. Also the signals as presented on the screen have a different appearance. Loran A transmits single pulses; Loran C transmits pulse groups or trains and a system of phase coding is used.

Continuous automatic readings of Loran C can be given with some receivers.

Airborne Loran receivers may give the position directly by means of a computer.

Plotting.

Loran A—Plate 12.15.

An observer at *A* would read 1505 for VL-1L3 (Magenta)
and 1287 for NL-1L2 (Green)

Loran C—Plate 12.16.

An observer at *P* would read 15965 for SL2-*X* (Red), that is the master station (R) and slave (A).
and 55450 for SL2-*Z* (Green), that is the master station (R) and slave (B).

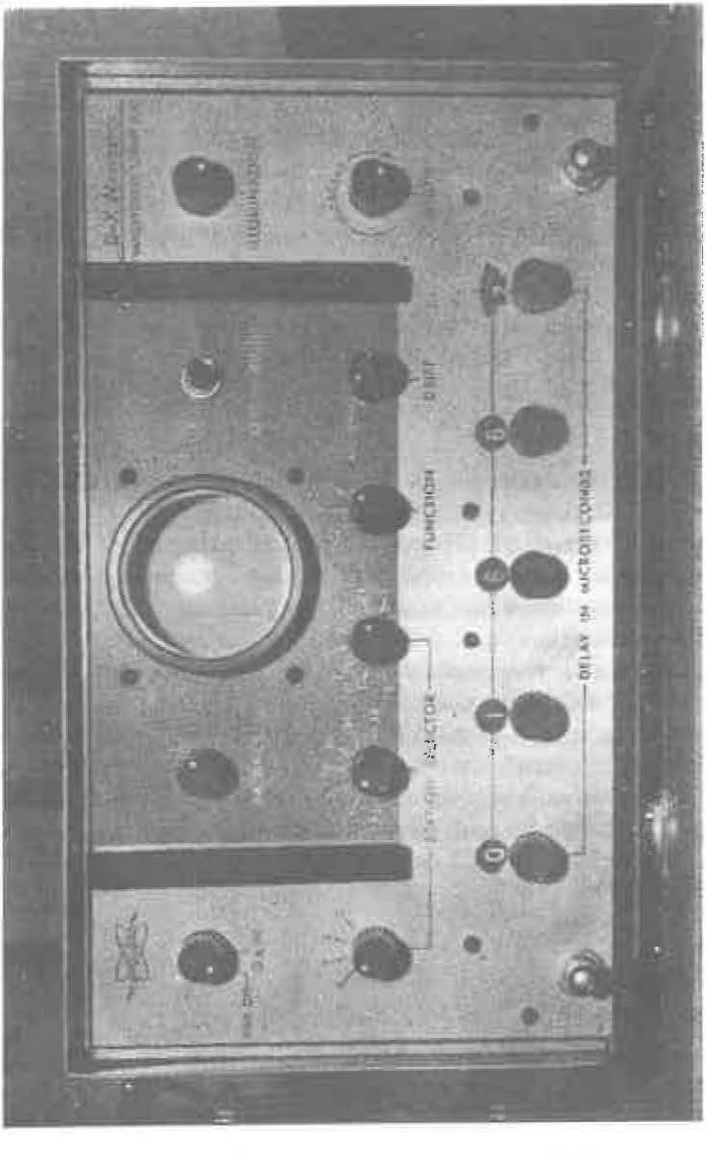


PLATE 12.17

The photograph of the D-X Navigator is reproduced by kind permission of The Marconi International Marine Company Limited.

Naturally the navigator's readings will seldom coincide with the marked hyperbola and interpolation is necessary in the same way as with other hyperbolic grids. An interpolation diagram is available, published by the U.S. Naval Oceanographic Office. It may be printed on light cardboard or it may appear printed on the chart.

Remember that in taking a Loran fix it may be necessary to run-up the first position line before crossing it with the position line from the second pair. The navigator will be guided in this respect by such considerations as time employed taking a reading and course and speed of ship.

Loran position lines may, of course, be crossed with other types of position lines and they may be used in running fixes.

Tables.

Special tables exist for Loran and these are published by the U.S. Naval Oceanographic Office. The operator takes the reading as previously described. From the tables are extracted the latitudes and longitudes of two, or preferably three, points at which the reading in question would occur. These points are plotted on an ordinary, non-lattice chart and joined up. The resulting line is the position line and corresponds to one of the lattice lines or interpolations thereof on a Loran chart.

Greater accuracy in plotting is obtained from tables than is possible from a small scale lattice chart. The likely accuracy of the Loran position line should however be borne in mind and the practice of plotting Loran position lines on to large scale charts should be approached with caution.

Errors.

Pattern Error:—

Some Loran charts are subject to a pattern correction. The corrections are due to incorrect geographic positions for the transmitters and Loran correction diagrams are over-printed on the charts concerned. Readings taken in these areas should be corrected accordingly.

Sky Waves:—

Radio waves as ground waves and sky waves have been mentioned in Chapter XI (page 208). A Loran signal may arrive at a receiver as a ground wave or as a sky wave. Frequently both are received. The operator can identify each.

Ground waves should always be matched in preference to sky waves. Even weak ground waves are preferable to strong sky waves. The average of several sky wave readings will be more reliable than a single sky wave reading. In taking Loran readings, sky waves are most reliable far from the transmitters.

The lattice lines on Loran charts are computed for the arrival of two ground waves. Similarly, Loran tables are computed for ground wave observations.

If sky waves are used to take a reading a correction may be necessary in certain localities. The sky wave correction reduces a sky wave time difference reading to an equivalent ground wave time difference reading so that a single system of position lines can be used in charts and tables.

Sky wave corrections are printed on Loran lattice charts.

In U.S. charts the relevant Loran rate is shown against each correction in each position, both rate and correction being in black. Both day and night values may be given. Further details are contained in the explanation appended to Plate 12.16.

In British Admiralty charts the corrections are shown in small blocks, each correction being in the colour of its corresponding Loran line. Examples may be seen in Plate 12.15.

The corrections may appear at intervals across the chart and they are applicable to the positions on the chart against which they are printed. For intermediate positions the corrections should be interpolated.

No sky wave corrections are tabulated at distances from a transmitting station where sky wave behaviour is uncertain. Thus no attempt should be made to extrapolate the sky wave corrections into areas not covered by tabulated values.

Examples of Plotting a Fix.

Example 1—Loran A—Plate 12.15.

Aboard a vessel in DR position Lat. 53° 15′ N., Long. 49° 00′ W. Loran readings of VL-1L3 and NL-1L2 were taken. Time differences were 2021 and 3622 respectively, sky wave blips being matched in each case. Find the ship's position.

Referring to Plate 12.15:—

If the corrections are large, rough values are applied and the approximate position noted on the chart. Accurate values for the sky wave corrections are then interpolated between the charted values.

The correction to VL-1L3 (magenta) is interpolated between −32 and −25 and is −28 in this case.

The correction to NL-1L2 (green) is interpolated between −39 and −56 and is −50 in this case.

	1L3	1L2
Sky wave reading	2021	3622
Sky wave correction	−28	−50
Equivalent ground wave reading	1993	3572

On plotting, the ship's position is at B.

Position: Lat. 53° 15·5′ N., Long. 48° 54′ W.

Example 2—Loran C—Plate 12.16.

In DR position, Lat. 58° 10′ N., Long. 172° 00′ W., at 2300 hours, local time, Loran readings of SL2-Y and SL2-Z were taken. Time differences were 35108 and 55174 respectively. In the case of SL2-Y the master ground wave blip was matched with the slave sky wave blip; in the case of SL2-Z two ground wave blips were matched. Find the ship's position.

Following the procedure described for Loran A, the correction to the SL2-Y (blue) time difference is interpolated between: −65 and −69 and is −66 in this case.

	SL2-Y		SL2-Z
Sky wave reading	35108		
Sky wave correction	—66		
Equiv. ground wave reading	35042	Ground wave reading	55174

On plotting, the ship's position is at Q.

Position: Lat. 58° 26′ N., Long. 171° 55′ W.

Base Line Extension.

As with all hyperbolic systems the base line extension areas are regions of low reliability. Systems should not be used in these areas and as the base line extension area is approached Loran lines should be treated with caution, the more so for readings obtained from sky waves.

Examples of base line extension areas can be seen in the reproductions of Loran charts in this chapter.

Coverage and Accuracy.

Loran coverage is available throughout much of the ocean area of the Northern Hemisphere. Reliable position lines can be obtained over a wide area and ranges may be as much as doubled by night. Approximate maximum ranges are, for Loran A, up to 1000 miles and for Loran C, up to 1500–2000 miles; or further with the most refined receiving equipment. The Loran D system has reduced power and a comparatively short range.

Ground waves may be badly affected by passage over land. Loran stations are therefore located so that signal paths are over water as much as possible in directions of greatest importance. Sky waves are less likely to be affected by intervening land.

The accuracy of a Loran position line or fix depends upon a considerable number of factors, many of them common to other position lines and fixes, especially those of other radio-hyperbolic aids. Among the most important factors may be mentioned, position in the grid, quality of the receiving equipment and skill of person operating it, and, when using sky waves, the fact that the tabulated corrections are average values.

A Loran chart folio includes an index chart and a coverage chart, giving details between them of stations, coverage and individual charts. Loran coverage diagrams also appear in the *Admiralty List of Radio Signals*. These diagrams should be consulted before using Loran.

Warnings.

Alterations to the Loran system, interruptions in transmissions or other faults are broadcast to mariners by Navigational Warnings.

OMEGA

The Omega Navigation System is a hyperbolic aid having very long range compared with the other systems which have been described. Indeed, it is hoped to provide world-wide coverage using only eight stations.

The system operates on the principle of measuring the phase difference of the signals received at the ship from any pair of transmitting stations. Each pair of stations used gives a position line. The long range is achieved by using very low frequency transmission. Signals of this frequency have proved dependable by day or night over long distances and over land or sea surfaces. They are even capable of penetrating sea-water or ice thus enabling submarines at modest depths to use the system in addition to ships and aircraft. The entire system is synchronised on Greenwich Time.

Pattern.

Each pair of Omega stations produces a hyperbolic pattern which is numbered off in lanes, the commencement of each lane being a line of zero phase difference. The patterns for the relevant pairs are overprinted on each Omega lattice chart. The baseline between stations can be up to 6,000 miles and the width of a lane on the baseline is about 8 miles.

Plate 12.18 shows part of an Omega Lattice Chart. In addition to being given a colour the grid for each pair is further identified by prefixing the lane number, at frequent lane intervals, with the station letters of the pair in question. Position lines are shown as dashed lines within 650 miles of a transmitter and mariners are cautioned that such position lines may be unreliable.

Notice that in Plate 12.18 the position lines derived from use of Station *A* (Norway) appear as dashed. These are the blue lines *AB* and the magenta lines *AD*.

Four stations make six lines of position possible. For example, with *A*, *B*, *C* and *D* the possible pairs are *A-B*, *A-C*, *A-D*, *B-C*, *B-D* and *C-D*. The three position lines which give the best crossing angles are selected for fixing.

Each Omega chart lists recommended pairs for use in the area covered (Plate 12.18).

Display.

The shipborne equipment is simple to operate and once selection of stations is made the indicated or uncorrected position line for each pair is taken from the numerical readout. The reading is given in lane and percentage of a lane.

Plate 12.19 illustrates the Omega Navigation Receiver.

12.19 (*a*) shows the complete receiver (SRN-12) which is intended for naval craft or for special use.

12.19 (*b*) shows the commercial receiver which is in fact an adaption of the bottom portion of the SRN-12 unit.

Note that the reading is:— Lane 483·51.

A graphic recording device is incorporated in the complete Omega receiver [Plate 12.19 (*a*)]. The two panels which make up the graphic recorder may be seen in the top left section of the receiver. The device provides a record of the ship's track in terms of lane and fraction of a lane against time and will also verify that a lane has not been dropped.

The small cathode ray tube to the top centre of the receiver is for testing and maintenance purposes.

Four stations can be tuned simultaneously. The pairs may be read singly or the readout may be set to 'automatic' with any three of the six possible position lines selected for display. On automatic the current value of the position line for each of these three pairs is presented consecutively on the read-out in rapid succession and at very frequent intervals.

The graphic recorder on the complete receiver keeps a continuous trace of the values of the three position lines selected. Two 2-pen recorders are used:—

Position lines 1 and 2 being shown on the left-hand panel.
Position lines 1 and 3 being shown on the right-hand panel.

Lane Count.

The Omega receiver must be set up at commencement of use.

Only the correct fraction of a lane is indicated by the 'phase difference' measuring equipment. The lane whole number must be selected by the operator. Consequently the equipment should be

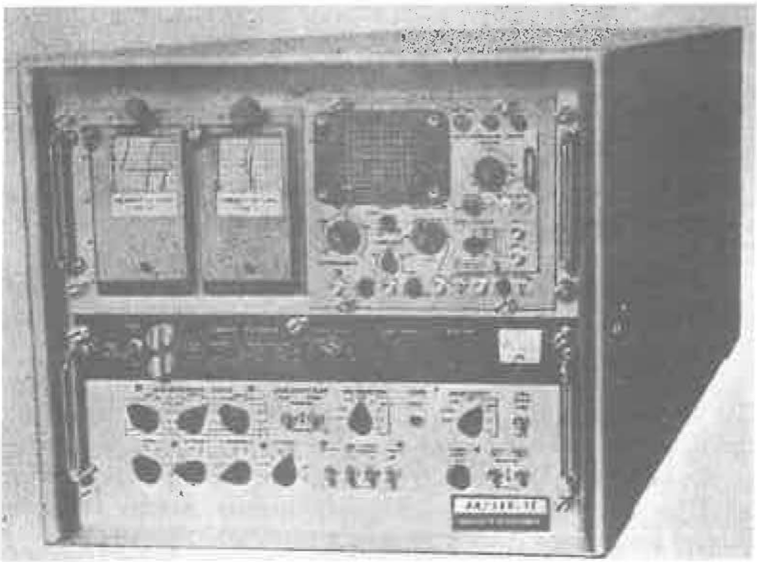


PLATE 12.19 (*a*)
Omega receiver manufactured by Northrop Corporation.

PLATE 12.19 (*b*)
Omega receiver manufactured by Northrop Corporation.

started in a known position, such as in port, prior to departure, or alternatively a good D.R. position may be used.

The lane readout is set to the correct whole number of lanes and the graphic recorder (if SRN-12) annotated. Thereafter the readout is changed automatically and the lane passages on the recorder may be counted as the ship moves across the lattice. The navigator is also expected to D.R. for additional assurance. It is important to note that there is no built-in lane identification system as with Decca.

In the event of equipment or transmitter failure, lane count must be re-established. This can usually be accomplished from an adequately maintained D.R.

The stations transmit on three, or at least two, frequencies. One frequency is the basic or general one for which the Omega charts are latticed and this gives a lane width of about eight miles on the baseline. The other frequencies provide separate patterns which produce lanes of considerably greater widths than the charted lanes of the general frequency.

The display units illustrated in Plate 12.19 are single frequency receivers and can operate on the basic frequency only.

With a two-frequency receiver the derived lane width is about 24 miles on the baseline; with a three-frequency, aircraft, receiver, 72 miles.

Every third charted line is thus equivalent to one lane as received by a two-frequency receiver. That is, every hyperbola in the basic frequency system which is evenly divisible by three is also a hyperbola in the two-frequency receiver system.

Errors.

Omega charts are constructed using arbitrary daytime propagation conditions for the very low frequency signals. Diurnal and seasonal variations of these conditions occur, giving the effect of a pattern error on the lattice charts of a similar nature to that described under 'Decca' (Fig. 12.2).

The corrections have been computed and are referred to as sky wave corrections. They are printed in Omega Skywave Correction Tables, published by the U.S. Naval Oceanographic Office. There are tables for each frequency system and the tables may be renewable from year to year.

Plate 12.20 shows an extract from Omega Skywave Correction Tables.

Note that the arguments are frequency, locality, stations-pair, season and G.M.T. Corrections are given in 1/100ths lanes and they are the predicted values of the corrections. They represent the amount to apply to the reading of the receiver display in order to obtain the charted Omega position line.

Omega is essentially a sky wave system hence sky wave corrections are always necessary. Attempts to determine a position without applying sky wave corrections can result in errors of position fixes in excess of 35 miles.

A vessel which expected to remain in one general vicinity for some time might find it convenient to construct a graph from the table. This is also shown in Plate 12.20, where the corrections for the period 1st–15th April, have been graphed.

If on inspection of a sky wave correction table or graph the correction is seen to vary rapidly, application of the correction during this period will be relatively uncertain. When the paths of the signals from stations to ship have led partly through a darkness zone of the earth and partly through a daylight zone, such a rapid variation may occur.

Interpolation of the listed corrections becomes inaccurate and an error in the ship's position may be expected. The best procedure is to avoid making a fix using the pair in question while the uncertainty lasts.

An example of a rapidly varying sky wave correction would be a change from —30 to +20 in one hour. No such case is present in Plate 12.20.

Interpolations between tabulated positions and between half months are not required.

Navigators are requested to check the predicted Omega sky wave corrections whenever possible. If an Omega receiver is situated ashore in a known position it becomes possible to check the predicted sky wave corrections for that position. Any error in the predicted corrections is discovered by the shore readings. The 'observed' corrections may then be transmitted by normal radio to vessels in the environments.

It is therefore helpful if Omega equipment is left 'on' when the ship is in a fixed location.

to the nearest 4° lat. and 4° long. → 36.0 N Lat. 76.0 W Long.

OMEGA SKYWAVE CORRECTIONS 10.2 kHz

36.0 N Lat. 76.0 W Long.

LOP: B-C TRINIDAD - HAIKU

Greenwich Mean Time

	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1-15 MAR	-32	-17	-3	11	24	31	31	31	31	31	31	59	60	54	45	32	16	9	3	-2	-7	-10	-13	-27	-32
16-31 MAR	-34	-21	-6	9	22	31	31	31	31	31	33	60	57	50	41	28	13	7	1	-4	-9	-12	-14	-24	-34
1-15 APR	-36	-25	-9	6	20	31	31	31	31	31	45	60	54	46	36	23	12	6	0	-6	-10	-14	-16	-22	-36
16-30 APR	-37	-28	-12	3	18	31	31	31	31	31	56	57	51	43	32	19	10	4	-2	-7	-11	-15	-16	-20	-37

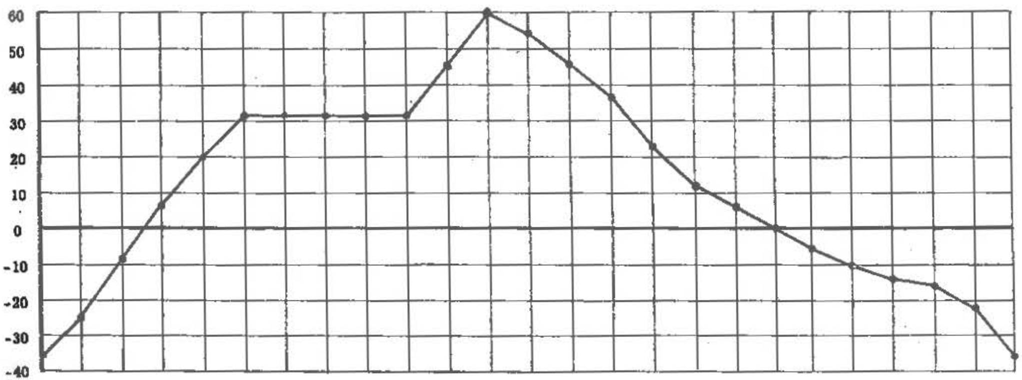


PLATE 12.20

Plate 12.20 is from: "The Contribution of the Omega Navigation System to Safe and Economical Ship Operations", by Captain Joseph F. Enright, U.S.N. (Ret.) of Northrop Corporation, and is reproduced by kind permission of the author.

Apparent inaccuracies in tabulated sky wave correction values should be reported.

Fixed Errors:—

As with Decca, it may be found in use that a general displacement of the Omega position lines is observable in any one area. In this case there may be published a fixed correction to apply to all readings of a pair in a stated locality.

Alternatively, corrections may be published which apply only to certain hours of the day.

Both these corrections, fixed and diurnal, may be treated as amendments to the published predicted sky wave corrections.

Plotting.

Readings from two or more Omega pairs give crossed position lines for a fix. An Omega position line may of course be crossed with another type of position line or may be used in a running fix. As with other aids to navigation it is advisable to take frequent fixes. This enables the ship's track to be plotted with as much accuracy as possible.

Plotting on an Omega lattice chart is accomplished in a similar manner to that described for a Decca chart, with the fractions being interpolated directly between charted lanes. An aid in plotting the per cent of lane is an interpolator, one type of which is illustrated in Plate 12.9.

Plate 12.21 shows part of an Omega lattice chart. There follows an example of plotting a position from Omega readings and an example of deducing expected Omega readings in a given position.

Example 1:—

On 21st April, 1968, at 1000 hours local time, vessel in the vicinity of Cape Hatteras. The readings for the Omega pairs *AC*, *BC* and *BD* were 842·59, 732·75 and 976·52 respectively. The sky wave corrections taken from the tables were +0·07, +0·19 and +0·07 respectively. Plot the position on the chartlet (Plate 12.21).

NOTE—The correction for *BC* (+0·19) may be checked with Plate 12.20.

Local Time: 1000. Date: 21/4/68. G.M.T.: 1500.

	Pair AC	*Pair BC*	*Pair BD*
Receiver	842·59	732·75	976·52
Correction	+0·07	+0·19	+0·07
Line of Position	842·66	732·94	976·59

Fix: Lat. 35° 51′·5 N., Long. 75° 03′·5 W.
When plotted the position is at 211000.

Example 2:—

On 21st April, 1968, at 0437 hours local time a vessel is in Lat. 35° 12·3′ N., Long. 74° 33·1′ W. (Position 210437, Plate 12.21). What would be the expected readings for the Omega pairs *AC* and *BD*, sky wave corrections being +0·46 and —0·16 respectively?

The sky wave corrections are applied in reverse on this occasion as it is desired to establish the readings displayed on the receiver.

	Pair AC	*Pair BD*
Correct position line	842·05	971·17
Correction (sign reversed)	—0·46	+0·16
Anticipated readings on display	841·59	971·33

Tables.

As with Consol and Loran, special tables exist for Omega. By means of these tables an Omega position line may be obtained without reference to a lattice chart.

The readout from the receiver is adjusted for sky wave correction, giving the Omega position line to be plotted. The Omega Charting Co-ordinate Tables are then entered and give two positions (Latitudes and Longitudes) through which the Omega position line runs. These points are plotted on an ordinary non-lattice chart and joined up. The resulting line is the Omega position line on which the ship is situated. The tables have been so drawn up that a navigator may safely use a straight line between any two positions resulting from the tables. Repeating with another pair of stations gives a fix.

Conversely the tables may be used to construct an Omega grid for an unlatticed chart of any locality within the area of coverage.

Homing.

Omega lattice lines lend themselves to the technique of 'Homing', as explained earlier in this chapter under 'Decca'.

Both Lattice Homing and the 'General Type' may be used and Omega can thus be used to assist in keeping the ship to a predetermined track.

Accuracy and Range.

Under normal circumstances Omega's accuracy is expected to be better than $\pm$ 1 mile by day, $\pm$ 2 miles by night. It is not advocated that an Omega chart with its inadequate scale be used for confined waters operations nor should the Omega general purpose equipment be used when precise piloting is called for.

Readings may be unreliable relative close to a transmitter where the ground wave, though suppressed, may be received rather than the desired sky wave. As stated previously the Omega lines for any pair are shown as dashed lines within 650 miles of either station.

Coverage, as has been stated, is expected to be world-wide. Signals from individual stations can be received out to maximum usable ranges of 4,000 miles and 8,000 miles. The shorter range can be expected for receivers to the west of the transmitter; the longer range for receivers to the east.

Information for ships with Omega navigation equipment is broadcast by means of Navigational Warnings.

CHAPTER XIII

APPLICATION TO CHARTWORK OF SOME NAVIGATION AIDS AND SYSTEMS

Navigation Aids have become increasingly accepted aboard vessels of all types. Some aids or systems have a direct application to chartwork in that they give a position line which can most readily be identified by the use of a lattice chart. Chapter XII has been exclusively concerned with such systems and charts.

Radio bearings, as given by radio direction-finding equipment, have been discussed in Chapter XI.

Other aids are of importance and in use in conjunction with charts. It is proposed to mention a few here, insofar as they apply to chartwork. Of concern in this respect is the type of information presented to the user by each navigation aid system and also the manner in which the information is presented.

RADAR

Radar, as used in a merchant ship, gives the bearing and distance of a target from the operating vessel. It has been shown in Chapters V and VI that bearing and distance is a recognised type of position fix. It would therefore seem at first sight that radar presents an important new method of navigating. Such is not strictly true but it is almost the case if the radar set is used within its limitations.

The P.P.I. display presents a continuous picture of all targets picked up at the time. Interpretation of the display is an important part of radar training.

The reader may be familiar with seeing the echo of the forward tug on the P.P.I. when berthing and remarking on how well his set is working. He may also be familiar with the sight of a long, distant coastline portrayed on the screen and recollect the difficulty experienced in deciding which bump was which point of land and which strong echo was which hill shown on the chart.

In the first case, finding the position of the ship relative to the tug was easy and accurate but in the second case finding the position of the ship to plot on the chart was not easy and was likely to be inaccurate.

Generally, the closer and more isolated the object the more useful it is likely to be as a navigating target. Other important considerations are the composition of the target, its aspect, the performance of the set and propagation and meteorological conditions.

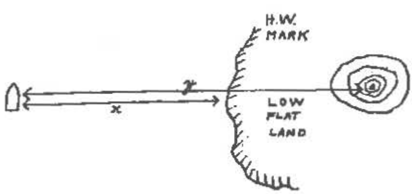
A steel tower will show up better and be detected sooner than a wooden structure. A cliff face is preferable to a sand-dune.

(a) Energy likely to be reflected backwards

(b) Much less energy will be reflected backwards

FIG. 13.1

It is extremely important to realise that on approaching a coastline the first thing which appears on the radar screen, unless in very favourable conditions, is unlikely to be the foreshore or even an object in close proximity to it. If a hill a mile inland is detected first the P.P.I. gives the impression that the ship is a mile further offshore than she actually is. Some objects make better targets from one bearing than from another.



x is the distance the vessel is actually offshore

y may be the distance offshore given by Radar

FIG. 13.2

It is the policy of the Admiralty to mark as such on their charts any natural or artificial feature which has been found to be conspicuous. The abbreviation Ra. (conspic.) is used.

Coastlining on all new charts has been improved and adjusted where possible to facilitate radar navigation. An important part of this is an attempt to include more accurate contouring thus enabling a radar observer to decide which geographical features are likely to provide the best targets and from which bearings optimum results are to be expected.

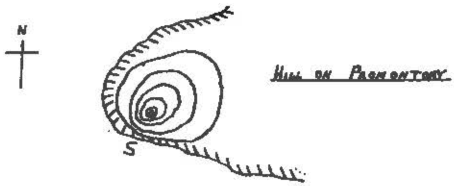


FIG. 13.3

In Fig. 13.3, *S*—closer spacing of the contour lines shows a steeper gradient to the S.W. The hill will thus probably be more radar conspicuous from this bearing.

Approximate contours appear as dashed lines.

For several reasons radar ranges are likely to be more accurate than radar bearings. Therefore rather than attempt position fixing by bearing and range of one object it is preferable to obtain a fix by means of ranges of three or more objects. That is, on the

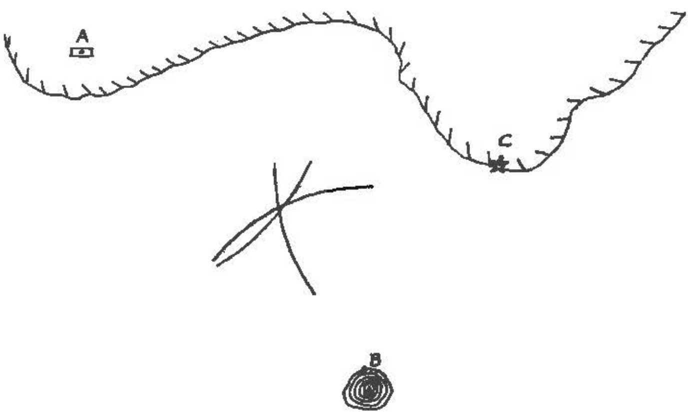


FIG. 13.4

chart for each object in turn, with centre the object and radius the range as measured by radar, draw an arc to seaward. In a satisfactory fix the arcs should cut in one spot or in a small 'cocked-hat'.

In fig. 13.4:

Target A—Large Building.

B—Nearest point of Steep Island.

C—Point Light House—Note that due to their shape lighthouses are not generally as conspicuous to Radar as they are to the eye.

One particularly useful occasion on which position fixing by radar can be employed is that of a vessel at anchor wishing to obtain or check anchor bearings.

It is essential in radar navigation that the objects used should be identified beyond doubt before reliance is placed on a fix plotted on the chart.

Modern radar equipment becomes increasingly sophisticated. The development of radar as an anti-collision device has probably had some priority over its development as a navigating device. A computer may be incorporated to diagnose radar information instantly and to help in the selection of a safe course.

Optical Navigation Attachment (ONA).

An important application of radar to navigation is found in a device which throws the image of a 'chart' on top of the P.P.I., thus superimposing the 'chart' or any writing on it on to the radar picture. Usually the chart must be prepared at the appropriate radar scale on tracing-paper or plastic sheet but the value of such a development will be evident. This principle was pioneered in the early days of radar by the development of a chart comparison unit.

The Hydrographic Department has prepared special chart on permatrace for use in ONA's fitted in Hovercraft. Permatrace is a translucent material and the charts are drawn up to a scale to cater for a particular radar range setting, for example O — 1½ miles. In various shades of grey and in black the charts present coastlines, drying areas, basic navigational features such as lighthouses, buoys and restricted areas and selected and suitable features ashore.

Plate 13.1 (*a*)

The radar set for Hovercraft use is fitted with variable radar scaling for matching the chart scale required.

Plate 13.1 illustrates two Decca Navigation Attachment Units.

13.1(*a*) shows the ONA-12 (which operates on the 12" display in Fast Patrol Boats, Fast Ferries, etc.)

13.1(*b*) shows the ONA/202—for use with Decca 202 Radar—Hovercraft, etc.

The purposes of the Optical Navigation Attachment are to provide the superimposition of charts, navigational data, diagrams, etc., on to the radar picture.

Conversely, a sketch chart of the coastline may be drawn up from a radar picture by 'on-the-spot' plotting and drawing; i.e. a radar survey.

Plate 13.1 (*b*)

The Hydrographer publishes a diagram to facilitate the construction of charts for use in the ONA fitted to Decca D202 Radar.

The main body of the ONA is fixed on the radar face like the standard visor which it replaces.

From its nature the Attachment also provides daylight viewing and paper plotting facilities.

A matched radar/chart picture may be a valuable aid in detection and indentification of charted objects such as buoys, and may also help with the identification of coastal features. It is important on initially setting up the ONA that it is accurately adjusted for parallax to facilitate precise matching techniques.

If a desired track is drawn on the 'chart' the ONA radar operator can at any moment give the ship's position in relation to this track. This has important applications in the navigation of hovercraft, such craft being capable of high speeds.

The ONA is normally used in conjunction with the True Motion Radar because this enables a chart to be projected on to the display with the minimum of chart movement to keep it in coincidence with the radar picture.

The ONA may be used by day or night; records drawn may be of a temporary or permanent nature. An important feature is that the plotted information such as coastlines, 'own ship's' track, 'other ships' contacted, is available not only to the operator but is externally displayed so that the Master, navigator or pilot, is given a valuable miniature-chart aid on the bridge external to the radar. Considerably more navigational information is thus available in one place and the necessity for transfer plotting is removed.

Many methods of chart matching have been used since the first introduction of radar as an aid to navigation but the ONA brings advanced navigation techniques for special applications within the scope of the radar user by means of a simple add-on unit to the display similar to a viewing unit.

PLATE 13.2

On some radar sets the projection by reflection or by photographic means of the radar PPI picture on to a special plotting surface is an arrangement which facilitates the comparison of the radar presentation with a chart. Plate 13.2 shows a view of Kelvin Hughes' transistorised Photoplot radar display.

THE ECHO SOUNDER

One of the original aids to navigation and one of the most trusted by the sailor is the echo-sounding machine. The ability to be able to obtain depth of water in which the ship is floating at any instant for comparison with the chart is an advantage of great importance to a navigator. The echo sounder provides this depth with minimal effort by the navigator and usually provides it with great reliability.

The echo-sounding machine works on the principle of measuring the time taken by a sound wave to travel from the ship to the sea bed and back again. The instrument transmits the signal, detects the echo and measures the elapsed time interval. For convenience the result is displayed in depths, the speed of the signal through water being known.

Two display units are in general use; the indicator type and the recorder type. Examples of these are illustrated in Plate 13.3

Plate 13.3 (*a*) shows the indicator type of display unit; in this case the Marconi Metron III, Visual Depth Meter.

Plate 13.3 (*b*) shows the recorder type of display unit; in this case the Marconi Contour II Recording Echosounder.

The first provides an instant depth indication; the second a permanent sounding record.

The nature of soundings shown on charts is described in Chapter I and uses of such soundings are shown in Chapters IX, V and elsewhere in this book. The echo sounder provides the practical connecting link between depth of water at ship and depths shown on the chart.

The indicator type of display gives the operator the depth of

Plate 13.3 (*a*)

Plate 13.3 (*b*)

water under the ship at any moment and this, of course, is extremely useful, especially when the depth is required quickly.

In the recorder type, paper from a roll moves under a pen or stylus and a mark appears on the paper against depth measured. The result is a continuous record of soundings taken which also has the form of a contour of the sea bed. The display in this case does not have to be constantly watched. Times may be marked on the paper and the resulting graph is ideal for comparison purposes in many uses of chart soundings; an example being the 'line of soundings' method of helping to determine a ship's position. In the Contour II recorder [Plate 13.3 (*b*)] a pointer above the pen also indicates the depths against a scale as a visual check.

Usually several ranges of soundings are presented on the displays, enabling depths to be measured from a few feet to some hundreds of fathoms; or metres as the case may be.

There are many points of similarity in the use of an echo sounder and of a radar set. The echo sounder measures depths through water while radar measures distance through air space. The reader is referred to books on Electrical and Radio Aids for details.

Perhaps of particular interest to chart users is the possibility of the sea-bottom being masked by intervening features. These may include air bubbles, shoals of fish, weed or other suspended matter, movements of water or existence of different layers of water. Modern sets are generally so efficient that the importance of such obstructions has diminished. Arrangements to reject echoes from intervening objects are incorporated in some sets, thus ensuring that only the signal reflected from the sea bed is displayed. The Marconi sounders shown in Plate 13.3, ignore such intervening targets. Some echo-sounding equipment is designed with the deliberate intention of picking up intervening features. Equipment to detect shoals of fish is an example.

Trouble has been experienced in obtaining soundings in shallow water. Various devices have been produced to obtain accurate soundings in shallow water. One example is the use of a cathode ray tube to indicate the depth of water in the last thirty feet or ten metres. Some sets are designed specially for use in shallow water. These may be fitted on such craft as fishing vessels, yachts or survey ships. Portable sets are available.

As in radar, the nature and aspect of the target affects the strength of the echo. Rock, coral and hard sand are good reflectors; thick mud is bad. A flat sea bed offers a better reflecting surface than a steeply sloping one.

When commencing soundings it is good practice to begin from the least range. Always treat shoal soundings with caution; generally they should be accepted if they are seen to rise from the bottom. If doubt arises the echo sounder should be checked with manual or mechanical soundings.

Refined sonar devices are used in oceanographic work for such purposes as constructing maps of the sea bed. This is important in geological work and in determining routes for cables and pipelines.

DECCA NAVIGATOR MARINE AUTOMATIC TRACK PLOTTER

The use of the Decca Navigator System in association with lattice charts is described in Chapter XII. An automatic extension of the Decca Navigator system is available in the form of a track-plotter. The equipment is used in conjunction with the Decca Navigator Receiver. Here the decometer information is translated into a pen and paper movement and enables a continuous plot of the ship's progressions to be displayed.

The hyperbolic Decca position line patterns are presented on the paper in a rectilinear form and the pen indicates the position of the ship upon this new pattern at any instant. As the ship moves across the Decca lattice a record of her movements is obtained.

Paper from a roll moves slowly under the pen (Plate 13.4). The pen is free to move across the plotter and the paper moves at right angles to this. The paper is squared in inches and tenths and a roll can contain up to 20 feet.

Five scales which may be selected range from ¼″ to 4″ per Decca Lane and this has the effect of producing sheets with natural scales which may range from 1 : 5,000 to 1 : 500,000, depending upon plotter scale selected and observer's position within the Decca grid.

Four orientations of the display are possible, each 90° from the next. This enables a rough approximation to a North or

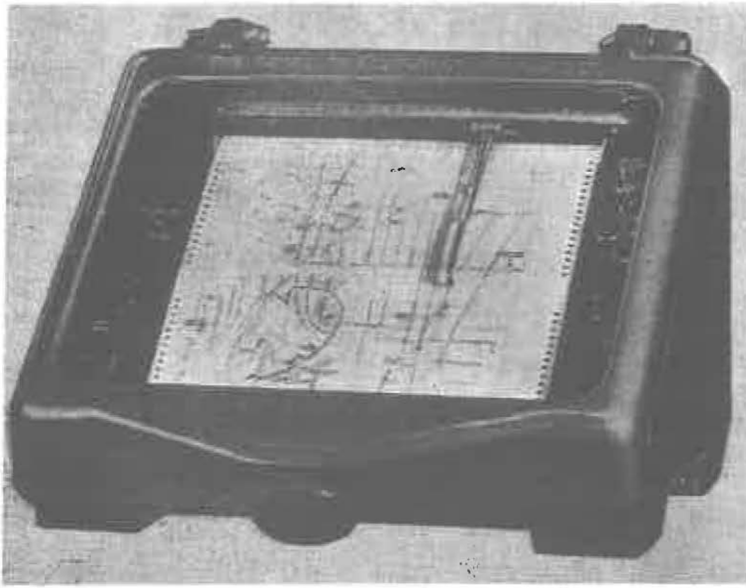


PLATE 13.4

heading-up display to be obtained in all parts of the coverage area.

Needless to say, a number of possible uses present themselves with such an instrument. The instrument enables a ship to follow a desired course with great accuracy and obviates the need for plotting. From a known starting spot, the vessel's position thereafter may be obtained visually.

The chief disadvantage of the Decca track plotter is the introduction of geographical distortion in the projection. This distortion is in fact a rather serious disadvantage and limits the track plotter from truly general use.

As stated earlier the plotter presents the position lines at right angles to one another. The actual Decca pattern is hyperbolic, the position lines having widely varying angles of cut which approach 90° only in a small part of the coverage. In the track plotter the hyperbolae have, as it were, been straightened out. Any neighbouring land mass which may be drawn in will therefore be portrayed with a corresponding distortion.

Thus on the track plotter paper the hyperbolic lines are portrayed as straight, evenly spaced and at right angles to one another. On the geographical chart the hyperbolic lines are not usually at right angles to each other; they 'turn' or 'curve', that is change direction, and in doing so constantly separate.

Considerable and varying land distortion results. Distortion is least in areas near the transmitters and/or where the actual hyperbolae cut at about 90°.

Another limiting feature resulting from this distortion is that a ship trying to steer a straight course over a fairly long distance would constantly be running off the 'chart' (paper) on the plotter.

The track plotter is therefore most suitable for use by vessels which are interested in making and remaking the same track of modest length; the portrayal of land, if any, in the vicinity being of lesser importance.

The plotter is useful for accurate holding of predetermined tracks or for the formation of complete track records.

Vessels to which the track plotter therefore finds particular application include fishing vessels, ferries, vessels engaged in such occupations as surveying or cable-laying, and also certain types of naval vessels.

A refined and developed version of the track plotter is available for special purposes such as marine surveying.

Loran C signals can be applied (through a Loran receiver) to a Decca track plotter. The instrument then works from these, instead of from the usual Decca signals.

An Admiralty chart cannot be used in a track plotter but a navigator may find it desirable to produce his own sketch chart on the normal squared paper and then use the paper during the relevant part of the voyage. Care must be taken with scales in producing and using a sketch chart and the above-mentioned distortion of features drawn must be borne in mind. Such a sketch chart will be seen inserted in the plotter shown in Plate 13.4.

Another feature of the track plotter is the provision of facilities for producing Decca lattice charts upon blank chart sheets.

To use an actual geographical lattice chart in a plotter in place of the normal squared paper requires the assistance of a computer. An arrangement of this nature is in fact deployed in aircraft equipment.

INERTIAL NAVIGATION SYSTEM

An Inertial Navigation System is an automatic navigation system based on the principle of dynamics that any change in direction, start, stop or alteration in speed is detectable. The accelerometer, gyroscope, computer and clock are the devices of greatest consequence making up such a system. The equipment is often referred to as SINS—The Ships Inertial Navigation System. In the British system the instrument takes all its references about the true vertical.

The instrument is entirely self-contained and once set up at a known departure point will function without reference to outside stations or observations of any description. It is independent of weather.

The instrument takes into account all movements of the ship over the surface of the earth. The ship's position is continually defined. Heading, course and speed made good and distance run are also given. Primary outputs are on dials. Position is presented in the form of Latitude and Longitude. Azimuth and vertical datum are defined with a high degree of accuracy. The system gives the ship's head at any moment and can be used as a steering reference in place of an ordinary compass. The system may thus control the vessel through an autopilot.

Since the main possible errors in the Inertial Navigation system are magnified with time it is prudent to check the equipment at intervals against some other navigational fix. Considerable accuracy remains, however, over an appreciable period.

The inertial navigator is independent of locality and is unaffected in regions where conventional navigation aids are unsatisfactory.

The system matches the needs of many naval vessels including submarines and craft, such as aircraft carriers, which may make frequent alterations of course yet require frequent and highly accurate fixes.

There would be no technical difficulty in providing a graphic display controlled directly from the Ships' Inertial Navigation System and if this becomes desirable either in naval or merchant vessels future instruments could give a direct plot on to a chart.

SONAR DOPPLER NAVIGATOR

Another automatic navigation system is found in the Sonar Doppler Navigator. Sonar equipment is similar to echo-sounding gear. The 'doppler effect' is concerned with the change in frequency of a sound or signal due to movement. In this case a signal transmitted from a moving object and reflected back from a stationary surface will indicate an apparent frequency shift.

The Sonar Doppler navigation equipment transmits sound beams through the water directed obliquely towards the ocean floor. These may be to each of the four cardinal directions of the compass or they may be with relation to the ship's fore-and-aft line. The reflected sound is changed in frequency due to the movement of the ship (the doppler effect, as above), the amount of this frequency shift depending upon the amount of movement of the vessel.

By measuring the doppler shift of these reflected sonar beams the system measures the vessel's velocity relative to the bottom over which she is moving. The results are processed to produce ships direction and speed.

The systems are gyro-compass controlled and in fact this determines their accuracy. The equipment is again self-contained and independent of outside references. It is also virtually independent of sea-bottom characteristics.

Reflection is from the sea-bottom in shallow water. This is up to about 600 feet (about 180 metres), depending on the system. In deeper water reflection is from the ocean mass and velocity is not therefore measured strictly with reference to the bottom.

The basic display is likely to be in the form of a console but graphic displays are also used. The equipment must be set up and thereafter, as will be seen, the display is relative to this known starting-point.

The console or panel display is digital. Standard information likely to be given is speed and distance travelled on the desired course, speed and distance travelled off course and the course to steer at any instant in order to make good the desired course. Latitude and Longitude are not given as such.

The graphic display has more application to chartwork. Such a display is in the form of a plotting board or track plotter. The plotter may be designed to take a special size sheet of blank paper or it may be adjustable to accommodate any standard nautical chart. The ship's course is traced out on the chart providing a graphic plot of the ship's progress. A selection of scales can be provided. These range from 50 yards per inch to 16 miles per inch, depending on manufacturer. Distance run can be displayed on counters. Position, course, speed and distance run are all determined.

An interesting application from the sailor's point of view is that since Sonar Doppler and SINS equipment measure movement over the ground, they provide the exact moment at which to drop the anchor. This could be a matter of some importance in such cases as large deep-draft vessels anchoring in exposed waters.

Considerable accuracy is achieved with the Sonar Doppler Navigator but errors may increase with time and the system should be checked at intervals against an outside navigational fix.

Certain less costly refinements of the Sonar Doppler apparatus are under study. The modification in the form of the sonar doppler log as mentioned in Chapter I is an example. An aid-to-docking refinement is also manufactured.

NAVIGATION SYSTEM BASED ON THE USE OF ARTIFICIAL EARTH SATELLITES

In Chapter VIII the underlying principle of astronomical position lines was shown (Fig. 8.1). As was seen the astronomical position line is part of a circle the centre of which is the geographical position of the heavenly body and the radius of the circle the zenith distance. An essential feature in the determination of the position line was a previous knowledge of the exact geographical position of the body and accurate means of measuring the zenith distance.

In Chapter XII it was shown how Radio Position Fixing systems can provide position lines of a hyperbolic nature. In this case the systems are operated by exactly located shore stations and measurements taken from the radio signals determine the hyperbolic line on which the observer is situated.

Similarly, if an exact position of an artificial satellite can be known and means provided to establish a similar circle or hyperbolic line then we have the basis of a navigation system using artificial earth satellites. Measurements are not made by visual observations but by radio techniques, this being possible as radio equipment may be fitted in an artificial satellite.

Such navigation systems have been developed or are under review. The principle of operation varies with system.

In any system there is ground control of the satellites in one form or another and the positions of the satellites in their orbits are precomputed and constantly verified. A common endeavour is to keep the ship-borne equipment as simple and as inexpensive as possible. Satellite navigation systems could vary from fully automatic, where upon use the ship's position is immediately displayed, to 'passive', where the navigator must calculate his own position from data provided.

Depending on requirements the number of satellites and ground stations making up a system alters. Sufficient satellites placed in orbits where the satellites move across the earth surface can give world-wide coverage. Modified coverage can be obtained by using geostationary satellites, that is satellites which remain stationary or nearly so over one part of the earth. The service with any system is full-time. Satellite navigation systems are independent of weather conditions.

The Satellite Doppler Navigation System.

In the first artificial satellite navigation system to become operational the ship's position is ascertained by receiving a succession of transmissions from a single passing satellite. Several satellites make up the system, each placed in polar orbit and maintaining heights of from 540 to 700 miles above the earth's surface.

In this system, the Satellite Doppler Navigation System, each satellite makes consecutive, 2-minute-long broadcasts which include the satellite's identification, its own position as computed for it by a ground station and the time.

The ship's equipment determines the position of the vessel with relation to the satellite by measuring the 'doppler shift' of the satellite's signals as it approaches and/or recedes from the vessel. As stated earlier in this chapter the doppler effect is concerned with the change in frequency of a sound or signal due to movement. The ship's position is then automatically displayed on board.

At least three-2-minute transmissions from the satellite must be received. Each one gives a hyperbolic-type position line for the ship. On reception of the signals, the ship's equipment, which includes a small computer, prints out the ship's position and the exact time. Later models display the latitude and longitude on digital indicators. The navigator must supply his approximate position, approximate G.M.T. and as accurate a course and speed made good as possible.

A modification, which avoids the expense of a ship-board computer, transmits the receiver output ashore via the ship's radio. From the remote computer the position fix and its time can be transmitted back to the ship within a few minutes.

Position-fix accuracies are in the order of $\pm \frac{1}{10}$ mile. This accuracy is maintained all over the world. For optimum results the altitude of the satellite pass should be approximately 15° to 70° above the horizon. Accuracy can be improved by taking more than the minimum three sets of doppler measurements; up to a maximum of nine per satellite pass is possible.

It is hoped to develop an inexpensive receiver which, though not quite so accurate and requiring some hand calculation, will bring the satellite system within the use of a large majority of commercial users.

With the several satellites in polar orbits the system provides world-wide coverage. The interval between satellite passages naturally depends upon the number of satellites used and (because of the polar orbits) upon the latitude of the observer.

Satellite navigation systems are subject to some errors, the most obvious being satellite position error. The arrangement of ground station tracking and injection of up-to-date data, however, keeps this error to a minimum.

Propogation errors, in the 'doppler'-type, are overcome by the method of transmission of the satellite signals.

In the Satellite Doppler Navigation System failure to provide the correct course and speed made good of the ship during the 'pass' of a satellite is the most likely source of error. In an effort to reduce such error later receiving sets accept velocity inputs from gyro compass and electro-magnetic log, Omega, Sonar Doppler and

SINS. Conversely, the resultant fix may be used to set up or up-date any of these or other navigational device, for example Decca.

It is interesting to note that in the future, by taking up to the maximum transmissions during a satellite pass it may be feasible for the system actually to provide the vessel with her true course and speed made good during the period.

As will be seen navigation systems may give mutual checks and used together can facilitate accurate navigation.

Operational satellite data is issued through the Navigational Warnings system. Information is given to enable a user to calculate details of satellite passes in his locality. Mechanical devices in the form of small-scale chart projections with overlays exist to facilitate recognition of suitable passes.

Thus the Satellite Doppler Navigation System is roughly similar in concept to radio hyperbolic navigation systems. The network of ground transmitting stations is replaced by a series of precisely computed positions of an orbiting satellite.

Another satellite navigation system at present under review is concerned with an exchange of signals among ground station/ satellite/ship, enabling the range from satellite to ship to be computed. A repetition with a second satellite would provide a fix. The operation would be controlled from the shore station and on completion the position transmitted to the ship.

This system envisages giving coverage to the greater part of the North and South Atlantic Ocean, using two geostationary satellites placed above the equator, one on each side of the ocean.

Accuracies are claimed of up to ± 1 mile. In a satellite system measuring range there is a pattern of accuracy variation.

Errors may include satellite position error and range measurement error. Propogation errors are computable to a large extent and therefore may be applied.

RADIO FACSIMILE WEATHER RECORDER

The reception aboard ship of facsimile copies of current weather charts is accomplished by a Radio Facsimile Weather Recorder. There are several types available; Plate 13.5 shows the Cossor 10-inch Weather Facsimile Recorder—Model JAX-10.

The World Meteorological Organisation co-ordinates national services and their reporting stations. Information is gathered from a large number of sources including observations from satellites and a group of weather facsimile transmitting stations has been established throughout the world. Broadcasts are made at scheduled times. Details of times, maps and other items relevant to facsimile transmissions are contained in the *Admiralty List of Radio Signals*. Charts may be received at sea or in port prior to sailing.

PLATE 13.5

Charts may be of a situation or prognostic nature and information given may be concerned with pressure distribution, isobars, winds and weather or it may deal with waves, ice information or sea surface temperatures.

A facsimile weather chart may be seen in the recorder illustrated in Plate 13.5. The chart is reproduced on electro-sensitive paper. All information is, of course, entered by meteorologists ashore.

A facsimile weather chart has obvious advantages of speed and can contain greater detail of information than can be transmitted by ordinary radio reports.

Ocean passage times may be shortened by the possession of information from a weather chart. Alternative routes may be considered and bad weather possibly avoided. Fishing grounds likely to be affected by bad weather may be recognised in advance. A facsimile weather chart is of particular value in areas subject to tropical revolving storms.

A shore-controlled weather routeing service for ships may be operated. For example, the British Meteorological Office offers such a service for ships on the North Atlantic trade. All meteorological information is gathered ashore and the vessel merely obeys radioed routeing instructions.

INTEGRATED NAVIGATION SYSTEMS

The possible mutual reliance of many of the navigation systems and aids described in this chapter and elsewhere in the book has been utilised to develop Integrated Navigation Systems. The more sophisticated of these are computer controlled.

Examples of units which might go to make up an integrated navigation system are computer, gyro compass, automatic steering, ship's log, radar (giving automatic warning of collision risk and other danger), echo-sounder, satellite navigation receiver, SINS or sonar doppler equipment, input from a radio hyperbolic aid, data logger.

Integrated Navigation might be said to be the use of all available information in an optimum manner.

An example of an actual automatic, self-contained navigation system is one consisting of an inertial navigator, backed up by sonar doppler equipment and regularly updated by satellite doppler fixes; the whole working in conjunction with a general purpose computer. Latitude, longitude and ship's head are constantly displayed. Course to steer and distance to steam to destination are also given.

The idea of integrated systems may also be extended to other spheres such as cargo handling work and hull loading. Associated with it is careful design and layout of bridge equipment.

At present the purposes of automated ship control are to reduce the human burden and to effect economies.

CHART PAPERS—WORKED EXAMPLES

WORKED EXAMPLE No. 1.

Cornish Coast

Variation 14° *W.* *Deviation Card No.* 1.

1. Find the course to steer by compass from a position 270° T. 3 miles from Trevose Head Lighthouse to a position 310° T., 2·5 miles from Pendeen Watch House, and give the distance on the course.

2. With the ship's head on the above compass course, Towan Head was observed to bear 117° C., and at the same time St. Agnes Head bore S. 7° W. by the same compass. Find the ship's position and the set and drift experienced, the ship having steamed 1 hour 15 minutes on the course at 8 knots.

3. With the ship's head on the same compass course (*see* Question 1), Godrevy Lighthouse bore 200° C. Thirty-six minutes later the same point bore S. 27° E. by compass. Find the position of the vessel when the 2nd bearing was taken, making due allowance for the effect of the tidal stream setting 238° T. at 2 knots, vessel steaming 8 knots.

4. Find the course to steer by compass from Latitude 50° 15′ N., Longitude 5° 45′ W., to reach Latitude 50° 30′ N., Longitude 5° 30′ W., counteracting the effect of the tidal stream setting 010° T. at 2 knots, vessel steaming 8 knots. Give also the distance the vessel will make good in 1½ hours.

5. From the following horizontal angles, find the ship's position using a station pointer:

Kelsey Head 49° St. Agnes Head 70° Godrevy Lighthouse

Explanation of Worked Example No. 1.

1. The point of departure is 270° T. from Trevose Head. This, a true bearing, is laid off using the outer circle of the compass rose, and the distance 3 miles measured along the bearing. Call this point *A*. The destination is found in the same manner, i.e. by laying off a line 310° T. from Pendeen Watch House and measuring 2·5 miles along the bearing. Call this position *B*. Join *A* to *B*. Now lay the edge of the parallel ruler along this line, *AB*, and move it carefully until the edge passes through the centre of the compass rose, and read off the true course. It will be found to be 227½° T.

To the true course apply the variation and the magnetic course is obtained. The deviation for the magnetic course can now be found from the card in the manner already explained and applied to the magnetic course, when the compass course will be known.

The working is as follows:—

True course	227½° T.	C.	D.	M.	
Variation	14° W.	270°	18° W.	252°	
	———	261½°	20° W.	241½°	241½°
Magnetic course	241½° M.	259°	21° W.	238°	238°
Deviation	20° W.		———	———	———
	———		3°	14°	3½°
Compass course	261½° C.				

A change of 14° (M.) gives a change of 3° (D.)

∴ A change of 3½° (M.) gives a change of $\frac{3\frac{1}{2}\times 3}{14}$ (D.)

= 1° (approx.).

Applying 1° to 21° W. in the direction of 18° W. gives 20° W. as the deviation.

NOTE—A full explanation is contained in the examples in Chapter X on the use of the deviation card.

Now measure the distance from *A* to *B*, using that part of the graduated meridian which is abreast of the two positions. It will be found to be 31·8 miles.

2. In Question 2, simultaneous compass bearings of two objects are given to fix the ship's position, but before these bearings can be laid off on the chart it is necessary to convert them into true bearings

by applying the error of the compass, which is the combined effect of the variation and deviation. The compass error to be applied is, as explained in the text, the error for the direction of the ship's head when the bearings were taken. The variation is 14° W. and the deviation is 20° W., therefore the error is 34° W.

Towan Head		*St. Agnes Head*	
Compass bearing	117° C.	Compass bearing	187° C.
Error	34° W.	Error	34° W.
True bearing	083° T.	True bearing	153° T.

These bearings laid off on the chart indicate at their point of intersection, *X*, the ship's position.

The set and drift experienced during the run can now be found by measuring along the course line from the departure position the distance the vessel has steamed in the given time. This will give the D.R. position, and the difference between this position and the cross bearing fix is the set and drift. Observe that the set is from D.R. position to cross bearing position.

The ship steamed for 1 hour 15 mins. at 8 knots, therefore she steamed 10 miles. Measure 10 miles along the course from *A* and call this point *D*, which is the D.R. position. Take off the Lat. and Long. of *X*. Find the bearing and distance of *X* from *D*, the bearing is the set and the distance is the drift.

These will be found to be:—

Latitude	50° 24′ 36″ N.	Set	184°
Longitude	5° 18′ 30″ W.	Drift	1·4 miles.

3. In Question 3 it is required to find the position of the vessel by running fix.

Correct the compass bearings for the error of the compass and lay the resulting true bearings off on the chart. Now from any point on the 1st bearing, say *E* on chart, lay off the course steered and the distance steamed in the given interval—36 minutes at 8 knots, i.e. 4·8 miles. Call this point *F*. From *F* lay off *FH* representing the effect of the tidal stream experienced, i.e. 238° 1·2 miles. Through *H*, draw a line parallel to the 1st bearing, and where this line cuts the 2nd bearing at J is the ship's position when that bearing was taken.

To correct the bearings:—

Godrevy Lighthouse

1st bearing		*2nd bearing*	
Compass bearing	200° C.	Compass bearing	153° C.
Error	34° W.	Error	34° W.
True bearing	163° T.	True bearing	119° T.

The position is:—

Latitude 50° 18′ 00″ N. Longitude 5° 34′ 12″ W.

4. In Question 4 it is required to find the course to steer by compass, counteracting the effect of a given tidal stream, from one given position to reach another given position.

Plot both positions. They are denoted by *K* and *L* on chart.

Join *K* to *L*. From *K* lay off *KM*, 010° 3 miles. This represents the tidal stream to be experienced in 1½ hours. Take in the dividers a distance of 12 miles, i.e. the distance to be steamed in 1½ hours, and with centre *M* cut *KL* in *N*. Join *M* to *N*. This is the true course to steer. It is 038°.

To find the compass course:—

True course	038° T.
Variation	14° W.
Magnetic course	052° M.
Deviation	16° E.
Compass course	036° C.

C.	D.	M.	
034°	15° E.	049°	049°
036°	16° E.	052°	052°
045°	18° E.	063°	
	3°	14°	3°

$$\frac{3\times 3}{14} = \frac{9}{14}$$

Taking this as 1° the required deviation is 16° E.

The compass course to steer is 036° C.

The distance made good in 1½ hours is indicated by the distance *KN*. It is 14·9 miles.

5. In Question 5 the position is required by the aid of a station pointer. Clamp the legs of the instrument at their respective angles, then manoeuvre it until the bevelled edges of the three legs pass through the given objects. The centre of the disc is the position of the observer (*P* on the chart). It is:—

Latitude 50° 22′ 00″ N. Longitude 5° 21′ 04″ W.

WORKED EXAMPLE No. 2.

CORNISH COAST

Variation 14° *W.* *Deviation Card No.* 2

1. Find the compass course to steer from a position with Guthensbras Point bearing 291° T. and Carn Du bearing 041° T. to arrive at a position with Gull Rock bearing 270° T. and Chapel Point 000° T., and give the distance on each course.

NOTE—Maintain a distance of 2 miles off Lizard Lighthouse when rounding.

2. With the ship's head on the 2nd compass course, Zoze Point bore 280° C. and at the same time Gull Rock bore N. 4° W. by the same compass. Find the ship's position and the set and drift experienced, supposing the expected position to be with Gull Rock abeam, ship making her course.

3. With the ship's head on the 1st compass course Carn Du bore 340° C. Fifty minutes later Lizard Head Lighthouse bore N. 84° E. by compass. Making due allowance for the effect of the tidal stream setting 272° T. at 2·4 knots, find the position when the 2nd bearing was taken, ship steaming 12 knots.

4. Find the course to steer by compass from a position with Black Head bearing 330° T. distant 6 miles to reach her destination (*see* Question 1), counteracting the effect of the tidal stream setting 058° T. at 2·5 knots, ship steaming 10 knots. Find also the time the ship would take to reach her destination.

5. The following horizontal angles were taken to determine the ship's position:—

Cudden Point 43° Portleven Light 67° Henscarth Red Light.

Find the latitude and longitude, using a station pointer.

Explanation of Worked Example No. 2

1. The point of departure is a cross bearing position, and as the bearings are true they should be laid down as they are given. Their point of intersection is the point of departure. Since the vessel has to maintain a distance of 2 miles off Lizard Lighthouse when rounding, with this distance as a radius and the lighthouse as a centre describe an arc of a circle. The destination is given by true bearings of Gull Rock and Chapel Point, therefore lay these bearings down with the aid of the compass rose on the chart. Their point of intersection is the destination.

Draw tangents from the point of departure and destination to the arc of the circle off Lizard Head. These tangents are the courses. Lines drawn from the Lizard Light, at right angles to the tangents, to cut them, give the points where the 1st course ends and the 2nd course begins. The part of the circle between these points is the distance the vessel steams while rounding the lighthouse. Take off the true courses, convert them into magnetic courses by applying the variation given in the question, then find their respective deviations and thence the compass courses.

First Course

True course	110° T.	C.	D.	M.	
Variation	14° W.	120°	8° E.	128°	
		115°	9° E.	124°	124°
Magnetic course	124° M.	110°	10° E.	120°	120°
Deviation	9° E.				
			2°	8°	4°
Compass course	115° C.				

$$\frac{4\times 2}{8} = 1^\circ$$

Second Course

True course	045° T.	C.	D.	M.	
Variation	14° W.	040°	13° E.	053°	053°
		045½°	13½° E.	059°	059°
Magnetic course	059° M.	050°	14° E.	064°	
Deviation	13½° E.				
			1°	11°	6°
Compass course	045½° C.				

$$\frac{6\times 1}{11} = \tfrac{1}{2}^\circ \text{ (approx.)}$$

Measure the distance on each course. The distance on the first course is 26 miles, and on the second course 21·8 miles.

2. In Question 2 the vessel's position is fixed by simultaneous compass bearings of Zoze Point and Gull Rock, taken when on the second course. Apply the error of the compass to these bearings to convert them into true bearings and lay the latter off on the chart.

Zoze Point		*Gull Rock*	
Compass bearing	280° C.	Compass bearing	356° C.
Error	½° W.	Error	½° W.
True bearing	279½° T.	True bearing	355½° T.

The intersection of these bearings is the fixed position of the vessel.

The expected position being with Gull Rock abeam ship making her course, draw from Gull Rock a line cutting the course at right angles. The point of intersection is the expected position. A line drawn from this position to the fixed position is the set and drift the vessel has experienced, while on the second course, up to the time the bearings were taken. Take off the latitude and longitude of the fixed position and the set and drift.

These are:—

Latitude	50° 7′ 36″ N.	Set	239°
Longitude	4° 53′ 48″ W.	Drift	2·75 miles

3. Question 3 requires the position by running fix. Convert the compass bearings into true bearings and lay them off on the chart. They are 335° T. and 079° T., respectively, as shown on the chart. From any point on the 1st bearing lay off the course steered and distance steamed in the given interval, i.e. 110° T., 10 miles. At the end of this run lay off the tidal stream experienced, i.e. 272° T., 2 miles. Through the end of the tidal stream line draw a line parallel to the 1st bearing. Where this line cuts the 2nd bearing is the ship's position. Working is shown on the chart. Position is:—

Latitude 49° 56′ 40″ N. Longitude 5° 19′ 15″ W.

4. It is required to find a compass course to steer to counteract

the effect of the tidal stream from a given position off Black Head to destination as denoted in Question 1.

Plot the position off Black Head and from it draw a line to the destination position. This represents the course to be made good. At the point of departure lay off, say, one hour's tidal stream effect, i.e. 058° T., 2·5 miles. Next take in the dividers the distance the vessel will steam in 1 hour, i.e. 10 miles, and placing one leg on the end of the tidal stream with the other cut the course to be made good. Join these two points and take off the direction of this line which is the true course to steer. It is 023° T.

Apply the variation to this course, find the deviation and thence the compass course.

True course	023° T.
Variation	14° W.
Magnetic course	037° M.
Deviation	11° E.
Compass course	026° C.

C.	D.	M.	
020°	10° E.	030°	030°
026°	11° E.	037°	037°
030°	12° E.	042°	
	2°	12°	7°

$$\frac{7\times 2}{12} = 1^\circ \text{ (approx.)}.$$

To find the time taken on the course, measure the distance the vessel makes good in 1 hour, when the time taken can be found by proportion as follows:—The distance to be made good is 19·2 miles, and the distance made good in 1 hour is 12·1 miles.

$$\frac{\text{Required time}}{60 \text{ mins.}} = \frac{19{\cdot}2}{12{\cdot}1}$$

$$\therefore \text{ Required time} = \frac{19{\cdot}2\times 60}{12{\cdot}1} \text{ mins.}$$

$$= 95 \text{ minutes}$$

$$= 1 \text{ hour } 35 \text{ minutes.}$$

5. Clamp the left and right legs of the station pointer at the given angles, i.e. 43° and 67°, respectively, and manoeuvre the instrument until the bevelled edges of the three legs pass through their respective objects. The centre of the disc is the required position. It is:—

Latitude 50° 0′ 18″ N. Longitude 5° 20′ 45″ W.

WORKED EXAMPLE No. 3.

CORNISH COAST

Variation 14° *W.* *Deviation Card No.* 1.

1. At noon a vessel steering 088° C., at 8 knots, obtained a meridian altitude of the Sun and found the Latitude to be 49° 53′ N. At 1 p.m. Wolf Rock Lighthouse was observed to bear 352° C.

Required the position of the vessel at noon and at 1 p.m., making due allowance for the effect of the tidal stream estimated to set 020° T. at 2 knots.

2. From the 1 p.m. position a course was set to pass 4 miles off Lizard Lighthouse to counteract the effect of the tidal stream setting 062° T. at 1·4 knots, ship steaming 8 knots.

Give the compass course steered and the time taken to bring Lizard Lighthouse abeam.

3. From a vessel steering 041° C., Seven Stones Light-vessel bore 4 points on the port bow. Fifteen minutes later it was abeam and after a further interval of 25 minutes it bore 4 points on the port quarter.

Required the true course the vessel is making good.

4. From a vessel bound up the Bristol Channel, Round Island Light just dipping was observed to bear 170° T. If the height of the observer's eye was 36 feet, find the position of the vessel.

Explanation of Worked Example No. 3

1. In this Question the latitude by meridian altitude is given, followed an hour later by a compass bearing of Wolf Rock Lighthouse. The question, therefore, involves the working of a running fix, the position lines being (1) the parallel of Latitude 49° 53′ N., and (2) the true bearing of Wolf Rock.

First find the deviation for the course being steered and thence the magnetic course. Apply the variation to the magnetic course and the true course will be known. Next find the compass error and apply it to the compass bearing of Wolf Rock to find its true bearing.

	Compass Course	*Deviation*	
	079°	19° E.	
088°			16° E.
	090°	15° E.	
2°	11°	4°	

A change of 11° (C.) gives a change of 4° (D.)

A change of 2° (C.) gives a change of $\frac{2\times4}{11}$

$=\frac{8°}{11}$

Taking this as 1°, the required deviation is 16° E.

Compass course	088° C.
Deviation	16° E.
Magnetic course	104° M.
Variation	14° W
True course	090° T.

Variation	14° W.
Deviation	16° E.
Error	2° E.

Wolf Rock Lighthouse

Compass bearing	352° C.
Error	2° E.
True bearing	354° T.

Draw in the parallel of latitude and lay down the true bearing of Wolf Rock. Since the 1st position line is the same as the true course, i.e. East (true), mark off on the parallel of latitude the distance steamed in the given interval, i.e. 8 miles, then from the end of this course line lay off another line to represent the tidal stream experienced during the interval. Through the end of the latter line draw a parallel of latitude, and where it cuts the true bearing of Wolf Rock is the position of the vessel when that bearing was taken.

To ascertain the position at noon:—

Find the course *made good* by joining the point on the parallel of 49° 53′ from which the run was marked off, to the end of the tidal stream line. From the position on the bearing of Wolf Rock draw a line parallel to the course made good and where it cuts the parallel of 49° 53′ is the noon position. Take the latitude and longitude of both positions off the chart. They are:—

Noon Position		*1 p.m. Position*	
Lat.	49° 53′ 00″ N.	Lat.	49° 54′ 48″ N.
Long.	6° 01′ 12″ W.	Long.	5° 47′ 48″ W.

Another method of finding the noon position and one which, in this case, may be more accurate than that just described, the angle of cut being rather acute, is as follows—After finding the course made good, take the *distance made good* in the dividers and placing one leg on the 1 p.m. position, with the other leg cut the parallel of 49° 53′. This point is the noon position.

2. In this question it is required to find the course steered to counteract the effect of the tidal stream to pass 4 miles off Lizard Lighthouse.

With the lighthouse as centre and radius 4 miles, describe an arc of a circle, on chart *ab*. From the 1 p.m. position draw a tangent to the arc, and this is the course required to be made good. From the 1 p.m. position lay off a line 062° to represent the tidal stream and measure along this line 1·5 miles, i.e. one hour's effect. Take the distance steamed in 1 hour, i.e. 8 miles, in the dividers, place one leg on the end of the tidal stream line and with the other leg cut the course to be made good. Join the end of the tidal stream line to this point and the line will represent the course steered. Take off the true course; apply the corrected variation; find the deviation for the magnetic course and thence the compass course.

		C.	D.	M.	
True course	099° T.	090°	15° E.	105°	
Variation	14° W.	100°	13° E.	113°	113°
Magnetic course	113° M.	101°	13° E.	114°	114°
Deviation	13° E.		2°	9°	1°
Compass course	100° C.				

$\frac{1\times 2}{9}$ can be taken as nil.

To find the time taken to bring the lighthouse abeam:

It should be remarked that the beam bearing is a line at right angles to the course steered and not to the course made good. A line at right angles to 099° T., the true course steered, runs 009° —189°, therefore lay off this line from the lighthouse and where it cuts the *course made good* is the position when the lighthouse was abeam. Measure the distance to this position from the point of departure. It is 22·3 miles. Now measure the distance the vessel is making good in one hour. It is 9·1 miles. Divide the distance 22·3 miles by the distance made good in one hour, i.e. 9·1 miles, and this will give the time taken to be abeam of Lizard Lighthouse, i.e.

$$\frac{22 \cdot 3}{9 \cdot 1} = 2 \cdot 45 \text{ hours}$$

$$= 2 \text{ hours } 27 \text{ minutes}$$

3. In this question, three bearings of Seven Stones Light-vessel are given from which it is required to find the course the vessel is making good over the ground. Since these bearings are relative to the direction of the ship's head, it is necessary to find the true course steered before the bearing can be laid down. The compass course is 041°, therefore find the deviation for this course and thence the compass error. Apply the error to the compass course and the true course steered is known. The deviation is found from the card as follows:—

	Compass Course	*Deviation*	
	034°	15° E.	
041°			17° E.
	045°	18° E.	
4°	11°	3°	

Variation	14° W.
Deviation	17° E.
Error	3° E.

$$\frac{4\times 3}{11}=1\,^{\circ}\ \text{(approx.)}$$

Compass course	041° C.
Error	3° E.
True course	044° T.

To lay off the bearings:—

Draw a line to represent the true course steered, then by means of the protractor on the parallel rulers make angles of 45°, 90° and 135° with this line, to pass through the object. If there is no protractor on the parallel rulers the bearings can be laid off with the aid of the compass rose as follows. The bearings are to port, therefore allow 45°, 90° and 135° to the left of the true course and these will give the true bearings.

To convert the relative bearings (red or port side) into true bearings:—

	1st Bearing	*2nd Bearing*	*3rd Bearing*
True course	044° T.	044° T.	044° T.
Relative bearing (port side)	45°	90°	135°
True bearing	359° T.	314° T.	269° T.

The intervals between the 1st and 2nd, and 2nd and 3rd bearings are 15 and 25 minutes, respectively. With the light as centre and 15 units from any scale as radius, describe an arc of a circle. Describe another arc with a radius of 25 units from the same scale, on the other side of the light. Draw tangents to these arcs parallel to the middle bearing. Join the points where these tangents cut the 1st and 3rd bearings and this is the course made good. It will be found to be 057½° T.

Bearings, arcs, tangents and course made good are shown on the chart.

4. Question 4 requires the position of a vessel from the bearing of a charted light which is just dipping (*see* Chapter VII). It will be observed from the chart that the height of Round Island Light is not stated, hence it will be necessary to make use of a table giving The Distance of the Sea Horizon. This is found in any book of nautical tables. The reader should also note the formulae as given on page 135.

From table, 36 feet = 6·90 miles
From table, 15 feet = 4·45 miles

Difference = 2·45 miles = Correction for height of eye.

Charted range = 20 miles
Correction for height of eye = 2·45 miles

Distance off dipping light = 22·45 miles

The true bearing 170° is laid down to pass through Round Island and the distance 22·45 miles measured along the bearing. The position of the vessel is at S., as shown on the chart.

It is:—

Latitude 50° 20′ 50″ N. Longitude 6° 25′ 36″ W.

WORKED EXAMPLE No. 4

NORTHERN ISLES

Variation 15° *W.* *Deviation Card No.* 2.

1. From a position with Auskerry Lighthouse bearing 270° T. distant 2 miles, set a course to reach a position 090° T. 3·5 miles from Start Point Lighthouse in 1 hour 45 minutes the tidal stream being estimated to set 354° T. at 1 knot.

Give the compass course to steer and the speed of the vessel.

2. After the vessel had steamed 1 hour and 30 minutes on the above compass course (*see* Question 1) Start Point Lighthouse bore 270° T. and at the same time Twinyas Point was observed to be open of Stromness.

Find the position of the vessel and the actual set and drift experienced during the run.

3. With the ship's head 356° C., and vessel steaming 9 knots, Dennis Ness Lighthouse bore N. 49° W. by compass and 30 minutes later it was abeam. Making due allowance for the effect of the tidal stream estimated to set 190° T. at 2½ knots, find the position of the vessel when the 2nd bearing was taken.

4. Find the position when the horizontal angle subtended by Hacks Ness and Els Ness reached its maximum to a vessel leaving a position midway between Ve Ness and Little Ness, and steering 058° T. Give also the value of the angle.

Explanation of Worked Example No. 4

1. Plot the departure and arrival positions and join them with a line, on the chart AB. This will represent the course to be made good. At the point of departure lay off AC representing the tidal stream to be experienced in 1 hr. 45 min. Join C to B, and this line will indicate the course to steer and also the distance to steam in 1 hr 45 min. Take off the course. It is 031°. Now apply the variation; find the deviation and thence the compass course.

True course	031° T.
Variation	15° W.
Magnetic course	046° M.
Deviation	12½° E.
Compass course	033½° C.

C.	D.	M.	
030°	12° E.	042°	042°
033½°	12½° E.	046°	046°
040°	13° E.	053°	
	1°	11°	4°

$$\frac{4 \times 1}{11} = \tfrac{1}{2}^{\circ} \text{ (approx.)}.$$

Measure the distance from the end of the tidal stream line to destination. It is 15·7 miles and since this distance has to be steamed in 1 hr. 45 min., then 15·7÷1·75 will give the speed. It is 8·97, say, 9 knots.

2. In Question 2 it is stated that the vessel steering the above course arrives at a certain position in 1 hour 30 minutes after leaving the departure position, and it is required to find the actual set and drift she has experienced in that time.

Plot the given position, D on chart. From the point of departure lay off the true course steered, i.e. 031°, and measure along this line the distance the vessel will steam in 1 hr. 30 min., i.e. 13·5 miles, AE on chart. E is the D.R. position and a line drawn from it to the true position indicates the actual set and drift experienced, ED on chart.

The vessel's position at D is:—

Latitude	59° 16′ 42″ N.	Longitude	2° 13′ 12″ W.
Actual set	027°.	Drift	3·9 miles.

3. In Question 3 the compass course is given and information for the working off a running fix. Find the deviation for the compass course and thence the compass error. Apply the compass error to the compass course, and the given compass bearings, to obtain their true counterparts.

	Compass Course	*Deviation*			
	000°	5° E.		Variation	15° W.
356°			3½° E.	Deviation	3½° E.
	350°	1° E.			
6°	10° :	4°		Error	11½° W.

$$\frac{6\times 4}{10} = 2\tfrac{1}{2}° \text{ (approx.)}.$$

Compass course	356° C.
Error	11½° W.
True course	344½° T.

Dennis Ness Lighthouse

1st Bearing		*Beam Bearing*	
Compass bearing	311° C.	True course	344½° T.
Error	11½° W.	Relative bearing (red)	90°
True bearing	299½° T.	True bearing	254½° T.

Lay off both true bearings of Dennis Ness Lighthouse, on chart *FG* and *FH*. From any point on the first bearing lay off the course steered and measure along it the distance run in 30 minutes, i.e. *GJ*, 4½ miles. At the end of the run lay off *JK* to represent the tidal stream, i.e. 190°, 1·25 miles. Through *K* draw a line *KL* parallel to the 1st bearing, and where it cuts the beam bearing in *M* is the ship's position. It is:—

Lat. 59° 24′ 10″ N. Long. 2° 17′ 30″ W.

4. Find the departure position by joining the position of Ve Ness and Little Ness, and bisecting the line. From this point lay off the given course, *NP* on chart.

To ascertain the maximum horizontal angle subtended by the two given points, join them with a straight line. At the middle point of this line erect a perpendicular and on this perpendicular find the centre (*Q* on chart) of a circle passing through the two points and just touching the course line. Describe the circle and the course line will make a tangent to it. The point of contact is the position where the angle subtended by the two points is at its maximum, and the latitude and longitude of this point can be taken off.

From *Q* draw *QR* perpendicular to *NP*, the course. Then *R* is the required position and the angle at *R* the required angle.

Position:—

Latitude 59° 11′ 15″ N. Longitude 2° 36′ 00″ W.

Maximum horizontal angle 100°.

WORKED EXAMPLE No. 5

Northern Isles

Variation 15° *W.* *Deviation Card No.* 1.

1. From a vessel steering 011° C. at 9 knots, Brough of Birsay Lighthouse bore 087° C. and was distant 4 miles. Course was then set to make a position with Noup Head Lighthouse 5 points on the bow when distant 3½ miles, and the log set at zero.

Give the compass course steered.

2. With the ship's head on the above course, and when the log showed 12, Noup Head Light was 5 points on the bow. When the log showed 15 the lighthouse was 3 points abaft the beam.

Required the position of the vessel when the 2nd bearing was taken, the tidal stream being estimated to set 060° at 3 knots during the interval.

3. From a position with Noup Head Lighthouse bearing 180° and subtending a vertical angle of 32′ 30″, find the course to steer to pass 2 miles off Dennis Ness Lighthouse, making due allowance for the effect of the tidal stream estimated to set 104° at 2½ knots.

Find also the time taken to be abeam of Dennis Ness Lighthouse, vessel steaming 9·5 knots.

4. A vessel uncertain of the deviation observes the horizontal angle subtended by Whal Point and Red Head to be 90°. At the same time the latitude by meridian altitude is found to be 59° 17′ N.

Find the ship's position.

Explanation of Worked Example No. 5

1. In the 1st question the direction of the vessel's head is given when a compass bearing of Brough of Birsay Lighthouse was taken. Find from the card the deviation for the direction of the ship's head. It is 8° E.—the deviation on N. by E. by compass. Apply the variation, which is 15° W., to the deviation to get the error of the compass. It is 7° W.

Convert the compass bearing into a true bearing and lay it off on the chart. It is 080° T. Measure along the bearing a distance of 4 miles and this gives the ship's departure position, *a* on chart.

The next part of the question is solved by employing a procedure set out in Chapter IV. The method is described under the heading, 'To Steer a Course in order to make a Point of Land a Given Number of Degrees on the Bow and a Given Distance off'. It appears on page 72 and fig. 4.4 illustrates the principle.

In order to find the position where Noup Head Lighthouse will be 5 points on the bow when distant 3·5 miles, draw an arc of 3·5 miles radius round the position of the lighthouse. Then enter the Traverse Table with 5 points as a course and 3·5 miles as distance and take out the corresponding departure. It is 2·9 miles. Now draw another arc round the light of 2·9 miles radius. From the departure position draw a tangent to the inner arc. This is the course to steer, *ab* on chart. Take off the true course, and find the corresponding compass course by applying the corrected variation and deviation.

True course	035° T.
Variation	15° W.
Magnetic course	050° M.
Deviation	15° E.
Compass course	035° C.

C.	D.	M.	
034°	15° E.	049°	049°
035°	15° E.	050°	050°
045°	13° E.	063°	
	2°	14°	1°

$\frac{1\times2}{14}$ can be taken as nil.

2. The 2nd question is an open bearing, or running fix. From the position of the lighthouse, draw a line through the point where the course intersects the outer arc, *dc* on chart. This is the 1st bearing, then with the aid of the parallel rulers, using the protractor marked thereon, lay off the 2nd bearing, *ec* on the chart. From any point on the 1st bearing lay off the course steered and the distance steamed, i.e. 035° T. 3 miles, *df* on the chart. At the end of the run lay off *fg*, 060° 1 mile to represent the effect of the tidal stream experienced. Through *g* draw a line parallel to the 1st bearing, and where it cuts the 2nd bearing in *h* is the ship's position. It is:—

Latitude 50° 22′ 54″ N. Longitude 3° 06′ 30″ W.

3. In question 3 the departure position is fixed by a bearing of Noup Head Lighthouse and distance off by a vertical sextant angle. Calculate the distance off by the formula:—

$$\text{Distance off in miles} = \frac{\text{Height of lighthouse in ft.} \times 0{\cdot}565}{\text{angle of elev. in minutes}} \quad \text{(see p. 114)}$$

$$= \frac{260 \times {\cdot}565}{32{\cdot}5} = 4{\cdot}5 \text{ miles}$$

Lay off the bearing and measure along it the above distance off. This is the point of departure, *k* on chart.

The vessel is required to pass 2 miles off Dennis Ness Lighthouse. With the position of the lighthouse as centre and a radius of 2 miles, describe an arc of a circle. From the departure position draw a tangent to this arc. This line represents the course it is required to make good, *kl* on chart. From the departure position draw a line to represent the effect of the tidal stream and measure on it, say *km*, 1 hour's stream effect, i.e. 104°, 2·5 miles. Take the distance steamed in 1 hour in the dividers, 9½ miles, place one leg on *m*, and with the other cut the course to be made good in *n*. Join *m* to *n*. This line indicates the course to steer to counteract the effect of the tidal stream. It is 082½° T.

To find the compass course apply the variation to the true course to get the magnetic course. Find the deviation for this course and thence the compass course.

True course	082½° T.
Variation	15° W.
Magnetic course	097½° M.
Deviation	19° E.
Compass course	078½° C.

C.	D.	M.
079°	19° E.	098°

On this occasion one of the listed compass courses with the deviation applied gives the magnetic course in question. It is thus unnecessary to go any further. The deviation is 19° E.

The distance from the departure position to the point of intersection of the lines representing the course steered and course made good is the distance which the vessel will make good in 1 hour. It is 11·9 miles.

To find the position when the vessel is abeam of Dennis Ness Lighthouse. Draw from the light a line at right angles to the course steered to cut the course made good, *Fp* on chart. Measure the distance between this point and the departure position. It is 20·9 miles. Divide this distance by the distance made good in 1 hour and this will give the time taken:

$$\frac{20 \cdot 9}{11 \cdot 9} = 1 \cdot 75 \text{ hours} = 1 \text{ hour } 45 \text{ minutes.}$$

4. To find the position in Question 4, draw a line joining Whal Point to Red Head. Find the middle point of this line and with this point as a centre, describe a circle to pass through the two headlands. The vessel is situated somewhere on this circle, since the angle in a semi-circle is a right angle. Draw in the parallel of Latitude 59° 17′ N., and where this parallel cuts the circle in *P* is the position. It will be observed that the parallel cuts the circle in two points, but since the point of intersection to the eastward places the vessel ashore, it is obvious that the other point is the required position. It is:—Lat. 59° 15′ N., Long. 2° 45′ 50″ W.

WORKED EXAMPLE No. 6

NORTHERN ISLES

Variation 15° *W.* *Deviation Card No.* 1.

1. At noon from a vessel steering 349° C. at 10·5 knots, Mull Head bore 280° C. and was distant 2 miles. At 12 hr. 20 min., Auskerry Lighthouse bore 093° C., and at 12 hr. 38 min. it bore 131° C.

Required the position of the vessel at 12 hr. 38 min. and the set and rate of the current experienced on the course.

2. A vessel in position by D.R. Lat. 59° 10′ N., Long. 3° 37′ W., observes the altitude of a planet bearing 260° and finds the longitude by obs. to be 3° 34′ W. She then steers 015° T. for 1 hour 15 minutes at 8 knots, through a current setting 050° T. at 2 knots, when the latitude by meridian altitude of a star is found to be 59° 22′ N. Find the position of the vessel when the latitude was determined.

3. Find the horizontal angle subtended by Galt Ness Church and Tech Ness Lighthouse in order to pass 8 cables off Beacon Rock.

4. (*a*) Where is the number of a chart to be found?
   (*b*) What is meant by the natural scale of a chart?
   (*c*) Define chart datum.

Explanation of Worked Example No. 6

1. This question can be worked by the three bearing method. A fixed position off Mull Head is given, and it is obvious that a line drawn from this position to Auskerry Lighthouse is a bearing of the latter point. Plot the noon position and draw in the bearing of Auskerry Lighthouse at that time. Convert the compass bearings taken at 12 hr 20 min. and 12 hr. 38 min into true bearings, and lay them off on the chart.

With the intervals of 20 minutes and 18 minutes as units taken from any scale, describe arcs of circles on their respective sides of Auskerry Lighthouse. Draw tangents to these arcs parallel to the 12 hr. 20 min. bearing to intersect the bearing drawn from the noon position to Auskerry, and that taken at 12 hr. 38 min. The line joining these points of intersection is the course the vessel is making good over the ground.

From the noon position draw a line parallel to the course made good, as found from the tangents, and where this line cuts the bearings of Auskerry is the position when each of these bearings was taken.

To find the set and drift, lay off from the noon position the true course steered and the distance steamed in the given time, i.e. 38 mins., and this will give the D.R. position. A line drawn from the D.R. position to the position at 12 hr. 38 min. represents the set and drift experienced—the rate can be calculated. The work should be set out as follows:—

Compass course	349° C.
Deviation	2° E.
Magnetic course	351° M.
Variation	15° W.
True course	336° T.

Variation	15° W.
Deviation	2° E.
Error	13° W.

	Mull Head	*Auskerry*	*Auskerry*
Compass bearing	280° C.	093° C.	131° C.
Error	13° W.	13° W.	13° W.
True bearing	267° T.	080° T.	118° T.

To find the distance steamed:—

$$38 \text{ mins. at } 10{\cdot}5 \text{ knots} = \frac{38 \times 10{\cdot}5}{60} = 6{\cdot}65 \text{ miles}$$

Position	Lat. 59° 3′ 30″ N.	Set	130°
	Long. 2° 41′ 24″ W.	Rate	2·4 knots

2. In Question 2, plot the position of the vessel as determined by the D.R. latitude and calculated longitude. Through this position draw the position line appropriate to the observation, i.e. at right angles to the planet's true bearing. From any point on this position line lay off the course steered and distance steamed in the given interval, i.e. 015° T., 10 miles.

At the end of the run lay off the current experienced, i.e. 050° T., 2·5 miles. Now draw in the second position line, which is the parallel of latitude found by the meridian altitude. Transfer the first position line to pass through the end of the current line, and where it cuts the 2nd position line is the position of the vessel when the latitude was determined.

It is:—

Lat. 59° 22′ N. Long. 3° 25′ 24″ W.

The different lines in connection with the problem are shown on the chart.

3. In Question 3 a horizontal angle is required.

With a radius of 8 cables in the compasses and the position of Beaçon Rock as a centre, describe an arc of a circle to seaward of the rock. Join the positions of Galt Ness Church and Tech Ness Lighthouse. Find the middle point of this line and draw another line through this point perpendicular to the line joining the two objects. On this perpendicular find the centre of a circle passing through the two objects and just touching the arc 8 cables off Beacon Rock. Draw in the circle.

Lines drawn from the two objects to intersect at any point on this circle will give the maximum angle subtended by the two objects. It should be measured with a protractor and will be found to be 78°.

4 *(a)*. The number of an Admiralty chart is found in the bottom right-hand corner. It may also be printed in the top left-hand corner, upside down, and may also appear outside on the label.

(b) The scale or natural scale of a chart is the ratio existing between the length of any unit on the chart and the corresponding unit on the surface of the Earth. It is expressed as a fraction.

(c) Chart datum is the level below which depths are given on the chart. It is more fully described in Chapter I, on page 23.

WORKED EXAMPLE No. 7

North Coast of Ireland

Variation 14° *W.* *Deviation Card No.* 2

1. At 1800 hrs., from a vessel steering 062° C., Fanad Point Light bore 110° C. At 1840 hrs, it bore 157° C. and the distance off by vertical angle was found to be 7 miles. At 1930 hrs. the same light bore 197° C. The tidal stream was known to set 266° T. at 3 knots. Required the speed of the vessel, the position at 1930 hrs. and the course made good.

2. In hazy weather a vessel in a position with Inishtrahull Lighthouse bearing 010° T. distant 2 miles, and steaming at a reduced speed of 8 knots, set a course to reach a position with Altacarry Head Lighthouse bearing 190° T. distant 3 miles. Two and a half hours later the weather cleared, speed was increased to 12 knots and course altered accordingly. The tidal stream was known to set 313° T. at 2½ knots.

Required the compass courses steered and the time taken to bring Rathlin Island West Lighthouse abeam.

3. From a vessel, the deviation of whose compass is uncertain, the following vertical sextant angles are taken.

Maidens Lighthouse 0° 9′. Nachore (1169) 1° 22′ 30″.

Find the position of the vessel.

4. How would you transfer a position from one chart to another?

Explanation of Worked Example No. 7

1. In Question 1 three bearings of Fanad Point Lighthouse are given with the time when each was taken.

First the deviation for the given compass course is found, thence the error of the compass, and the true course steered. The error is applied to the compass bearings and the true bearings are known.

From the Deviation Card it is seen that the deviation does not vary in the proximity of 062° C. The deviation is therefore 14° E.

Variation	14° W.
Deviation	14° E.
Error	Nil

Compass course	062° C.
Error	—
True course	062° T.

The compass bearings may similarly be taken as true bearings, i.e. 110° T., 157° T. and 197° T. respectively.

These are laid down. *AL*, *BL* and *CL* on the chart, and a distance of 7 miles measured along the middle bearing, which fixes the ship's position when that bearing was taken, *D* on chart. From *D* the set and drift of the tidal stream between 1800 hrs. and 1840 hrs. is laid off in the reverse direction, i.e. 086° 2 miles, *DE* on the chart. From *E* the true course reversed, i.e., 242°, is laid off, and where this line cuts *AL* in *F* is the position of the ship when the 1st bearing was taken. The positions when the 1st and 2nd bearings were taken now being known, it follows that the course the vessel is making good is the line joining *F* to *D*, and this line produced to intersect *CL* is the ship's position when the 3rd bearing was taken, *H* on chart. The speed of the vessel is found by measuring *FE*, which is the distance steamed in 40 minutes. It is 8 miles, which gives a speed of 12 knots. The course made good *FD* or *FH* is 053°. The position when the 3rd bearing was taken is Lat. 55° 27′ 30″ N., Long. 7° 32′ 15″ W. This completes Question 1.

2. In Question 2 a vessel leaves a given position to make another position, steering a course to counteract the effect of the tidal

stream. The feature of this question is that during the run the vessel increases speed, the effect of the tidal stream remaining the same, thus an alteration of the course steered becomes necessary.

The departure position and destination are plotted *J* and *K* respectively on the chart, and the line *JK* drawn in. At *J* the effect of the tidal stream for 2½ hours is laid off, i.e. 313° T., 6·25 miles, *JM* on the chart. The distance steamed in 2½ hours is taken in the dividers, i.e. 20 miles, and placing one leg on *M* the other is made to cut JK in *N*. Then *MN* represents the course steered for the first 2½ hours of the run. *N* is the position where the speed was increased and the course adjusted.

This latter course is found in the usual way. At *N* lay off, say, one hour's tidal stream effect, *NP* on the chart, and with a radius of 12 miles—the new speed—and centre *P*, cut *JK* in *Q*. Then *PQ* is the course to steer and *NQ*, which measures 10 miles, the distance made good in one hour.

The true courses are 106° and 102°.

These are now turned into compass courses by applying the variation and deviation. The variation is 14° W. and the deviation is found from the card.

First Course

True course	106°	T.
Variation	14°	W.
Magnetic course	120°	M.
Deviation	10°	E.
Compass course	110°	C.

C.	D.	M.
110°	10° E.	120°

Second Course

True Course	102°	T.
Variation	14°	W.
Magnetic course	116°	M.
Deviation	10°½	E.
Compass course	105°½	C.

C.	D.	M.	
100°	11° E.	111°	
105°½	10°½ E.	116°	116°
110°	10° E.	120°	120°
	1°	9°	4°

$$\frac{4 \times 1}{9} = \tfrac{1}{2}° \text{ (approx.)}$$

The time taken is found as follows:—

A line at right angles to the 2nd true course steered is laid off from Rathlin Island West Light to cut the course made good in *R*. *NR*, which is 18·8 miles, is the distance to be made good on the 2nd course and the time taken to cover this distance can be found by proportion.

Time taken to make good 10 miles	= 60 min.
Time taken to make good 1 mile	= 6 min.
Time taken to make good 18·8 miles	= 6×18·8 mins.
	= 112·8 min.
	= 1 hour 53 mins.
Time taken to cover distance *JN*	= 2 hours 30 mins.
Time taken to cover distance *NR*	= 1 hour 53 mins.
Total time taken	4 hours 23 mins.

This completes Question 2.

3. In this question the vertical sextant angles of the objects enable the observer to calculate the distance off by means of the formula:—

$$\text{Distance off in miles} = \frac{\text{Ht. of object in ft.} \times \cdot 565}{\text{Angle in minutes}}$$ (see p. 114)

Maidens Lighthouse	*Nachore* (1169)
$\text{Distance off} = \frac{95 \times \cdot 565}{9}$	$\text{Distance off} = \frac{1169 \times \cdot 565}{82 \cdot 5}$
$= 5 \cdot 96$ miles	$= 8$ miles

With the objects as centres and the distances off as radii, two circles are described which intersect each other in *X* and *Y*. The vessel may be at either of these points, but since *Y* is inadmissible then *X* is the required position. It is:—

Lat. 55° 01′ 20″ N. Long. 5° 46′ 50″ W.

4. Transfer the position by means of a bearing and distance of a point common to both charts and check by latitude and longitude. Do not rely on the graduations; they may differ.

WORKED EXAMPLE No. 8

NORTH COAST OF IRELAND

Variation 14° *W.* *Deviation Card No.* 2

1. A vessel, whose position by dead reckoning was Lat. 55° 35′ N., Long. 7° 25′ W., obtained the following soundings while steering 117° T., and steaming 7·5 knots during foggy weather.

Times	0600 hrs.	0632 hrs.	0708 hrs.	0736 hrs.	0808 hrs.	0840 hrs.
Soundings	31 fms.	34 fms.	37 fms.	29 fms.	41 fms.	43 fms. Sand and Shells

All soundings are reduced to the level of chart datum. The tidal stream set 080° at 2 knots. Required the probable position of the vessel at 0840 hours.

2. From a position, Lat. 55° 26′ N., Long. 6° 31′ W., set a course to steer by compass to reach a position denoted by:—

Chuirn I. Lt. Ho. 110° Cathsgeir Lt. Ves. 70° Glenacardock Pt.

Take into account the effect of the tidal stream estimated to set 100° T. at 2·5 knots, and make 5° allowance for leeway due to a strong N.W. wind, the vessel steaming 14 knots.

3. From a vessel steering 350° C. and steaming 12 knots, Mull of Kintyre Lighthouse was observed to bear 053° C. Forty-five minutes later it bore 129° C. The vessel was making 7° of leeway on account of a strong West wind and the tidal stream was known to be setting 320° T. at 2·7 knots. Required the position of the vessel when the second bearing was taken.

4. In the selection of objects for fixing position, to which factors would you pay particular attention?

5. What causes distortion in charts and how would you know if it existed?

Explanation of Worked Example No. 8

Question 1. Herein is given the D.R. position previous to a number of soundings taken on a course, and it is required to determine therefrom the position of the vessel.

The procedure adopted to 'pick up a line of soundings' has been fully explained in Chapter IX.

The preliminary work is done on the chart clear of the expected position.

On the chart *ab* represents the course steered and distance steamed, i.e. 117°, 20 miles, when the series of soundings was taken. *bc* represents the effect of the tidal stream, 080°, 5¼ miles, experienced while on the course and *ac* the course made good.

The distances steamed between the soundings are 4, 4½, 3½, 4 and 4 miles, respectively.

These distances measured on *ab* give the points *d, e, f, g* and *b*. From *d, e, f* and *g* lines are drawn parallel to *bc* and the points *a, h, j, k, l* and *c* indicate the relative positions of the soundings along the course made good.

Laying the edge of the parallel rulers along the course made good, marking thereon the points *a, h, j, k, l* and *c*, and manoeuvring the rulers in the vicinity of the D.R. position, until the depths recorded, appropriate to the marks, agree with those printed on the chart is the procedure to be adopted to determine the required positions on this course.

On the chart it will be observed the soundings agree with the depth marked at :—a^1, h^1, j^1, k^1, l^1 and c^1.

It may be reasonably assumed the soundings were taken in these positions.

The required position is:—

At 0840 hours, Lat. 55° 26′ 20″ N., Long. 6° 35′ 20″ W.

The D.R. position naturally gives an indication of the vicinity to be examined for the recorded depths, and a depth of 43 fms., sand and shells serves as a further guide.

Question 2. It is required to find the compass course to steer making allowance for the tidal stream and leeway.

The departure position is plotted. On the chart it is position *m*. The point of destination is indicated by horizontal angles whose sum is 180°, and therefore the parallel rulers can be used to find the position, thus: Join the right and left-hand objects with a straight line. Using the protractor on the ruler, make an angle of 70° from Glenacardock Point with the line just drawn, then move the ruler until its edge passes through the centre object. Mark the point on the line on the chart *n*.

Join position *m* to position *n*.

At *m* lay off *mp* to represent the effect of the tidal stream to be experienced in one hour.

Take in the dividers one hour's steaming distance and placing one leg on *p* cut the line *mn* in *q*. Take off the direction of *pq*. It is 057°.

To this true course apply the variation to obtain the magnetic course, which, in turn, is to be adjusted to allow for leeway, before finding the deviation, and thence the compass course.

The working is as follows:—

		C.	D.	M.
True course to make good	057° T.			
Leeway	5°	050°	14° E.	064°
		052°	14° E.	066°
True course to steer	052° T.	060°	14° E.	074°
Variation	14° W.			
Magnetic course	066° M.			
Deviation	14° E.			
Compass course	052° C.			

Question 3. The vessel's position is required on the second bearing and the data provided is suitable for the working of a running fix.

It is to be noted, however, that during the interval elapsed between the bearings the vessel was making 7° of leeway due to a west wind. The course must, therefore, be adjusted to take this into account, when the problem can be worked out in the usual manner.

Course and bearings are corrected as follows:—

Compass course	350° C.		
Deviation	1° E.		
	———	Variation	14° W.
Magnetic course	351° M.	Deviation	1° E.
Variation	14° W.		———
	———	Error	13° W.
True course	337° T.		
Leeway	7°		
Leeway course or	———		
Course made good	344° T.		

	1st Bearing	*2nd Bearing*
Compass bearing	053° C.	129° C.
Error	13° W.	13° W.
True bearing	040° T.	116° T.

Observe that the leeway, applied to the true course, is allowed away from the wind. The bearings are, of course, unaffected by leeway.

Both bearings are laid off on the chart, *wv* and *yv*, and from any point on the first bearing, *r* on the chart, the adjusted true course and distance steamed between the bearings, i.e. 344° T., 9 miles, is then laid down, *rs* on the chart. *st* represents the effect of the tidal stream which set 320°, 2 miles in the given interval. *wv* the 1st bearing which is, of course, the first position line, transferred to pass through *t*, cuts *yv*, the 2nd bearing and position line in *x*, which is the ship's position.

It is Lat. 55° 23′ 5″ N., Long. 6° 3′ 20″ W.

Question 4. The objects should be well defined and as near as practicable. The angle of cut should be as near 90° as possible and in no case less than 30°

Question 5. In order to allow the paper to absorb the ink properly from the cuts on the plate the paper has to be damped. Distortion may be caused due to the print shrinking on drying.

The dimensions of the chart in inches or millimetres between the inner lines of the graduations, are shown outside the margin in the bottom right-hand corner. The figures may be in brackets. They are useful in checking the extent of any distortion.

In order to provide the reader with practice in the setting of courses, fixing position, and other matters already explained in the text, and subsequently illustrated in Worked Examples, the following Examples for Exercise are appended:—

The examples are adapted to the following charts:—

Nos. 1, 2 and 3.	'ST. GEORGE'S CHANNEL'	19p (per post 28½p)
4, 5 and 6.	'KYLE AKIN'	19p (per post 28½p)
7, 8, 9 and 16.	'TASMANIA'	19p (per post 28½p)
10, 11, 12, 13, 14 and 15.	'ENGLISH CHANNEL, BRISTOL and PART OF ST. GEORGE'S CHANNEL'	19p (per post 28½p)

These practice charts are printed and published by Messrs. Brown, Son & Ferguson, Ltd., The Nautical Press, 52 Darnley Street, Glasgow, G41 2SG, from whom they can be purchased.

EXAMPLE FOR EXERCISE No. 1

St. George's Channel

Variation 14½° *W.* *Deviation Card No.* 1.

1. Find the courses to steer by compass from a position with Bailey Lighthouse bearing 005° T., distant 2 miles, to reach a position with Tuskar Rock Light bearing 090°, distant 3 miles, and give the distance on each course.

Note—Alter course when Wicklow Head Light bears 270° T., distant 3 miles.

2. With the ship's head on the 1st compass course Bray Head Light bore 345° C., and at the same time Wicklow Head Light bore 261° C. Find the ship's position and the set and drift of the tidal stream, the ship having steamed for 1 hour 42 minutes on the course at 10 knots.

3. With the ship's head on the 2nd compass course, Mizen Head bore 290° C., and after the ship had steamed for 42 minutes at 10 knots Mizen Head bore 005° C. Find the position of the ship when the 2nd bearing was taken, making due allowance for the effect of the tidal stream setting 172° at 2 knots.

4. Find the course to steer by compass from the position where the course was altered (*see* Question 1) to destination, to counteract the effect of the tidal stream which was estimated to set 165° T. at 2½ knots, ship steaming 9½ knots. Find also the time taken on the course.

5. From the following horizontal angles find the latitude and longitude of the observer:—

Bray Head Light 31° Dalkey Island 30° Bailey Light.

EXAMPLE FOR EXERCISE No. 2

St. George's Channel

Variation 14½° *W.* *Deviation Card No.* 1.

1. From a position in 6 fathoms soundings and with Aberdovey Head bearing 118° set courses for a position 157½° M., 5 miles from Holyhead Light. Maintain a distance of 4 miles from Bardsey Island Light and measure the distance steamed while rounding. Give the compass courses and distances, allowing 5° leeway on the 1st course, and 2° on 2nd course, for a strong N.E. wind.

2. With the ship's head on the 1st compass course, the E. extremity of Wylfa Head bore 069° C. and at the same time Bardsey Island Lighthouse bore 351° C. by the same compass. Required the latitude and longitude of the vessel, also the set and drift of the tidal stream, the estimated position being with Bardsey Island Lighthouse bearing 000°, distant 4 miles.

3. With the ship's head on the 2nd compass course, Carnarvon Bay Light-vessel bore 324½° C., and 48 minutes later it bore 269½° C. Making due allowance for the effect of the strong N.E. wind, and of the tidal stream estimated to set 356° T. at 3 knots, find the position of the vessel when the 2nd bearing was taken, ship steaming 9½ knots. Give also the distance made good between the bearings.

4. Find the course to steer by compass from a position with Skerries Lighthouse bearing 090° M., distant 5 miles to a position 090° T., 5 miles from Bailey Lighthouse to counteract the effect of the tidal stream setting 180° M. at 2½ knots, vessel steaming 8½ knots. Find also the distance the vessel will make good in 5 hours.

5. From the following horizontal angles find the ship's position:—

Bardsey Island L.H. 64° Braich Y Pwll 116° Wylfa (S. Extremity)

EXAMPLE FOR EXERCISE No. 3

ST. GEORGE'S CHANNEL

Variation 14½° *W.* *Deviation Card No.* 1.

1. At noon A.T.S. from a vessel steering 090° C. the latitude by meridian altitude was found to be 52° 05′ N. At 13 hours 30 minutes Strumble Head Lighthouse was observed to bear 128° C. Find the ship's position at noon and at 13 hours 30 minutes, making due allowance for the effect of the tidal stream setting 022½° M. at 3·5 knots, vessel steaming 12 knots.

2. From the position at 13 hours 30 minutes (*see* Question 1) a course was set to reach an anchorage in Lat. 52° 53′ N., Long 4° 08′ W., to counteract the effect of the tidal stream which was estimated to set 020° T. at 3 knots, ship steaming 12 knots.

After steaming 3½ hours on this course, the ship was found to be in a position with Bardsey Island Lighthouse bearing 280° C., and Wylfa Head (E. Extremity) bearing 002° C. Give the compass course steered, the ship's position when fixed by cross bearings, and the actual set and drift experienced.

3. From a position:—

Barrels Light-vessel 59° Carnsore Point (N. Extremity) 82° Tuskar Rock Light, find the course to steer by compass to make a position with Strumble Head Light 5 points on the bow and distant 12 miles. Give also the latitude and longitude of the position off Strumble Head.

EXAMPLE FOR EXERCISE No. 4

KYLE AKIN

Variation as shown. *Deviation Card No.* 1.

1. From a vessel steering 005° C. Duncansby Head was observed to be abeam distant 1 mile. Course was then set to pass 6 cables off West Point Light and subsequently altered to reach a position with Cantick Head Light bearing 315° M., distant ½ mile, maintaining a distance of 6 cables off West Point Light. Find the compass courses steered and distance steamed while rounding West Point Light.

2. With the ship's head on the 1st compass course Caigo Point bore 032° C. Twenty minutes later Torridon Head bore 269½° C. Making due allowance for the effect of the tidal stream setting 123½° M. at 2¼ knots, find the position of the ship when the 2nd bearing was taken, ship steaming 9 knots. Also find her distance from Caigo Point when the 1st bearing was taken.

3. With the ship's head on the 2nd course, Gillean Lighthouse was observed to be abeam and the vertical sextant angle subtended by the lighthouse was 0° 20′. Find the position of the observer at this time, and the set and drift experienced, the ship having steamed 16 minutes on the course at 9 knots.

4. From a position 112½° M. 5 cables from Gills Point a course was set to reach a position with Cantick Head Lighthouse bearing West distant 4 cables. Making due allowance for the effect of the tidal stream setting 105° T. at 4½ knots, find the compass course steered and speed of vessel to reach destination in 50 minutes.

EXAMPLE FOR EXERCISE No. 5

Kyle Akin

Variation as shown. *Deviation Card No. 1.*

1. From a vessel steering 180° C. at 8·5 knots, Helya Lighthouse was observed to be abeam distant ¾ mile. From this position, find the courses to steer by compass to reach a position 1 mile, 180° M. off Auskerry Lighthouse. Alter the course when Tor Ness bears 054° T., distant ½ mile, and on the 2nd course make due allowance for the effect of the tidal stream setting 022° T. at 2½ knots.

2. Fifty minutes after altering course Gillean Point bore 311½° C. and Auskerry Lighthouse bore 057° C. Required the position of the vessel at this time and the actual set and drift experienced on the 2nd course.

3. With the ship's head on the 2nd course Brims Ness △ 412 and South Walls △ 684 were observed to be in transit, and 18 minutes later South Walls △ 684 bore 313½° C. Required the position of the vessel when the 2nd bearing was taken and the distance made good between the bearings, making due allowance for the effect of the tidal stream ascertained in Question 2.

4. A vessel steering 355° T. observes Auskerry Lighthouse right ahead. Find the maximum horizontal angle subtended by Cape Ray and East Cape Lighthouse while on this course, and the position of the vessel at that time.

5. From the following horizontal angles find the ship's position:—
Muckle Skerry Lighthouse 79° Tarf Tail 43° North Head of Swona.

EXAMPLE FOR EXERCISE No. 6

Kyle Akin

Variation as shown. *Deviation Card No.* 1.

1. From a position with Torridon Head ⌀ Caigo Point and Steward Head ⌀ East Cape Lighthouse, find the compass course to steer and speed to steam to reach a position with Dunnet Head Lighthouse bearing 180°, distant 6 cables, in 1½ hours, the tidal stream being expected to set E.S.E. at 3 knots.

2. One hour after leaving the departure position (*see* Question 1) Muckle Skerry Lighthouse was observed to be abeam to starboard and Dunnet Head Lighthouse bore 22° on the port bow. Find the position of the vessel and the actual set and rate of the tidal stream experienced up to this time.

3. With the ship's head on the above compass course (*see* Question 1) West Point Lighthouse bore 039° C. Twenty minutes later Muckle Skerry Lighthouse bore 352° C. Making due allowance for the effect of the tidal stream setting 090° M. at 1½ knots, find the position of the vessel when the 2nd bearing was taken, ship steaming 10 knots.

4. From a vessel uncertain of her deviation the following compass bearings were taken to fix her position:—

Scaffskerry Head 232° C. St. John's Point 186° C. Duncansby Ness 125° C.

Find the ship's position and the approximate deviation for the direction of the ship's head.

EXAMPLE FOR EXERCISE No. 7

Tasmania

Variation as shown. *Deviation Card No.* 1.

1. A vessel steering 135° C. and steaming 10 knots, observed South West Cape bearing 319° C. and at the same time Needle Rock Lighthouse bore 056° C Course was then set to make a position with Tasman Head 4¾ points on the bow and distant 15 miles, the log being set at zero. Give the latitude and longitude of the departure position and the compass course steered.

2. With the ship's head on the above course Tasman Head was 5 points on the bow and the log showed 36. When the log showed 51 Tasman Head was 3 points abaft the beam. During the interval between the bearings the tidal stream set 101° M. at 2 knots. Required the position of the vessel when the 2nd bearing was taken.

3. From the above position (*see* Question 2) a course was set to pass 5 miles off Tasman Island Lighthouse to counteract the effect of the tidal stream setting 090° T. at 2 knots, vessel steaming 10·5 knots. Give the compass course steered and time taken to be abeam of Tasman Island Lighthouse.

4. From a vessel steering 005° C. Ragged Head (Maria Island) was observed to bear 4 points on the bow. Fifty minutes later it was abeam, and after a further interval of 70 minutes it bore 4 points abaft the beam. Required the course made good.

EXAMPLE FOR EXERCISE No. 8

TASMANIA

Variation as shown. *Deviation Card No.* 1.

1. At noon, from a vessel steering 315° C. at 10 knots, the latitude by meridian altitude was found to be 43° 40′ S., and at the same time South West Cape bore 049° C. One hour later Hilliard Head bore 056° C. and after a further interval of one hour it bore 095½° C. Required the position of the vessel at 1400 hours, the course made good and the set and rate of the tidal stream.

2. From the position at 1400 hours (*see* Question 1) find the compass course to steer and speed to steam to reach a position 270° T., 12 miles from Cape Sorrell Light in 6 hours. Make due allowance for the effect of the tidal stream estimated to set 325° T. at 3 knots.

3. A vessel steering 334° C. at 9·5 knots, in D.R. Latitude 42° 05′ S., obtained an observation of a star bearing 292° T. and found the longitude to be 144° 45′ E. Three hours later the N. Extremity of Sandy Cape was observed to be abeam. Making due allowance for the effect of the tidal stream setting 326° T. at 2 knots, find the position of the vessel when the star was observed and also when Sandy Cape was abeam.

EXAMPLE FOR EXERCISE No. 9

TASMANIA

Variation as shown. *Deviation Card No.* 1.

1. From a vessel, an observation of a star on the prime vertical gave a longitude of 149° 55′ E. and, at the same time, a wireless bearing of 081° T. was received from Eddystone Point Lighthouse. Course was then set to pass through Banks Strait midway between Swan Island and Clarks Island and the log set at 0. The tidal stream was estimated to set 055° T. at 2 knots, the vessel steaming 12 knots. When the log showed 60 the tidal stream was estimated to be setting 096° T. at 3 knots, and the course was altered accordingly. Find the departure position, the compass courses steered and the position when the course was altered.

2. With Cape Portland abeam, ship making her course (*see* Question 1), the course was altered to 266° C. One hour and 50 minutes later Ninth Island (E. extremity) was observed to bear 220° C. and at the same time Waterhouse Island (N. extremity) bore 116° C. Required the ship's position, and the set and drift experienced in the above time.

3. With the ship's head on the above compass course (*see* Question 2), Low Head Lighthouse bore 216° C. Fifty minutes later it bore 168° C. Making due allowance for the effect of the tidal stream setting 270° M. at 3 knots, find the position of the vessel when the 2nd bearing was taken.

EXAMPLE FOR EXERCISE No. 10

ENGLISH CHANNEL, BRISTOL AND PART OF ST. GEORGE'S CHANNEL

Variation 12° *W.* *Deviation Card No.* 2.

1. In hazy weather, a vessel in the vicinity of the Casquets, steering 022½° C. at 9 knots, through a current estimated to set 076° T. at 2·5 knots, obtained the following soundings which are reduced to chart datum:—

8.30 a.m.	9.03 a.m.	9.27 a.m.	10.47 a.m.	Noon.
37 fms. rock.	43 fms.	92 fms.	33 fms.	31 fms.

Required the position of the vessel at noon.

2. At noon the course was set for the Nab Tower, counteracting the effect of the tidal stream estimated to set 094° T. at 2·5 knots, vessel steaming 11 knots.

Find the compass course steered and time taken to be abeam of St. Catherine Point.

3. At midnight, from a vessel steering 080° C. at 15 knots, Start Point Light bore 035° C. At 12 hrs. 50 mins. a.m. it bore 330° C. Making due allowance for the effect of the tidal stream, estimated to set 106° T. at 2·5 knots, find the position of the vessel when the 2nd bearing was taken.

4. A vessel steering 090° C. at 10 knots, observed Lizard Lighthouse to bear 4 points on the bow. Forty-five minutes later Lizard Lighthouse was abeam and the distance off by vertical angles was found to be 10 miles. After a further interval of one hour it was 4 points on the quarter.

Required the position of the vessel when the 3rd bearing was taken, the course made good and the set and drift experienced during the run.

EXAMPLE FOR EXERCISE No. 11

English Channel, Bristol and Part of St. George's Channel

Variation 12° *W.* *Deviation Card No.* 2.

1. From a vessel in D.R. position Latitude 50° 36′ N., Longitude 5° 34′ W., steering 007° C. at 9 knots through a current setting 052° T. at 2 knots. Trevose Hd. Lt. Ho. bore 105° C., but owing to poor visibility no further bearing was obtained. Two hours later a wireless message was received ordering the vessel to proceed to a position 210° T. distant 5 miles from Lundy Is. South Lt. and course was immediately altered to 037° C. What other single alteration of course should be made, and when should it be made, in order to reach the position off Lundy, the ship's speed and the direction and rate of the current being unaltered?

2. Find the course to steer by compass from a position with Lizard Lt. Ho. bearing 330° T. and subtending a vertical angle of 0° 26′ to reach a position with Eddystone Lt. Ho. bearing 090° T., distant 3 miles. The tidal stream is setting 084° T. at 1½ knots, Give also the distance that would be shown on the log for the run, vessel steaming 12 knots.

3. From a position with Bishop Rock Lt. Ho. bearing 348° T., distant 8 miles find the course to steer by compass to a position with Wolf Rock Lt. Ho. 30° abaft the beam and distant 7 miles. Give also the latitude and longitude of this position.

EXAMPLE FOR EXERCISE No. 12

ENGLISH CHANNEL, BRISTOL AND PART OF ST. GEORGE'S CHANNEL

Variation 9° *W.* *Deviation Card No.* 1

1. A vessel in D.R. Long. 0° finds her Lat. by Ex-Meridian observation of the sun, Azimuth 185° T., to be 50° 30′ N. At the same time the bearing of Beachy Head Light House is 205° C., vessel steering 285° C. Find the position at this time and also what would be the position after steaming 4 hours at 10 knots, allowing for a tide setting 045° T. at 3½ knots and allowing for 10° of leeway due to a strong Northerly wind?

2. In D.R. position, Lat. 51° 10′ N., Long. 8° 00′ W. and steering 200° T. at 15 knots the relative bearing of Round Island Radio Beacon was 332°, Quadrantal correction—2°. After 2½ hours an observation of the sun bearing 135° T. was obtained and this gave an intercept of 10′ away. A D.R. position of Lat. 50° 45′ N., Long. 6° 50′ W. being used to work the sight.

Required the ship's position at the time of the sight. What must have been the ship's position when the D.F. bearing was taken?

3. At 1800 hours from a vessel steering 124° C. at 10 knots and making 5° of leeway due to a strong Southerly wind, Bishop Rock Light bore 063° C.

At 1850 hours the engines broke down and while repairs were in progress it was estimated the ship made 2½ miles of leeway due to the wind.

At 2020 hours the vessel resumed her original course and speed, wind unchanged and at 2220 hours Wolf Light bore 350° C.

If a current set 075° T. at 3 knots throughout the period, find the ship's position on the 1st and 2nd bearings.

4. At 1200 hours with Tusker Rock Light House bearing 270° T., distant 5 miles, a vessel was steering 190° T.

When in Lat. 51° 35′ N. course was altered to 160° T.

If a current set 157° at 2 knots throughout and the vessel was steaming 12 knots, what time would you expect St. Gowans Light Vessel to be abeam on the second course and what would be the position at that time?

5. In D.R. position, Lat. 48° 55′ N., an observation of a star bearing 300° T. gave a Long. of 4° 30′ W. At the same time I. de Bas and R. de Morlaix lights were in transit. Find the position.

Now find the compass courses to steer to pass 5 miles off Anvil Point Light, allowing for the mean tidal set which is estimated to be that at Position C on the chart, 1 hour before H.W. at Dover, and allowing for 5° of leeway due to a strong South-Easterly wind.

For the first four hours speed was 11 knots, thereafter speed was 15 knots.

Also give the total time taken to bring the Casquets Light abeam.

EXAMPLE FOR EXERCISE No. 13

ENGLISH CHANNEL, BRISTOL AND PART OF ST. GEORGE'S CHANNEL

Variation 9° *W.* *Deviation Card No.* 2.

1. The D.R. position at noon was Lat. 49° 10′ N., Long. 6° 20′ W. The vessel then set a course to make good a course of 252° T., allowing for a current setting 220° T. at 2 knots. Due to fog vessel's speed was 7 knots.

The following soundings were subsequently obtained:—

1330 hours	70 fms.	
1425 hours	64 fms.	Stone and Shell
1652 hours	70 fms.	
1817 hours	72 fms.	Fine Sand and Shell
2107 hours	70 fms.	
2142 hours	87 fms.	Coarse Sand and Shell

Find the position on the last sounding and the compass course steered. What must have been the position at noon?

2. The Bishop Rock Light bore 348° C. and Lizard Head Light bore 047° C. At the same time Wolf Light and Longships Light were in transit. Find the ship's position and the deviation for the ship's head, variation being as above. (Ignore the excessive distances in this question.)

3. From a position midway between Lundy Island South Light and Hartland Point Light set a compass course to reach a position 000° T., 13 miles from Round Island Light. Allow for a current setting 290° T. at 3 knots. Vessel's speed 14 knots.

After steaming for two hours on this course the engines broke down and repairs were not completed until 2 hours 30 minutes later.

Reset the compass course to reach the original destination position, current remaining the same.

State compass courses steered and the time taken on the entire journey.

4. At 1100 hours, vessel steering 282° C., in fog, the South Bishop bore 058½° by the ship's DF apparatus, relative bearing. (Allow half-convergency of ½°; Quadrantal Error, Nil.)

Course was immediately altered to bring the radiobeacon 35° on the starboard bow by compass. Vessel then steamed at 9 knots until 1300 hours when in clearing weather the Smalls Lighthouse bore 335° C. and St. Gowan Shoals Light Vessel bore 054° C.

Current set 226° T. at 1·5 knots throughout.
Find the position at noon.

5. Find the vertical angle to set on the sextant, index error 2′ off the arc, to pass 3 miles off the South Bishop Lighthouse.

6. From a vessel steering 070° T. at 15 knots, I. de Bas Light bore 4 points on the bow. Fifty minutes later the light was abeam and after a further interval of seventy minutes it was 4 points abaft the beam. The tidal stream set 280° T. at an uncertain rate. Required the position of the vessel when I. de Bas Light was abeam, the rate of the tidal stream and the true course made good.

7. Steering 075° T. at 10 knots, Casquets Light was abeam, the tidal stream setting 110° T. at 3 knots. 1 hour 45 minutes later the course was altered to 085° T. to counteract the tide which was now setting 130° T. at 2 knots. 1 hour 15 minutes later the course was altered to 125° T. to round Pte. de Barfleur, the tide now setting 175° T., rate 2 knots. 2 hours later Pte. de Barfleur was abeam.

Find the ship's position when Pte. de Barfleur was abeam.

8. A vessel steering 042° C. at 12 knots is in D.R. position, Lat. 51° 20′ N., Long. 7° 10′ W. At 5.30 a.m. a Polaris sight gave Lat. 51° 24·0′ N. and at 7.15 a.m. speed was reduced to 6 knots due to fog. At 9.45 a.m. the relative bearing of the Tuskar Rock Radiobeacon was 326°. Find the positions at the sight and at the bearing; current 068° T. at 2½ knots throughout.

9. A vessel making her course and distance logged observes the bearing of a lighthouse to be 32° on the port bow, log 50. When should the log be read again so that the difference between the log readings will be the distance the vessel will pass off when abeam of the lighthouse?

EXAMPLE FOR EXERCISE No. 14

ENGLISH CHANNEL, BRISTOL AND PART OF ST. GEORGE'S CHANNEL

Variation 9° *W.* *Deviation Card No.* 1.

1. A vessel takes her departure from a position to the south of Breaksea Light-Vessel and sets course for Cork Harbour; speed 15 knots.

After 40 minutes fog is encountered and speed is reduced to 7 knots. The echo-sounder is started almost immediately and at the same time the course is adjusted to counteract a current setting 260° T. at an unknown rate. The following is extracted from the detail shown on the recorder paper:

Time	*Corrected Sounding*	*Remarks*
0728	10 fms.	Commenced soundings
0856	15 fms.	
0917	20 fms.	
1142	23 fms.	
1404	36 fms.	
1544	50 fms.	
1631	60 fms.	
1808	50 fms.	

Find the compass course steered, the rate of the current and the position of the vessel at Noon.

Allowing for the current found above and the vessel's speed remaining unchanged, what alteration of course should be made at 2000 hours to reach a position 045° T., 3 miles from Cork Harbour Light Vessel, and when would you expect to get there?

2. Steering 020° T. at 17 knots, a vessel to the westwards of Ushant observes the vertical sextant angle of the N.W. Lighthouse to be 21′ 18″. 4½ hours later the radar bearing of Lizard Head Lighthouse was Red 65. Allowing for 10° of leeway due to the combined effects of an East wind and an ebb-tide, find the position off the Lizard. What must have been the bearing and distance of the Ushant Lighthouse at the start?

3. A vessel uncertain of her position takes two D.F. bearings, one of Lundy Island and the other of Round Island (Scilly). Changed from relative bearings to true bearings these come to 082½° T. and 123½° T. respectively. Find the Latitude and Longitude of the vessel.

4. At 2100 hours a vessel steering 057° C. observed the Smalls Light to bear 112° C. At 2142 hours Smalls Light was again observed bearing 164° C. At 2242 hours the vessel's position was fixed when South Bishop Light bore 167° C. and Strumble Head Light bore 069° C.; vessel steaming 9·5 knots. Find the true course made good, the position when the second bearing of the Smalls Light was taken and the set and drift experienced during the whole run.

5. From a vessel steering 300° C. and steaming 12 knots, Casquets Light bore 253° C. and after 1 hour 35 minutes it bore 173° C. A current was known to set 242° M. at an unknown rate. Find the position when the second bearing was taken.

6. St. Catherine Point Light bore 29½° on the port bow and after steaming 8·5 miles it bore 52½° on the bow. What will be the distance off when abeam?

7. To which point is the vertical angle of a lighthouse measured? Why is the height of eye usually ignored when taking a vertical angle of a lighthouse and in what circumstances is it not ignored?

EXAMPLE FOR EXERCISE No. 15

ENGLISH CHANNEL, BRISTOL AND PART OF ST. GEORGE'S CHANNEL.

Variation 9° *W.* *Deviation Card No.* 2.

1. NOTE—Do not use the deviation card in this question and ignore night effect on D.F.

On 23rd September, at 0400 hours, a vessel in D.R. position, Lat. 49° 47′ N., Long. 8° 20′ W. and steering 050° T. finds the relative bearing of Round Island Radiobeacon to be 036° and at the same time an observation of a star bearing 115° T. gave an intercept of 7′ away.

Allow half-convergency 1°; Quadrantal Error +2°.

Find the position of the ship.

From this position a compass course was set to pass 6 miles off Hartland Point Light House. A deviation of 6° W. was allowed; vessel's speed 15 knots. Sometime afterwards the sun was observed to rise 109° by compass but course was not altered. At 0830 hours the position was fixed by the Decca Navigator as Lat. 50° 32·0′ N., Long. 7° 09·0′ W.

Find the set and drift.

Reset the compass course at 0830 hours to pass 6 miles off Hartland Point. Allow for a current as found above and assume there is no change in the deviation as found in the earlier part of the run. State the compass course steered and the approximate time when Lundy Island South Light would be abeam.

2. Beachy Head Light House bore 035° C. and at the same time St. Catherine Point Radiobeacon bore 030° relative by the ship's loop, Q.C.—5°. (NOTE—Use the position of St. Catherine Point Lighthouse as the position of the radiobeacon). The vessel was steaming 271° C. at 19 knots and making 5° of leeway due to a strong S'ly wind. Two hours later the bearing of the Nab Tower was found to be 13° abaft the beam.

Course was immediately altered to bring St. Catherine Point Radiobeacon 40° on the starboard bow. A current set 295° T. throughout and leeway remained unchanged.

Give the following:—

(*a*) The exact bearing of St. Catherine Point to plot on the chart (i.e. the bearing at the beginning of the run).

(*b*) The rate of the current.

(*c*) The true beam bearing of the Shambles Light Vessel.

(*d*) The time when the Shambles Light Vessel was abeam.

3. From a vessel in Lat. 51° 55·75′ N. and with the Tuskar Rock Light dead astern, the dipping light of the Smalls was observed on the port bow.

Find the vessel's course and longitude using the height of the light as given on the chart and an observer's height of eye of 49 ft. (15 metres).

From this position set a new course to reach a point 180° T., 20 miles from the Old Head of Kinsale Light in 5 hours allowing for a current estimated to set 200° T. at 4 knots.

After steaming 4 hours 45 minutes the vessel was found to be 180° T., 10 miles from Old Head of Kinsale Light.

Find the compass course steered, the speed of the vessel by log and the set and rate of the current actually experienced.

4. Attempt this question without the use of a station pointer.

At 2200 hours G.M.T. a horizontal sextant angle was taken as follows:—

Wolf Light 130° Lizard Head Light.

At the same time the P.P.I.-showed the ranges of both lighthouses to be the same. Find the position.

Course was now set to pass 10 miles off Ushant N.W. Lighthouse, vessel to pass to the westward. Allowing for 7° of leeway due to a strong Westerly wind, find the course to steer by gyro-compass and if the speed is 11 knots and the height of eye 20 feet (6 metres) at what time should Ushant Light be sighted?

5. Explain how you would find the Great Circle Track between two points, using a Gnomonic Chart, and describe how you would transfer the track to a Mercator's Chart.

How is the High Water Mark shown on a coast line?

What are the normal limiting depths for the blue tint and the blue line, as inserted in certain charts?

What does the term 'arc of visibility' drawn round a light indicate?

6. (*a*) What are the chart symbols or abbreviations for the following:—

Green
Light
Sounding in fathoms and feet
Sandy coastline
Tide rip
Pebbles
Flood Stream
Coast Radio Station
Life Boat
Chimney
The 200-fathom line
The various symbols for dangerous rocks.
The 5 metre Line

(*b*) What are the meanings of the following chart symbols or abbreviations:—

 E.D.

75

Ck

1 : 150,000 (under the title)

Sn

Co

d

★ Gp. Occ. (2) W.R. 5 sec. 130 ft. 12M

EXAMPLE FOR EXERCISE No. 16

TASMANIA

Variation as stated in question. *Deviation Card No.* 1.

1. A vessel in Lat. 42° 00′ S., Long. 144° 10′ E. sets course to reach a position with West Point Lighthouse bearing 090° T. —10 miles, allowing for a current estimated to set 075° T. at 4 knots and allowing for 7° of leeway due to a strong westerly wind. Vessel steaming 15 knots. Take the variation to be 6° E.

After 3½ hours on this course the vessel's position was fixed when an observation of the sun bearing 077° T. was crossed with a visual bearing of West Point Lighthouse of 082° C. Worked by the longitude by chronometer method the sight gave 143° 57′ E., a latitude of 41° 00′ S. being used to work the sight.

Find the ship's final position and the set, drift and rate of the actual current experienced.

2. In D.R. position, Lat. 41° 50′ S., Long. 149° 00′ E. and bound through Banks Strait a vessel takes an observation of the sun bearing 010° T. and finds the intercept to be 6′ away. The vessel's course is 020° T., speed 17 knots, allowing for a current setting 070° T. at 4 knots.

Two hours later speed is reduced to 10 knots due to poor visibility and nothing further is seen. What other single alteration in the compass course should be made and when should it be made so as to reach a point 000° T., four miles from Swan Island Lighthouse, the current remaining the same? Take the variation to be 8° E.

ANSWERS

Exercise No. 10.1 (a). (Page No. 184)

1.	Dev. 5° E.	Var. 20° W.
2.	296° C.	Var. 5° E.
3.	202° C.	190° T.
4.	Dev. 5° W.	128° M.
5.	358° C.	002° T.
6.	358° C.	358° T.
7.	Dev. 4° W.	Var. 9° E.
8.	159° C.	Var. Nil.
9.	Dev. Nil.	268° M.
10.	Dev. 2° W.	Var. 2° W.
11.	087° M.	102° T.
12.	260° M.	Var. Nil.

Exercise No. 10.1 (b). (Page No. 184)

1.	Error 15° W.	N. 30° E. True.
2.	Dev. 5° E.	Error 25° E.
3.	S. 10° E. Comp.	Var. 12° W.
4.	Dev. Nil.	Error 8° E.
5.	Error 3° W.	S. 58° E. True
6.	N. 04° W. Comp.	Var. 7° W.

Exercise No. 10.2 (Page No. 188)

1.	Dev. 13° E.	4.	Dev. 10° W.
2.	,, 18° E.	5.	,, 21° W.
3.	,, 1° E.	6.	,, 0°

Exercise No. 10.3 (a). (Page No; 192)

1.	Dev. 13° E.	Comp. Co. 026° C.
2.	,, 21° E.	,, ,, 069° C.
3.	,, 14½° E.	,, ,, 092½° C.
4.	,, 1° E.	,, ,, 140° C.
5.	,, 11° W.	,, ,, 186° C.
6.	,, 18° W.	,, ,, 208° C.

Exercise No. 10.3 (b). (Page No. 193)

1.	Mag. Co. 230° M.	Dev. 22° W.	Comp. Co. 252° C.
2.	,, ,, 267° M.	,, 15° W.	,, ,, 282° C.
3.	,, ,, 288° M.	,, 11° W.	,, ,, 299° C.
4.	,, ,, 320° M.	,, 4½° W.	,, ,, 324½° C.
5.	,, ,, 346° M.	,, 1° E.	,, ,, 345° C.
6.	,, ,, 350° M.	,, 2° E	,, ,, 348° C.

Exercise No. 10.4 (a). (Page No. 195)

	True course steered	*True course made good (Leeway course)*
1.	032° T.	027° True
2.	241° T.	245° ,,
3.	342° T.	350° ,,
4.	154° T.	144° ,,
5.	089° T.	091° ,,
6.	328° T.	326° ,,
7.	355° T.	001° ,,
8.	184° T.	184° ,,

Exercise No. 10.4 (b). (Page No. 196)

	True course to steer to counteract leeway	*Mag. course to steer*	*Dev.*	*Comp. course to steer*
1.	065° T.	067° M.	14° E.	053° C.
2.	190° T.	185° M.	10° W.	195° C.
3.	269° T.	279° M.	15° W.	294° C.
4.	161° T.	154° M.	1° E.	153° C.
5.	342° T.	347° M.	Nil.	347° C.
6.	357° T.	005° M.	5° E.	000° C.
7.	130° T.	130° M.	7½° E.	122½° C.
8.	191° T.	179° M.	8° W.	187° C.

Exercise No. 11.1 (Page No. 216)

1. 228°½
2. 302°
3. 067°·8
4. 098°

ANSWERS TO CHART PAPERS

Exercise No. 1. St. George's Channel

Variation 14½° W. *Deviation Card No.* 1

1. 1st Compass course S. 11½° W. or 191½° C. Var. 14½° W. Dev. 12° W.
   2nd ,, S. 52½° W. or 232½° C. Var. 14½° W. Dev. 24° W.
   1st Distance 22·0 miles.
   2nd Distance 47·3 miles.
2. Latitude 53° 01′ 00″ N. Longitude 5° 55′ 00″ W.
   Set 125°. Drift 3·0 miles.
3. Latitude 52° 45′ 15″ N. Longitude 5° 59′ 15″ W.
4. Compass course S. 59½° W. or 239½° C. Var. 14½° W. Dev. 24° W.
   Time taken 4 hours 5 minutes.
5. Latitude 53° 14′ 24″ N. Longitude 5° 58′ 24″ W.

Exercise No. 2. St. George's Channel

Variation 14½° *W.* *Deviation Card No.* 1

1. 1st compass course N. 47° W. or 313° C. Var. 14½° W. Dev. 7½° W.
   2nd ,, N. 29° E. or 029° C. ,, 14½° W. ,, 14° E.
   1st distance 27·2 miles. 2nd Distance 28·2 miles.
   Distance steamed while rounding light 6·75 miles.
2. Latitude 52° 38′ 30″ N. Longitude 4° 43′ 00″ W.
   Set 125° T. Drift 5·0 miles.
3. Latitude 53° 06′ 15″ N. Longitude 4° 39′ 15″ W.
   Distance made good 9·8 miles.
4. Compass course N. 53° W. or 307° C. Var. 14½° W. Dev. 9° W.
   Distance made good 38·75 miles.
5. Latitude 52° 45′ 40″ N. Longitude 4° 45′ 30″ W.

Exercise No. 3. St. George's Channel

Variation 14½° *W.* *Deviation Card No.* 1

1. Position at Noon { Latitude 52° 05′ 00″ N. Longitude 5° 44′ 00″ W.
   Posn. at 13h 30m { Latitude 52° 10′ 20″ N. Longitude 5° 20′ 20″ W.
2. Compass course N. 50½° E. or 050½° C. Var. 14½° W. Dev. 19½° E.
   Latitude 52° 42′ 00″ N. Longitude 4° 30′ 15″ W.
   Set 354°. Drift 8·0 miles.
3. Compass course N. 81½° E. or 081½° C. Var. 14½° W. Dev. 18° E.
   Latitude 52° 11′ 20″ N. Longitude 5° 15′ 15″ W.

Exercise No. 4. Kyle Akin

Variation as shown. *Deviation Card No.* 1

1. 1st compass course N. 33½° W. or 326½° C. Deviation 4° W.
   2nd ,, N. 3° E. or 003° C. ,, 6° E.
   Distance steamed while rounding light 4·5 cables.
2. Latitude 57° 14′ 52″ N. Longitude 5° 45′ 10″ W.
   Distance from Caigo Point, 1 mile 1·3 cables.
3. Latitude 57° 19′ 03″ N. Longitude 5° 47′ 10″ W.
   Set 009° T. Drift 7·75 cables.
4. Compass course N. 13° W. or 347° C. Deviation 1½° E.
   Speed 10·34 knots.

Exercise No. 5. Kyle Akin

Variation as shown. *Deviation Card No.* 1

1. 1st compass course S. 30½° E. or 149½° C. Deviation 7° W.
   2nd ,, S. 70½° E. or 109½° C. ,, 10° E.
2. Latitude 57° 17′ 50″ N. Longitude 5° 39′ 00″ W.
   Actual set and drift 057° T., 2 miles 7·5 cables.
3. Latitude 57° 18′ 11″ N. Longitude 5° 47′ 45″ W.
   Distance made good 3 miles 2·3 cables.
4. Maximum horizontal angle 37°.
   Latitude 57° 15′ 57″ N. Longitude 5° 35′ 07″ W.
5. Latitude 57° 17′ 00″ N. Longitude 5° 52′ 32″ W.

Exercise No. 6. Kyle Akin

Variation as shown. *Deviation Card No.* 1

1. Compass course N. 64° W. or 296° C. Deviation 12° W. Speed 9·3 knots.
2. Latitude 57° 14′ 06″ N. Longitude 5° 54′ 15″ W. Actual set 104° T. Rate 2·3 knots.
3. Latitude 57° 14′ 08″ N. Longitude 5° 53′ 10″ W.
4. Latitude 57° 14′ 36″ N. Longitude 5° 50′ 10″ W Approximate deviation 5½° E.

Exercise No. 7. Tasmania

Variation as shown. *Deviation Card No.* 1

1. Latitude 43° 42′ 00″ S. Longitude 146° 09′ 30″ E. Compass course N. 60° E. or 060° C. Deviation 22° E.
2. Latitude 43° 43′ 30″ S. Longitude 147° 31′ 00″ E.
3. Compass course N. 18° E. or 018° C. Deviation 10° E Time 3 hours 9 minutes.
4. Course made good 031° T.

Exercise No. 8. Tasmania

Variation as shown. *Deviation Card No.* 1

1. Latitude 43° 19′ 45″ S. Longitude 145° 29′ 00″ E.
   Course made good 324½° T.
   Set 350°. Rate 3·0 knots.
2. Compass course N. 23½° W. or 336½° C. Deviation 1° W. Speed 9·5 knots.
3. Position by Star { Latitude 42° 01′ 30″ S. Longitude 144° 47′ 00″ E.

   Position off Sandy Cape { Latitude 41° 29′ 45″ S. Longitude 144° 30′ 00″ E.

Exercise No. 9. Tasmania

Variation as shown. *Deviation Card No.* 1

1. Correction to W/T bearing:—31·4′ or ½°.

   Departure position { Latitude 40° 48′ 00″ S. Longitude 149° 55′ 00″ E.

   1st compass course N. 84° W. or 276° C. Deviation 10° W
   2nd ,, N. 79° W. or 281° C. ,, 15° W

   Position where course was altered { Latitude 40° 42′ 40″ S. Longitude 148° 46′ 30″ E.
2. Course steered 256° T. Compass error 10° W.
   Latitude 40° 43′ 45″ S. Longitude 147° 21′ 45″ E.
   Set 276°. Drift 6·0 miles.
3. Latitude 40° 51′ 00″ S. Longitude 146° 41′ 00″ E.

Exercise No. 10. English Channel

Variation 12° *W*. *Deviation Card No.* 2

1. Course steered 021° T. Deviation 10½° E.
   Noon position:—Latitude 50° 12′ 00″ N. Longitude 2° 08′ 30″ W.
2. Compass course 048½° C. Dev. 14° E. Time taken 3 hrs. 5 mins.
3. Latitude 50° 02′ 45″ N. Longitude 3° 29′ 00″ W.
4. Latitude 49° 45′ 45″ N. Longitude 4° 53′ 30″ W.
   Course made good 097° T.
   Set 146° T. 4·0 miles.

Exercise No. 11. English Channel

Variation 12° *W*. *Deviation Card No.* 2

1. Course to reach destination:—True Course 109°. Compass Course 112°. Dev. 9° E.
   Alteration of compass course 75° to starboard. Time 1 hr. 31 m.
2. True course 055°. Compass course 053°. Deviation 14° E. Distance by log 31 miles.
3. True course 077°. Compass course 075½°. Deviation 13½° E. Latitude 49° 51′ N. Longitude 5° 40′ W.

Exercise No. 12

English Channel, Bristol and Part of St. George's Channel

Variation 9° *W*. *Deviation Card No.* 1

1. Position at the Ex-Meridian—	Lat.	50°	29·0′ N.
	Long.	0°	14·0′ E.
Position at the end of 4 hours—	Lat.	50°	26·7′ N.
	Long.	0°	30·0′ W.
2. Position at the D.F. Bearing—	Lat.	51°	25·5′ N.
	Long.	6°	43·5′ W.
Position at the Sight	Lat.	50°	50·2′ N.
	Long.	7°	04·0′ W.
3. Position on 1st bearing—	Lat.	49°	47·3′ N.
	Long.	6°	41·0′ W.
Position on 2nd bearing—	Lat.	49°	40·5′ N.
	Long.	5°	43·0′ W.
4. Time Lt. V. abeam 1807 hours. Position—	Lat.	51°	21·5′ N.
	Long.	5°	03·0′ W.
5. Position—	Lat.	49°	02·0′ N.
	Long.	4°	24·0′ W.

1st Compass Course 055° C.
2nd Compass Course 052° C.
Time taken — 8 hours 2 minutes.

Exercise No. 13

English Channel, Bristol and Part of St. George's Channel

Variation 9° *W*. *Deviation Card No.* 2

1. Position at Noon— Lat. 49° 09·8′ N. Long. 6° 28·5′ W.

   Position on last sounding— Lat. 48° 43·8′ N. Long. 8° 30·5′ W.

   Compass Course steered 285° C.

2. Position— Lat. 49° 15·5′ N. Long. 6° 08·0′ W.

   Deviation 3° E.

3. 1st Compass Course 244½° C.
   2nd Compass Course 236° C.
   Time taken 7 hrs. 54 mins.

4. Position at noon—Lat. 51° 23·0′ N.
   Long. 4° 51·3′ W.

5. Angle to set—0° 25′

6. Position—Lat. 48° 56·0′ N.
   Long. 4° 07·5′ W.
   Rate — 3·9 kts.
   Course made good—060½° T.

7. Position—Lat. 49° 48·5′ N.
   Long. 1° 08·0′ W.

8. Position at the Sight Lat. 51° 24·0′ N. Long. 7° 17·0′ W.

   Position at the Bearing Lat. 51° 52·8′ N. Long. 6° 20·0′ W.

9. Read the log when the lighthouse bears 59° 02′ on the port bow.

Exercise No. 14

English Channel, Bristol and Part of St. George's Channel

Variation 9° *W*. *Deviation Card No.* 1

1. Compass Course steered 304° C.
   Rate of current 3·2 kts.
   Position at Noon—Lat. 51° 25·2′ N.
   Long. 4° 48·5′ W.
   Alter course to 292° T., 309½° C.
   or,—alteration of course 7° to starboard (true); 5½° to starboard by compass.
   E.T.A. 0050 hours, the following day.

2. Position off Lizard— Lat. 49° 46·6′ N. Long. 4° 54·7′ W.

   Ushant, Original Bearing 130° T., Distant 6·0 mls.

3. Lat. 50° 57·0′ N. Long. 8° 32·0′ W.

4. True Course made good—057° T.
   Position—Lat. 51° 53·2′ N.
   Long. 5° 41·5′ W.
   Set 025° T. Drift 6·1 mls.

5. Position—Lat. 49° 56·0′ N.
   Long. 2° 32·8′ W.

6. Distance off 8·5 mls.

Exercise No. 15

English Channel, Bristol and Part of St. George's Channel

Variation 9° W. *Deviation Card No. 2.*

1. Position—Lat. 49° 57·2′ N.
   Long. 8° 25·0′ W.
   Set 279° T. Drift 10·1 mls.
   New Compass Course 093° C.
   Time 1618 Hours.

2. (a) Bearing of St. Catherine Point 269½° T.
   (b) Rate 3 Kts.
   (c) Beam Bearing of Lt. V. 351° T.
   (d) Time—2 hrs. 33 mins. after the alteration

3. Course 170° T.
   Longitude 6° 08·0′ W.
   Compass Course Steered 281½° C.
   Speed by log 17 knots.
   Set 227° T. Rate 3·15 kts.

4. Position—Lat. 49° 51·7′ N.
   Long. 5° 30·2′ W.
   Course to Steer 184° T.
   Time 0355 hours the following morning.

Exercise No. 16. Tasmania

Variation as stated in question *Deviation Card No. 1*

1. Final position—Lat. 40° 58·8′ S. Set 327°
   Long. 143° 56·5′ E. Drift 10 miles
   Rate 2·9 knots
   (Course to counteract current only 355° T.)
   (Course to counteract current and leeway 348° T.)

2. Alter course to 276½° C. (268½° T.)
   or—alteration of compass course (alteration of true course 111°½)
   89° to port.
   Time to make the alteration—2 hours 33 minutes after reducing speed.

APPENDIX

THE NAUTICAL MILE

For many years the length of a nautical mile was accepted as 6080 feet (1·8532 kilomoters). This is an approximate mean value and is nearly equal to the actual length of a nautical mile in the English Channel. It is known as the British or U.K. Nautical Mile.

The International Nautical Mile of 1·8520 kilometres (1852 metres, 6076·1 feet) has superseded the earlier mile and is in general use for all measurements of distance.

The length of 1852 metres is again a mean value and is close to the length of a minute of latitude (*see* page 11) at latitude 45° (1852·3 metres, 6077·1 feet).

This accepted length also bears a relationship to the original definition of the metre. This stated that the metre was one ten-millionth part of a meridianal quadrant of the earth. That is, $\frac{1}{10,000,000}$th of the way from the equator to the pole, the meridianal measurements being made along the polar quadrant passing through Dunkirk and Barcelona. (This is also the meridian of Paris.)

Following this definition the polar circumference of the earth would be 4 × 10,000,000 metres or 40,000 kilometres.

The number of minutes of arc in a circle is (360 × 60) or 21,600′,

$$\frac{40,000}{21,600} = 1 \cdot 85187\text{-}$$

Thus, the length of the international nautical mile approximates to the mean length of a minute of arc taking the polar circumference of the earth to be 40,000 kilometres. In agreement, it is a very close approximation to the length of a nautical mile in latitude 45°.

It is interesting to note that, for the sake of accuracy and for ease of measurement and comparison, the metre has been defined in modern times in terms of a number of wavelengths of a certain very high-frequency radiated wave under specified conditions.

SCALES (PLANS)—*See* page 9

On plans of places towards the poles or equator, the scales of latitude and distance may differ fractionally. The linear scale is always in nautical miles of 1852 metres; the length of a minute of latitude in the latitude scale varies furthest from this mean value in high or low latitudes.

DISTANCE OFF BY VERTICAL SEXTANT ANGLE—*See* page 113

In the formula given on page 114:

$$\text{Distance off in miles} = \frac{\text{Height of object in feet}}{\text{Angle of elevation in mins.}} \times \cdot 565$$

both $\frac{3438}{6076\cdot 1}$ and $\frac{3438}{6080}$ give 0·565 for all practical purposes.

The formula, therefore, gives the distance off in nautical miles, either International or U.K., the difference being negligible for present purposes over such short distances.

Similarly for metric units:

$$\text{Distance off in metres} = \frac{\text{Height of object in metres} \times 3438}{\theta \text{ in mins.}}$$

$$\text{Distance off in miles} = \frac{\text{Height of object in metres} \times 3438}{\theta \text{ in mins.} \times 1852} \text{ (See p.12)}$$

$$\text{Distance off in miles} = \frac{\text{Height of object in metres}}{\text{Angle of elevation in mins.}} \times 1\cdot 85$$

Conversely:

$$\text{Angle of elevation in mins.} = \frac{\text{Height of object in metres}}{\text{Distance off in miles}} \times 1\cdot 85$$

PROJECTION AND SCALES—*See* also Chapter I

The Mercator projection is used for all Admiralty charts having a natural scale smaller than $\frac{1}{50,000}$ that is, a scale of less than about 37 millimetres to 1 mile or about $1\frac{1}{2}$ inches to 1 mile.

A gnomonic or gnomonic-type projection is used for charts of greater scale than $\frac{1}{50,000}$. The reason is that such charts are usually in-shore sheets and as the bearing of an object, as taken with the eye, is a great circle bearing, it is desirous to represent this line truly on the chart when dangers may be close. On these gnomonic projections the straight line drawn is, therefore, the true bearing.

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