FIG. IV.

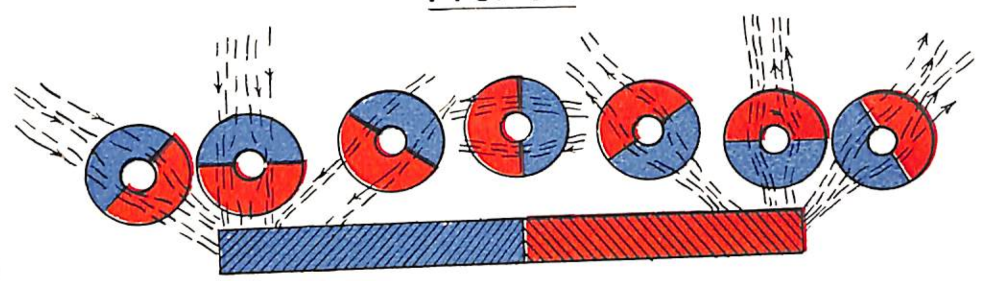


FIG. IVA.

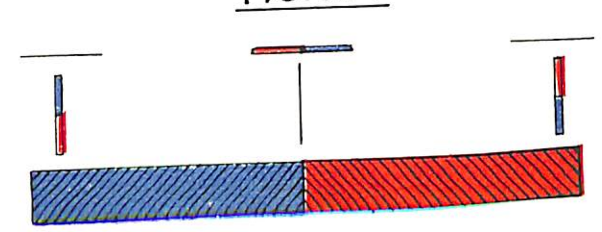
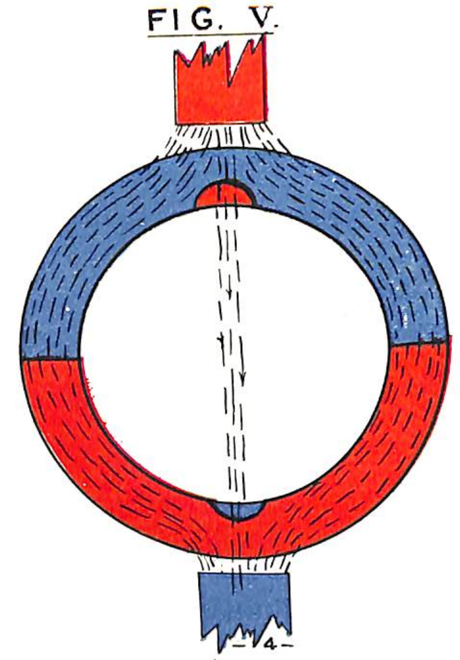


FIG. V.



of B will be adjacent to the blue pole of A, or *vice versâ*. This may be simply explained by the lines of force. Lines of force on leaving the red pole of the magnet go in the direction of least magnetic resistance, and as the resistance in soft iron is less than that of the surrounding medium, owing to its greater permeability, they all crowd *in* to the soft iron and form a blue pole; where they emerge again a red pole will naturally be formed.

If the soft iron bar be reversed end for end, the magnetism in it will be found to be entirely reversed, and the end which was a red pole before will now be found to be a blue one; and if the bar be removed it will cease to be magnetic from that cause, but we may say here that no soft iron is entirely nonmagnetic, since it is always acted on by the magnetism of the Earth.

(*See* Fig. IV.)

In Fig. 4 we see the effect of induction in small soft iron rings, such as are used in compass correction, by a magnet. A rapid revolution of the rings does not affect the positions of the red and blue (north and south) poles in them with reference to the magnet, so long as they retain their relative positions from the magnets. Here we see that the lines of force pass through the ring, forming, as before, a blue pole where they enter and a red pole where they emerge.

(*See* Fig. IVA.)

If, instead of a ring, a soft iron rod, which for these purposes must be considered as having length only, is carried horizontally over the magnet, and lying either in the same direction as the magnet or at right angles to it, we see that in the first case the rod is unmagnetised at the poles, since the lines of force pass through it at right angles, and it is magnetised at the Equator or neutral zone of the magnet, where they pass through its length. In the second case, the rod is magnetised at the poles since the lines of force pass through its length, and is not magnetised at the equator or neutral zone.

(*See* Fig. V.)

Another case of induction is that of a large soft iron ring placed between two magnetic poles, as in Fig. 5. Here the lines of force from the red pole enter the ring and, following the line of least resistance, go round the ring, coming out of it again opposite the blue pole; so that in the ring itself we should find a red pole opposite the blue magnetic pole and *vice virsâ*. Since the lines of force all pass through the ring, and none cross it, a magnetic needle inside would have no force to direct it, and therefore would point in any direction, showing that the ring has diverted all the directive force from the area inside it. Actually, since no iron is absolutely soft, and is, as it were, a composition of hard and soft, a certain percentage of the lines of force cross the ring, forming on the inside of the ring, where they leave it, a red pole, and where they enter it again, a blue pole. These few lines of force form the directive force in an all steel machine, and since the greater number go through the iron, the directive force is much less than outside.

Electric Installations.—Every electric machine has a magnetic field, and a single electric wire will deflect a compass needle. The magnetic lines of force produced round a wire conveying an electric current act at right angles to the direction of the same current, but if two wires are laid together with the current flowing in opposite directions the effect of one will neutralise the effect of the other. This is done in the wiring of lighting sets, and care must be taken that single wires are nowhere near a compass.

Dynamos, motors, &c., all have their magnetic fields; none of them should be close to the compass. Moreover, no iron or steel should be at a less distance than 5 feet from a compass.

Terrestrial Magnetism.

The Earth, being a great spherical magnet, possesses the same property as other magnets; so that a freely suspended magnetised needle has its North-seeking or red end drawn in the direction of the Geographic North, and *vice versâ*.

For convenience the effect on the North-seeking end only is considered, as the effect on the South-seeking end is equal and opposite to that on the North-seeking end. Hence this force is merely one of direction and not of translation.

If we combine this directive force of the Earth with the lines of force of any permanent magnet within whose "field" our magnetic needle may happen to be placed, we shall find the directive force on the needle either increased or decreased according as to whether the two fields are acting together or in opposition.

If the lines of force of the magnet are running parallel to those of the Earth there will be no deflection of the needle, but an increase or decrease of directive force only.

If they are running at an angle to the needle they will also cause a deflection of the needle. When running at right angles to the disturbed needle they will cause a maximum deflection, and have no effect on the directive force. This increase or decrease of directive force can be found by deflecting the needle and timing the oscillations it makes; the longer the time of swing, the less the directive force. The value of the directive force varies inversely as the square of the times.

Definitions.

Line of total force is the direction which a freely suspended magnetised needle takes up under the influence of the Earth's magnetism, varying according to the geographical position.

Magnetic Poles are the two positions on the globe where the line of total force is vertical and towards which the needle points in all adjoining regions.

Magnetic Foci.—There are four positions of maximum intensity in the Earth's field of force, called the magnetic foci, two in each hemisphere.

Magnetic Equator is the line separating the red and blue magnetism of the Earth, on which the line of total force is horizontal.

Magnetic Meridian is the vertical plane passing through the longitudinal axis of a magnetised needle resting in a line of total force.

Magnetic Variation is the horizontal angle contained between the directions of the magnetic and true meridians.

Magnetic Dip or Inclination is the vertical angle contained between the directions of a freely suspended magnetised needle resting in the line of total force and the horizontal plane passing through its centre.

The magnetic dip at Greenwich is about 67° and the variation about 15° W.

Magnetic Latitude is measured from the magnetic equator and is analogous to ordinary latitude. Lines of equal dip correspond to parallels of latitude.

Now the total force can be resolved in a horizontal and vertical direction.

If θ is the angle of dip,

T is the total force;

Then Z is the vertical component $= T \sin \theta$,

and H, the horizontal force $= T \cos \theta$, &c., &c.

The horizontal force is referred to Greenwich, where the value is considered to be 1.

Chart 3 shows the comparative values for it at any place on the Earth. Notice that it is greatest near the equator and diminishes towards the poles.

The dip is measured by means of a dip circle.

Chart 2 gives the lines and values of equal magnetic dip and the natural tangent of the angle in the margin.

Variation.—Variation can be found by observations.

Chart 1 gives the Isogonic lines, or lines of equal variation, westerly variation being shown by continuous lines and easterly variation by pecked lines.

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The variation is not constant, but changes year by year. This annual change is given on the variation chart supplied, as well as in the title of every chart supplied, and should never be forgotten. The use of this variation chart is most important to the navigator, enabling him to ascertain the correct magnetic course to steer and to calculate the deviation of his compass. It is most important on a long flight to allow for the change in the variation, due to the alteration in geographic position of the aircraft. The closeness of the lines of equal variation, crossed by the aircraft's course, show at once if the variation is altering rapidly.

Chart 4 gives the lines of equal vertical force from the formula $Z = H \tan \text{dip}$.

Local Magnetic Disturbance.—This term is used to denote forces outside the aircraft altogether, and does not refer to the effect of the iron in the aircraft.

Numerous areas of local disturbance are found on land, where the magnetic conditions differ largely from those immediately round them. Several similar areas have been found in the land under the sea, and it is when passing over these that a compass will be affected, for it is only under such conditions that the disturbing force will be near enough to have any effect.

This will only be in shallow water. The magnetism of the visible land cannot affect a ship's compasses, owing to its distance away.

The most remarkable of these areas so far discovered is near Cossack, Western Australia, where in 9 fathoms of water the observed variation differed from 56° E. to 26° W. within a space of 200 yards.

No authentic case of local magnetic disturbance in the air has yet been reported. Clouds have no effect on a compass unless charged with electricity, as may occur in thundery type of weather.

COMPASSES.

Swinging for Compass Adjustment.

We will now proceed to describe the method of swinging. This is the process employed, in the first place, to adjust for the original compass errors and secondly to determine the small errors remaining after adjustment.

The aero compass adjusted for one magnetic latitude is to all intents adjusted for any other, but the excessive vibration, heavy landings, shocks due to firing guns and being hit by gun fire, &c., tend to change the deviation. The navigator or pilot, therefore, cannot be too careful, and a constant watch on his compass by swinging frequently is the only real safeguard against losing himself, owing to unknown deviation. It is sometimes possible to swing on a few points only, owing to shortage of time, &c., but no opportunity of doing so should be

lost, and specially before a long flight the deviation on the courses likely to be steered should be obtained.

The pilot who has paid careful attention to his compass will, in clouds or foggy weather, feel comparative security in that branch of his work at any rate.

The general idea in swinging is that the machine is placed in each of the magnetic directions, N., N.E., E., S.E., S., S.W., W., N.W., alternately, and the headings of the machine as shown by compass taken in each case, the difference between the magnetic and compass directions being the deviation. Where more than one compass is fitted, the second one may be done at the same time; or at any subsequent time, if it is compared with the other, its deviation can be obtained.

Example:—

Machine's Head by A Compass.	Deviation of A Compass.	Machine's Head by B Compass.	Deviation of B Compass.
2°	3° W.	4°	5° W.

Before swinging, the following points must be attended to:—

(1) Machine should be upright (tyres inflated to the same extent).

(2) Cap and pivot of compass in good order. This may be found by deflecting the card 45° and noting whether the card returns to its original position exactly when it comes to rest.

(3) It should be ascertained that the lubber line is in the fore and aft line of the aircraft.

(4) Everything in the shape of iron or steel should be in the proper place occupied by it whilst flying.

(5) No other machine should be within 30 yards.

There is one standard method of swinging aircraft. A spot is selected free fron local magnetic disturbance, at least 100 yards from the nearest shed or railway line, &c.

A landing compass is set up on its tripod over the spot A, and from it pegs are driven into the ground on the bearings N., N.E., E., S.E., S., S.W., W., and N.W. The opposite points are then joined either by rope lines when the "base" is a temporary one, or by lines painted or otherwise marked on the concrete in the case of permanent bases. (Concrete circles 20 feet in diameter are now laid at most of the aerodromes.)

You have now got marked on the Earth's surface lines running magnetic North and South, East and West, N.E. and S.W., S.E., and N.W. Two plumb lines are attached in the central fore and aft line of the machine, one near the nose and one near the tail.

The machine is then wheeled on to the base and its fore and aft line (as shown by the plumb lines) made to correspond with the lines on the base, and the difference between the reading shown by the lubber line on the compass and that on the base is the deviation.

If the reading of the compass is *less* than the magnetic the deviation is Easterly or +.

If the reading of the compass is more than the magnetic the deviation is Westerly or −.

Thus, machine is on the N.E. and S.W. line heading N.E. or 45°, lubber line shows machine heading 40°.

Deviation is 5° Easterly or +.

A table is then made out for the machine and should be secured where it can easily be seen by the pilot, preferably on the instrument board close to the compass.

This table shows what the compass reads when the machine is heading in the various magnetic directions, and by simple interpolation the compass reading for any intermediate direction may be obtained.

A sample table is here given:—

For Magnetic Course.		Steer by Compass.
North	0°	358°
N.E.	45°	42°
East	90°	90°
S.E.	135°	138°
South	180°	182°
S.W.	225°	223°
West	270°	270°
N.W.	315°	318°

During flight, deviations of the compass may be obtained by flying directly at two conspicuous objects which are in line and comparing your course with the magnetic direction of the line joining the two objects on the chart or map.

Lighter-than-air craft are usually swung before the envelope is attached, but can be done on a very calm day with the envelope attached; since, however, the presence of the envelope makes no difference magnetically, it is more convenient, when possible, to swing before attaching the envelope.

Rigid airships present great difficulties, as they must be done in the air, when it is exceedingly difficult to keep them steady, and the only possible ways of swinging them will be—

(1) by the Sun when it is very low in altitude;

(2) by placing a compass on top of the ship where it will be unaffected by magnetic material, and adjusting the remaining compasses by this one.

The Germans, having realised this, are most careful to place no magnetic material within 30 feet of the compass, and there are consequently no errors of a size worth considering.

Swinging by the Sun.—First set your watch to S.A.T.

The airship is then flown as slowly as possible in the various directions by compass.

As the airship is steadied on each point the bearing of the Sun by compass is taken, the time being also taken; the true bearing of the Sun is obtained from Burdwood's tables, to this the variation is applied and thus magnetic bearing of the Sun is obtained, which, compared with compass bearing, gives the deviation.

Magnetism of Aircraft.

The Cause of Deviation.—If an aircraft were built entirely of non-magnetic material, there is no reason why the compass should have any deviation, and such, in fact, is the case; but since aircraft are built partly of steel, there will be, first of all, magnetism caused in the hard iron of its construction by the hammering to which the parts are subjected, making them into a permanent magnetic system, having two distinct poles.

Besides this there is a certain amount of soft iron liable to instantaneous magnetisation by induction of the Earth and de-magnetisation, according to direction of aircraft's head.

Both of these tend to cause a deviation of the compass needle from the magnetic meridian, and also an increase or decrease in the directive force at the compass position.

Permanent Magnetism.

Generally the process of construction causes the iron and steel parts of an aircraft first of all to acquire an amount of permanent magnetism in excess of what they can permanently carry, but after trials, &c., this overdose of magnetism gets shaken out, and what is left remains permanently. The aircraft then acts as a permanent magnet, having its poles lying in some definite direction.

We may then suppose the compass to be placed in the vicinity of the poles of a permanent magnet, which will turn round with the aircraft.

Take, as an example, an aircraft having a red pole, low down, forward on the starboard side, and a blue pole, high up, further aft on the port side.

The compass being in the midships line and abaft both of these poles. (This is what generally occurs in heavier than air machines.)

Its permanent magnetism would be represented as in Fig. VI.

It is only necessary to consider the action on the compass of the pole S, nearest to the compass A, as the effect of N will only modify this slightly, being further away.

If now it were possible to place a magnet near the compass with its poles in exactly the opposite direction to those of the aircraft itself, the disturbing effect of the permanent magnetism of the aircraft would be annulled. As there are difficulties in doing this in practice, it is simpler to deal separately with each component of the aircraft's permanent magnetism.

Thus, at a compass at A, the magnetic force acting through it due to SN is the resultant of three forces acting in this case (1) towards the nose, (2) towards the port side, (3) vertically upwards. The permanent magnetism of any aircraft is always split up into these three components, and they are denoted by the letters P, Q, R. + P denotes an attraction towards the nose, − P towards the tail, + Q to the starboard side, − Q to the port side, + R vertically downwards, − R upwards.

In the above example there is a + P, − Q and − R. R will produce no deviation, as it acts through the pivot of the compass, and may be disregarded. So we may now assume that P and Q are acting in the plane of the compass needles, *i. e.*, horizontally.

Consider now the effect of these two forces, + P and − Q.

+ P is a pull to nose.

(*See* Fig. VII.)

The above figure shows the result of a pull to nose on a compass in an aircraft as it is placed in each direction. The maximum effect is on E. and W., where the force is at right angles to the needles, the effect on W. being equal and opposite to the effect on E.

On N. and S. there is no deviation, but an increase and decrease respectively in directive force.

Thus it is clear that the deviation due to a − P starts at 0 at N. and increases with the sine of the angle to maximum at E., decreasing again to S., from where it increases again to maximum in the opposite direction on W., and comes down to 0 on N.

If the curve of this similar to above be drawn, it will be seen that it also is a sine curve.

Similarly with the force Q, a cosine curve is obtained since it will cause no deviation on E. and W., but will cause its maximum on N. and S. Since both these curves are semi-circular, that part of the deviation caused by the permanent magnetism of the aircraft on any course is equal to P sin course + Q cos course; the values of P and Q being taken as

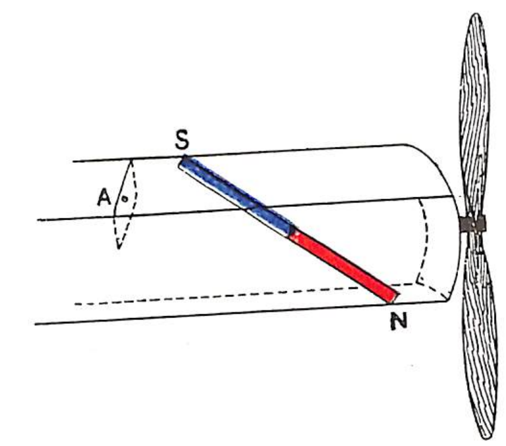

FIG. VI.

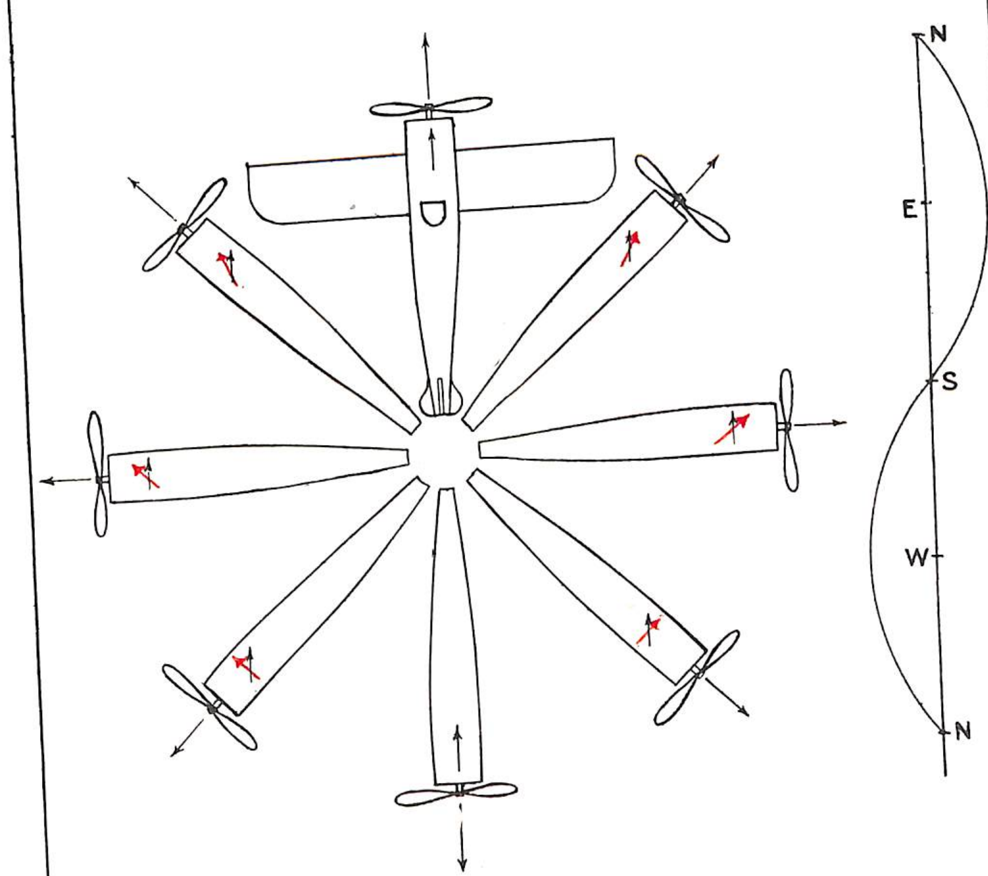

FIG. VII.

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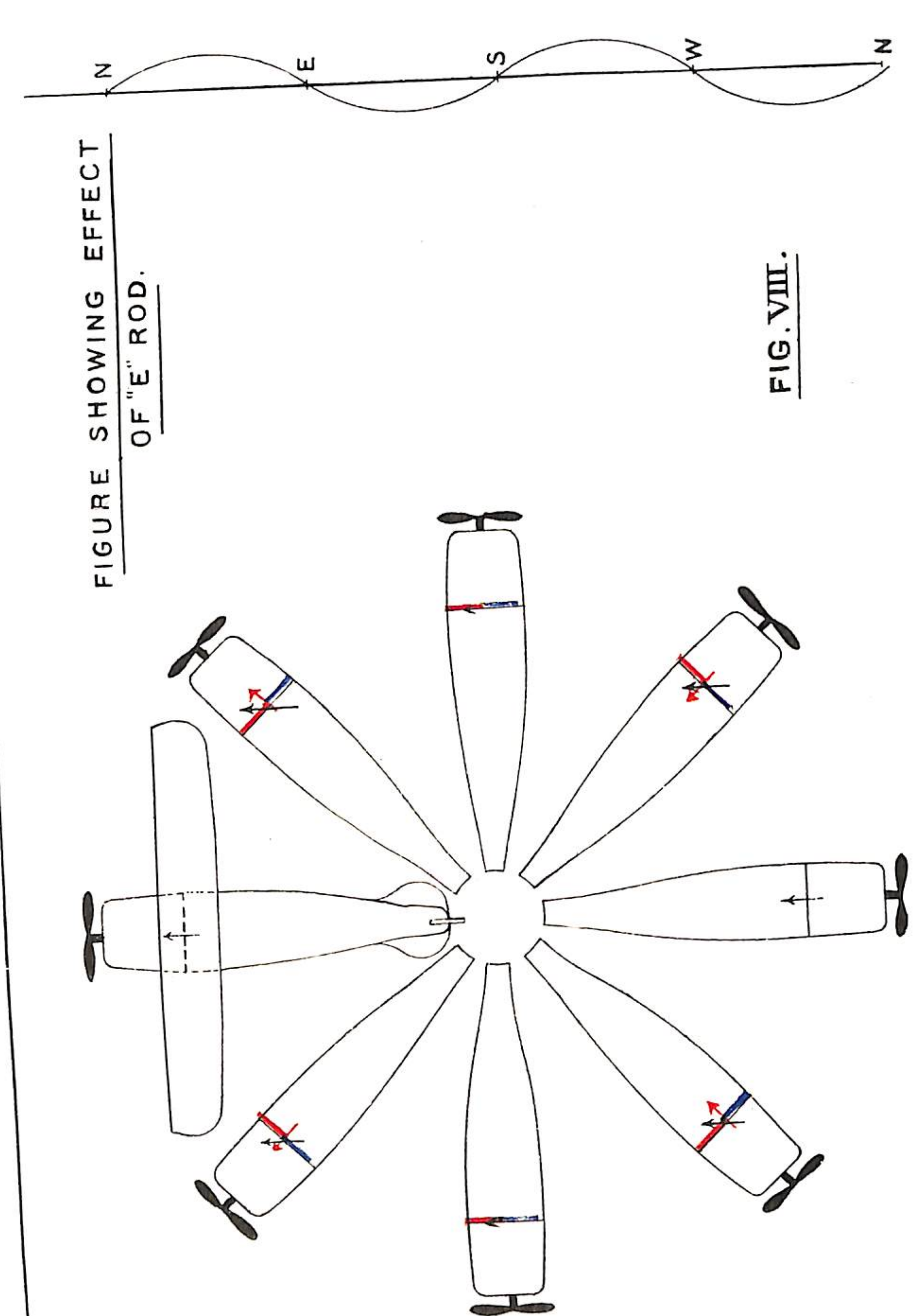

FIGURE SHOWING EFFECT OF "E" ROD.

FIG. VIII.

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equal to the maximum amount of deviation they respectively cause. P is corrected by permanent magnets placed in fore and aft direction.

Q is corrected by permanent magnets placed in an athwartship direction.

It will be obvious that correcting magnets will produce an equal and opposite effect on the compass to what the forces P and Q will produce, and that the effect of the correctors will vary in the same way as P and Q. Therefore, by placing the aircraft on N. or S. and inserting magnets in the athwartship tubes till the compass shows machine to be heading N. or S., Q will be corrected. Similarly on E. or W., P will be corrected by placing magnets in the fore and aft tubes.

Induced Magnetism.

The whole of the effect of magnetism induced by the Earth in those parts of an aircraft's construction which come under the heading "soft iron" may be represented by the action on the compass of two typical soft iron rods having length but no thickness, passing through the compass, one in the athwartship direction and the other in a fore and aft direction, both lying horizontally.

Being horizontal and supposed to have no thickness, these rods will be magnetised by the Earth's horizontal force only.

Consider now the effect of these two rods.

The rod going athwartships, we will call "e," for reference.

The rod going fore and aft, we will call "a," for reference.

(*See* Fig. VIII.)

The figure shows the result of the rod "e." On N., S., E., and W. the effect is *nil*, since on N. and S. the rod is not magnetised, and on E. and W. it is in line with the needles.

On the quadrantal points N. E., S. E., S. W. and N. W. it will have its maximum effect, and it will be noticed that it changes sign in each quadrant.

Thus it can be represented by a sine 2θ curve, where θ is the course in degrees.

By drawing a similar picture for an "a" rod, it will be seen that it produces exactly the opposite effect to that caused by the "e" rod; however, in all aircraft the "e" has a larger effect than "a" because its poles are closer to the compass, and the result is that a corrector has to be introduced to correct a weak "e" rod.

This can only be done in compasses Pattern Nos. 255, 256, and 258.

The method of correcting this error is by introducing on each side of the compass circles of soft iron, called spheres, which, owing to their position, cause an equal and opposite deviation to the "e" rod.

In all modern heavier than air machines where the tanks are constructed of non-magnetic material, the amount of error produced by this cause is less than ·5°, so it may be neglected.

Having adjusted a Machine, to find out the Cause of the Errors remaining.—(*a*) Mean all the deviations; this will tell you whether the fore and aft line of compass corresponds to fore and aft line of aircraft.

(*b*) Mean the deviations on E. and W., changing the sign on W.; this tells you the amount of error due to P remaining.

(*c*) Mean the deviations on N. and S., changing the sign on S.; this tells you the amount of error due to Q remaining.

(*d*) Mean the deviations on N. E., S. E., S. W., N. W., changing the signs on S. E. and N. W.; this tells you the amount of error due to soft iron remaining.

(i) If (*a*) comes out − the fore and aft line of compass should be moved to port the number of degrees equal to the mean and *vice versâ*.

(ii) If (*b*) comes out − magnets are required Red Aft.

(iii) If (*c*) comes out − magnets are required Red to Port.

(iv) If (*d*) comes out + spheres are required, and *vice versâ*.

The Use of Compasses.

Having adjusted a compass in an aircraft as already explained, we now come to a consideration of the actual use of the instrument and the natural limitations which attend its employment.

Provided that the card is kept horizontal, it will always register the correct direction in which an aircraft is traveling; in order to allow it to remain horizontal, a clearance of between 30° and 40° is allowed for, so that under any ordinary climb or glide the card will register correctly.

Since, however, in executing banked turns, the card, under the influence of centrifugal force, instead of remaining horizontal to the Earth's surface, takes up the same plane as the machine and therefore becomes inclined to the horizontal, the needles are gradually tilted out of the Earth's horizontal component into the vertical component, and so the tendency is for the card to rotate till the North point is pointing vertically downwards, the result being that a machine may be actually turning without any turn being indicated by the compass card.

This feature is intensified in these latitudes (British Isles) where the vertical component is greater than the horizontal component, but except when executing a turn off a northerly course this may be neglected.

In executing a turn off a northerly course, if it is desired that the compass should register the turn, the turn should be executed slowly and with very little bank.

This feature can be almost entirely overcome by so reducing the strength of the needles of the compass that the vertical force of the Earth acts on the needles so weakly that the card turns more slowly than the machine does; but it should be remembered that if this is done when horizontal, the horizontal force will also act very weakly, the result being an extremely sluggish compass which when once disturbed takes a considerable time to settle down.

The one type of compass possessing this weak system of needles in use at present is the early Pattern 255. The later Pattern 255 has a stronger system. In the Royal Flying Corps a compass (Mark II R.A.F.) having an even weaker system of needles, is in use. In Patterns 256, 258, and 259 the needle system is considerably stronger, and using one of these types the caution before mentioned should be borne in mind.

The edge of the card, when used in conjunction with the cross wires on the face, will form a most useful side slip indicator, also an inclinometer.

Description of Compasses.

The standard type of aero compass is the "Upright" type designed by Captain Creagh-Osborne, R.N. It is made in three sizes and four patterns. The essential features are the same, so a description of one pattern only is given. *See* Figs. IX. and X.

The compass is sensitive in action and is undisturbed by vibration or gunfire. This is ensured by immersing the card in liquid consisting of two parts pure alcohol to three parts of distilled water; this mixture prevents it freezing at temperatures above − 12° Fah. The bowl is attached to the outer containing ring by means of four anti-vibrational spring attachments. An expansion chamber is fitted to allow for expansion and contraction of liquid. The pivot, which is made of agate, is attached to the card; the cup in which it works, mounted on a stem attached to the bottom of the bowl, is of sapphire.

The needles are inside the float and are thus protected against rust.

The card is made of mica, painted red and blue to indicate the northerly and southerly semi-circles; the degree markings are painted in white.

The card, which stands on its edge and represents a portion of a cylinder, is attached to the float by means of copper or white metal clips.

The compass is read from the after side; the lubber line being on the after side should be considered to follow in its motion the movements of the tail, but indicates the course being steered.

The card is marked with radium paint to illuminate it, no other lighting arrangement being necessary.

The tubes for correcting magnets are attached on top of the outer containing ring.

The Pattern 255 compass is fitted with two windows for pilot's and observer's use when the observer sits in front. Period about 45 seconds (this period has recently been reduced to 25 to 30 seconds), weight 5½ lbs.

Pattern 258 is exactly the same size as pattern 255, but having only one window and period 25 to 30 seconds.

Pattern 256, a large edition of pattern 258, weight 9¼ lbs.

Pattern 259 is a small edition of pattern 258, period 17 to 20 seconds, weight 2 lbs.

To remove a Bubble from the Compass.

The compass should first be taken out of the machine (do not remove it from the outer support ring), then manipulate it till the bubble is immediately below the filling plug. Remove same and pour in pure water (pure alcohol, if at hand, should be used, otherwise water as free from dirt or sediment as possible) till the bowl overflows. Screw in the filling plug and if bubble has not disappeared repeat the operation till it does.

When a bubble is being removed the bowl should be as cool as possible so that the maximum amount of liquid is introduced into the bowl.

Supplied with each compass is a copy of Chapter IV. of "The Magnetic Compass in Aircraft," by Captain Creagh-Osborne, R.N., with which all pilots and observers should make themselves familiar.

Bearing Plates.

There are two types of bearing plates at present in use, one, the "aero bearing plate," for use of observers, the other, the "upright compass bearing plate," is attached to the face of the vertical compass or to any suitable part of the aircraft and is principally for the use of pilots.

Instructions for use of Aero Bearing Plate.—The bearing plate must always be fitted in position with the arrow head or lubber point pointing parallel to the fore and aft axis of the aircraft.

To take a compass bearing of an object, set the outer dial with the division representing the compass course cutting the arrow head or lubber line.

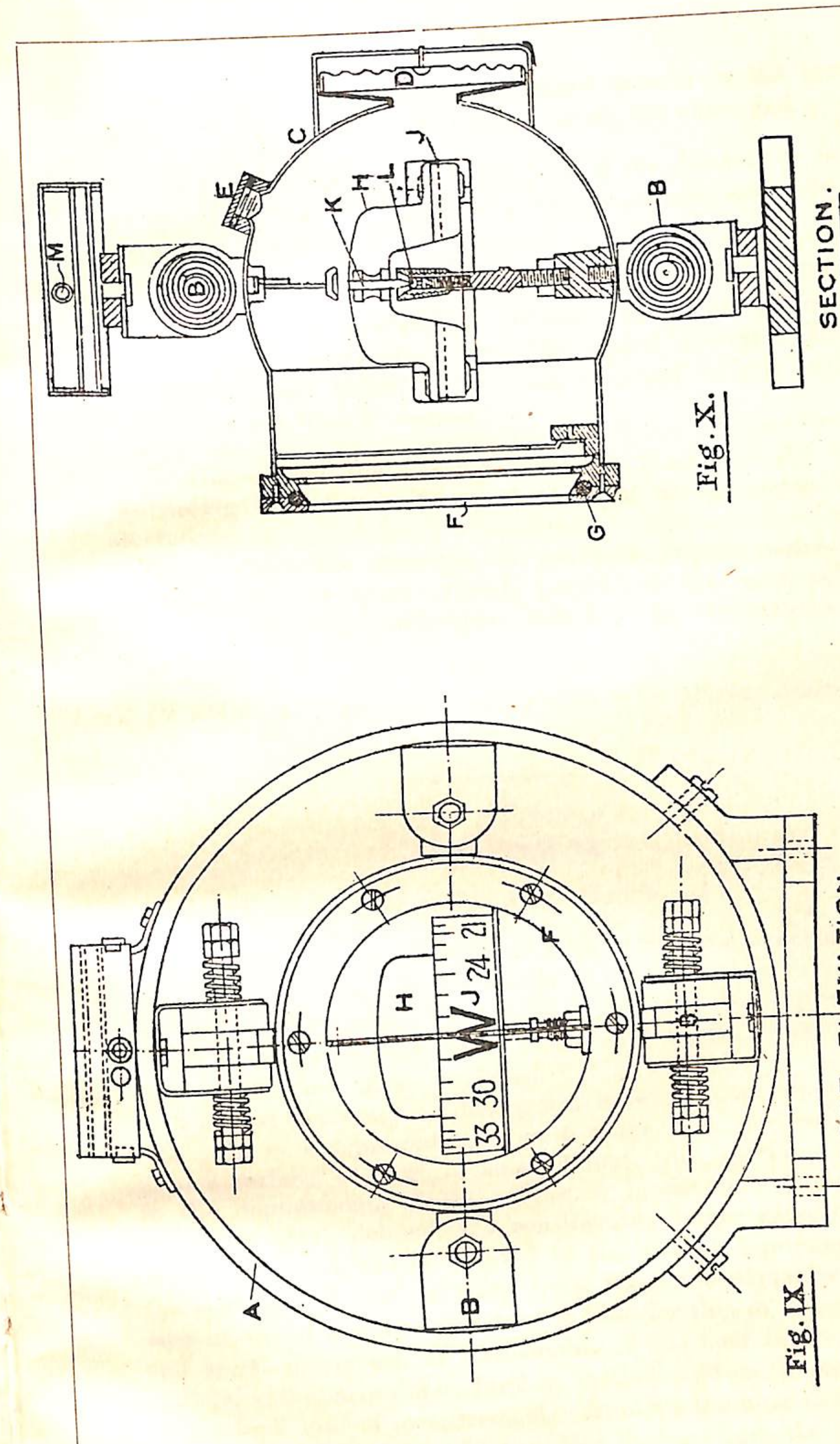

Fig. IX. FRONT ELEVATION

A. Outer Support Ring.
B. Anti-vibrational Spring attachment.
C. Bowl.
D. Expansion Chamber.
E. Filling Plug Screw.
F. Glass Window.
G. India Rubber Ring.
H. Float.

Fig. X. SECTION.

J. Card.
K. Pivot.
L. Cup.
M. Correcting Magnet Tubes.

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mile of 6,080 feet. Relief in maps is in feet, whilst in charts and plans it may be in fathoms or feet.

Projections.

A projection is a representation of a figure on a plane formed by the intersection of that plane by lines drawn from the observer's eye to every visible point of the figure.

Thus in Figure I. an observer at A views through a piece of flat glass B, at a tangent to a globe C, a delineation of a continent. Lines drawn from A to various points on C will form, where they cut B, a representation of the continent. The figure is called a *projection* and B is said to be the *primitive plane*. Such a projection is called a *natural projection*, which is simply a perspective delineation of any object on the primitive plane. Where the projection is not a perspective delineation it is called *artificial*.

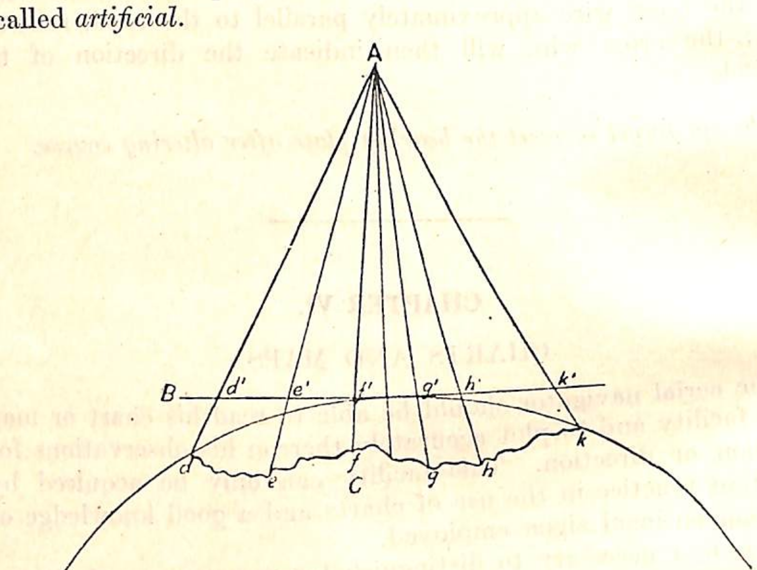


Fig. I.

Original naval surveys and ordnance maps are constructed on the *gnomonic* projection, or one closely allied to it, but charts evolved from the original surveys are on *Mercator's* and the majority of plans on a *plane* projection.

Gnomonic Projection.—The *gnomonic* projection supposes the observer to be at the centre of the earth and the primitive plane to be a tangent to the earth, touching it only at the central point of the plane. From the centre of the earth lines are drawn passing through the different

points on the surface until they reach the primitive plane. Since the plane of every great circle passes through the observer's eye, all meridians and the equator are shown as straight lines. The parallels of latitude will appear as curves, concave towards the poles, and cutting each meridian at right angles. They are in fact conic sections. In Figures II. and III. BCDE is the primitive plane; G, H, N, L places projected on that plane through F, H, M and K; P the pole, O the centre of the earth, and A the point where the converging meridians on the plane will meet if extended.

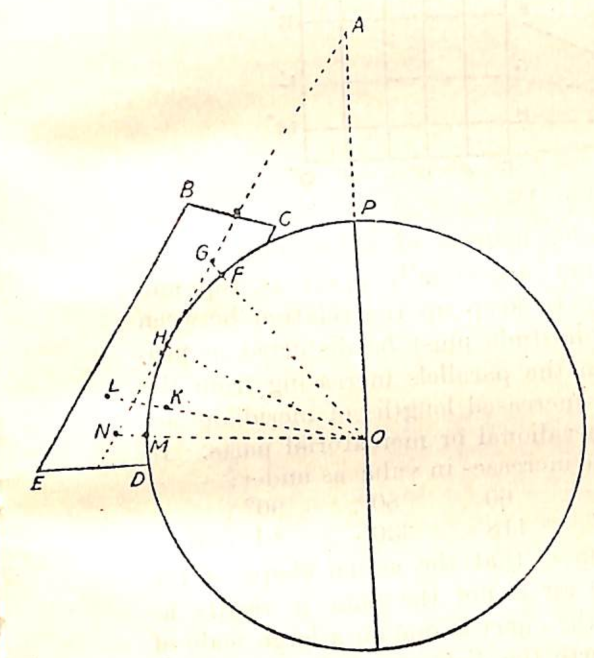


Fig. II.

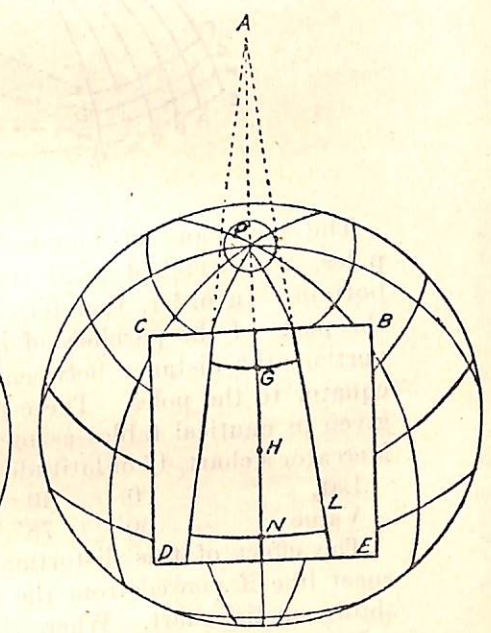


Fig. III.

The convergency of the meridians and the curvature of the parallels are here shown greatly exaggerated. On a large scale map they will be hardly apparent.

It will be seen that the further the primitive plane is from the surface of the earth the greater will be the distortion of the projection.

Thus distortion increases from the centre of the gnomonic chart and will become very considerable if a large portion of the earth be shown. Gnomonic charts are therefore only used for charts over a scale 2 inches = 1 mile.

It should be noted that the marginal lines of the chart on this projection are drawn parallel and at right angles to the central meridian instead of to the nearest marginal meridians.

Ordinary maps in atlasses are on this projection, and it can generally be detected by the slight convergency of the meridians and curvature of the parallels.

Mercator's Projection.—In this, which is an artificial projection, all meridians are drawn as straight lines at right angles to the parallels of latitude and the equator, which are also shown as parallel straight lines. Fig. IV.

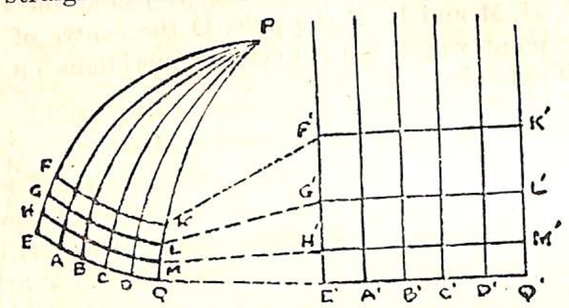


Fig. IV

The meridians of longitude, instead of converging at the poles, are stretched until they are equally apart at top and bottom. In order, therefore, to keep up the relation between the parts of the parallels of latitude must be distorted in proportion, the distance between the parallels increasing from the equator to the poles. These increased lengths of meridians are given in nautical tables as meridional or mercatorial parts. In Mercator's chart, 1° of latitude increases in value as under:—

Lat.	–	0	40	60	80°	90°
Value	–	60′	78′	118′	330′	? Infinity.

The effect of this distortion is that the actual shape of the coast line if viewed from the air is not the same in reality as shown on the chart. Where the chart is one on a large scale of only a small portion of the earth the distortion is inappreciable, but the further from the equator and the smaller the scale of the chart the greater the distortion appears. To take an extreme case. By reference to the above table it will be seen that if an island in latitude 60° and another of equal size on the equator are shown on the same Mercator's chart, the former will appear twice the size of the latter, yet if it were possible to view both from the air at the same time they would appear of equal size. *Mercator's* projection is used for all charts under a scale of 2 inches to the mile.

Plane Projection.—In addition to the two foregoing projections, since a small portion of the surface of the earth may be considered as a plane without sensible error, charts of harbours, anchorages, and small portions of the earth's surface are shown on a *plane* projection. Latitude and longitude are

not shown in these plane charts which are usually termed *plans*, their object being to give bearings and distances and to show everything in greater detail.

Charts and Plans.

Measurement and Scale.

Measurement.—In charts the surface distance on the meridians from the equator to the poles is divided into 90 degrees of latitude, and each degree is taken as of equal length. Every degree contains 60 minutes, and one minute, written 1′, is called a *sea mile* and taken as 6,080 feet.

A sea mile contains 10 cables, approximately 200 yards each.

Distances at sea are always expressed in sea miles and speed in *knots*. A *knot* is a speed of one sea mile per hour.

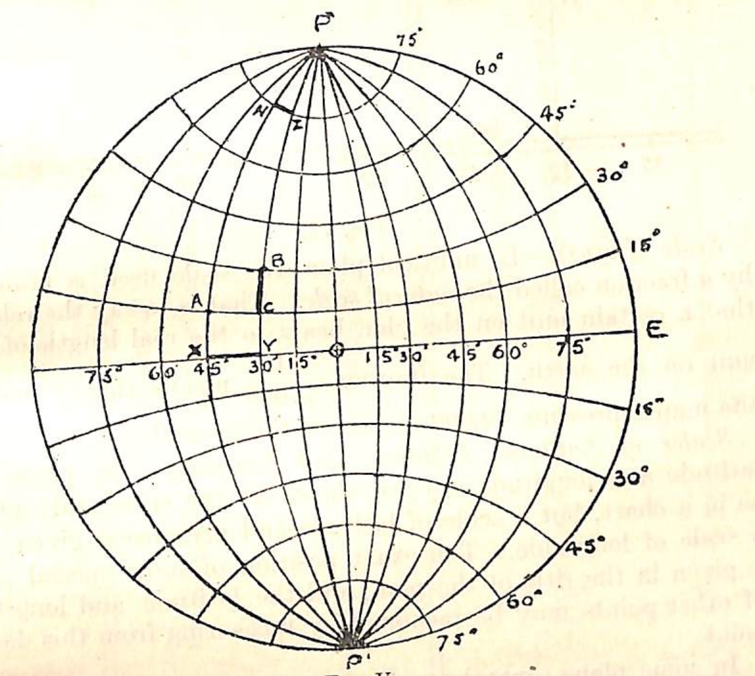


Fig. V.

The parallels of latitude are equally divided into degrees of longitude, but these vary in length on the surface according to the latitude in which they are measured. For example, the arc XY (Fig. V.) on the equator is 15°, and the arc NZ in latitude 75° is also 15°, but it is obvious that each degree of linear measurement of NZ must be much smaller than those of XY. Consequently longitude cannot be used for measurement of distance.

Scale (Charts).—Every chart has two scales.

The scale of latitude and distance will be found at the sides of the chart, AB in Fig. VI. and the scale of longitude at the top and bottom, CD in Fig. VI.

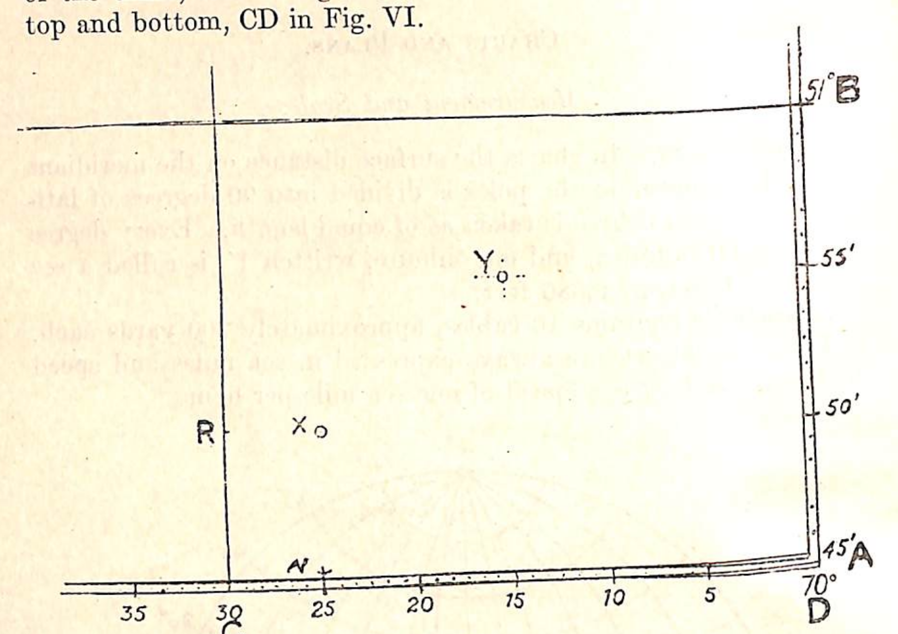


Fig. VI.

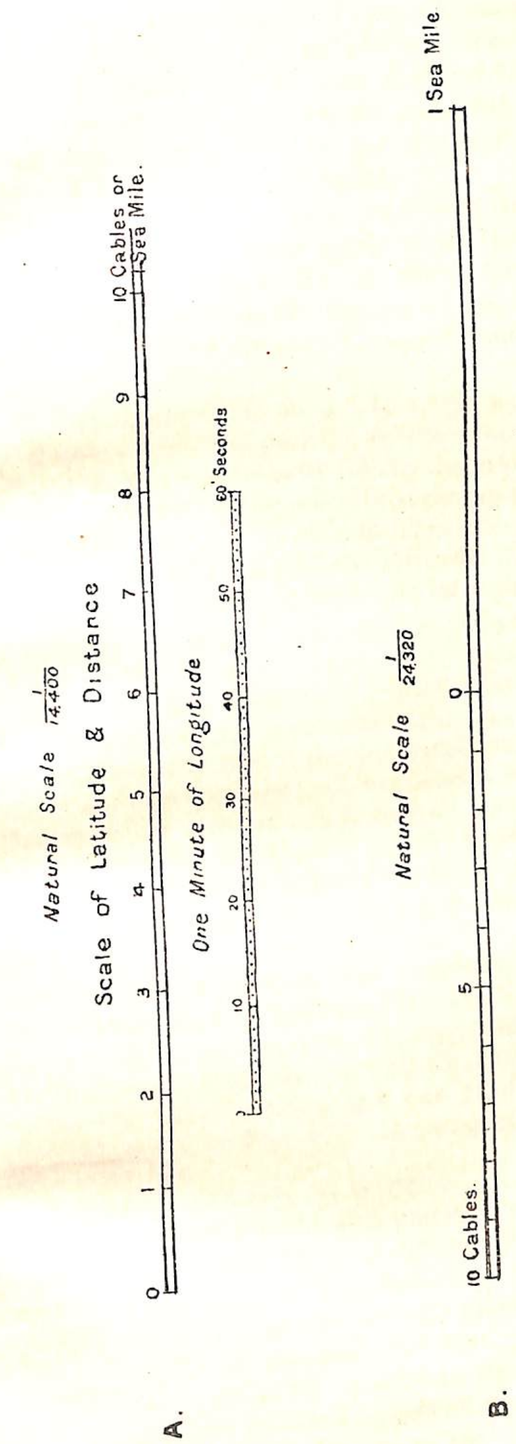
Scale (Plans).—In nautical plans the scale used is indicated by a fraction called the *natural scale*. That is to say the relation that a certain unit on the plan bears to the real length of that unit on the earth. The fraction $\frac{1}{72990}$ means that 1 inch on the map represents 72,990 inches on the ground.

Scales of Latitude, Distance, and Longitude.—In plans the latitude and longitude are not shown at the sides and bottom as in a chart, but a scale of latitude and distance is given, also a scale of longitude. The exact position of some special point is given in the title of the plan, and the latitude and longitude of other points may be reckoned by measuring from this datum point.

In some plans séparate scales of latitude and of distance will be given. These will be identically the same in length, but will be divided differently.

For scales in a plan *see* Fig. VII.

To fix a Position on a Chart or Plan.—When it is required to fix the position of an airship on a chart or plan, proceed as directed in Chapter II., page 23, to fix the position by compass bearings or sextant angles, laying off bearings as directed and recollecting to correct the variation given on the chart or plan to the date of the observations.



Scales on a Nautical Plan.

The Scale of Latitude and Distance may be shown graduated either as in A or in B.

FIG. VII.

74-1.

Malby & Sons, Lith.

To Face Page 74.

To find the Distance on a Chart.—Measure with the dividers the distance between the two places. Transfer the space to the graduated meridian at the side of the chart as nearly opposite the places as possible. (Scale AB, Fig. VI.) The degrees turned into minutes will be the distance required in nautical miles. XY in Fig. VI. = $8\frac{3}{4}$ miles.

If the places have the same or nearly the same latitude, take the space between them, apply it to the graduated meridian *above and below* the parallel on which the places are situated. The difference between the degrees of the extreme points turned into minutes will be the approximate distance required in nautical miles.

To find the Latitude on a Chart.—Measure with the dividers the distance from the position to the nearest parallel of latitude, XM in Fig. VI., and transfer this to the graduated meridian at the side of the chart, taking care to measure from the same parallel of latitude. The leg of the dividers which was on the position of the aircraft will indicate the latitude. If the degrees increase in number towards the North, the latitude is North, and if they increase to the South, the latitude is South. In this case the latitude is 50° 55′ N.

To find the Longitude on a Chart.—Measure with the dividers the distance from the position to the nearest meridian of longitude, XR, and transfer this to the graduated parallel at the top or bottom of the chart, taking care to measure from the same meridian. The leg of the dividers which was on the position of the aircraft will indicate the longitude. If the degrees increase in number towards the East, the longitude is East; if they increase towards the West, the longitude is West. In this case the longitude is 70° 15′ W.

To lay off the Latitude and Longitude on a Chart.—To show the position of Y in latitude 50° 55′ N., longitude 70° 15′ W. Reverse the foregoing steps, guessing within a quarter of an inch where to scratch lightly the latitude and longitude, the point at which the two scratches cut one another being the required position—at Y in Fig. VI.; the short dotted arcs show the two light scratches.

To find the Distance on a Plan.—Measure with the dividers the distance between the two places. Transfer the space to the scale of latitude and distance and read off the amount shown.

To find Latitude and Longitude on a Plan.—Refer to the title of the plan where the latitude and longitude of the datum point will be found. To ascertain the latitude and longitude of some other point, draw a line parallel to the top of the plan through the datum point; this will represent a parallel of latitude. Then draw a line parallel to the side of the plan through the datum to represent a meridian of longitude. With the dividers and the scale of latitude measure off the difference of latitude of the required position and the datum; this will give the required latitude. With the dividers and the scale of longitude proceed similarly to obtain the required longitude.

Admiralty Charts and Plans.—These are of four kinds:—

(I.) World charts.
(II.) Ocean charts.
(III.) General charts.
(IV.) Plans.

I. and II. on a small scale give data such as magnetic variation, coaling stations, ocean tracks, or large extents of the earth's surface, such as the North and South Atlantic. III. contain very full information over a limited area, *e. g.*, portions of the English Channel, North Sea, &c., &c. IV. Plans show small areas on a large scale, such as harbours, anchorages, &c., and contain much detail. The first three are drawn on Mercator's projection and the last on a plane projection. Polar charts and some plans are on the gnomonic projection.

How to read a Chart or Plan.—Read through the title; this is the key to the chart. It gives the locality covered, date of survey, abbreviations for lights, buoys, and description of the sea bottom; also information as to the heights, variation, soundings, &c.

Ascertain the date of publication in order to determine the realibility of the chart. This will be found in the center of the margin at the foot of the chart. In the left-hand corner of the margin will be found the dates in Roman numerals of any small corrections which have been made since it was published.

Study carefully the chart of abbreviations and conventional signs (*see* Plate I.) and memorise as much as possible.

When wishing to describe a chart, the title, number, date of publication, and date of last small corrections should be given. Thus—South Coast of Ireland to Land's End, 1123, published 1888, small corrections XI. 14.

Soundings.—These are reduced to the level of mean low water spring tides (M.L.W.S.). They may be in fathoms or feet and this will be stated under the title of the chart. In charts they are usually in fathoms and in plans in feet. Six feet = one fathom.

Fathom lines indicate relief and show the shape of the sea bottom in exactly the same way that contour lines on a map show the shape of the earth's surface. The conventional signs for the different fathom lines should be committed to memory.

The position of shoal water, sandbanks, &c., in the partol area of the aircraft should be carefully noted and the different symbols used to distinguish them. Banks which dry at low water generally have a figure on them with a line beneath it, *e. g.*, 5. This indicates, as a rule, the amount of feet that the bank

Buoys and Beacons

Light Buoys
Bell Buoys
Can Buoys — B, W, R, H.S, V.S, Cheq
Conical Buoys — B, W, R, H.S, V.S, Cheq
Spherical Buoys — H.S, W

Buoys with Topmarks
Spar Buoys
Mooring Buoys
Fixed or Floating Beacons
Light Vessels or Floats

The Position of a Light Vessel, Buoy or Beacon is the Centre of the Base, and is usually indicated by a small circle.

B, Blk..	Black	S.B.	Submarine bell (Sounded by wave action)
Cheq.	Chequered	S.F.B.	Submarine Fog Bell (Mechanically sounded)
G..	Green	V.S.	Vertical Stripes
Gy.	Gray	Y....	Yellow
H.S.	Horizontal Stripes	W., Wh	White
No.	Number		
R..	Red		

The Heights given against Beacons or marks forming beacons (such as Chimneys) represent the Height of the Top of the object above Mean High Water Spring Tides, or above the Sea level where there is no tide.

Conventional Signs used in Admiralty Charts.

Trees — Firs, Palms, Casuarinas
Cultivated Land
Swampy, Marshy or Mossy Land
Sand Hills or Dunes
Cliffy Coast line
Steep Coast
Sandy shore
Stony or Shingly shore
Mangroves
Figures bracketed against islands and rocks express the Heights in Feet above Mean High Water Springs, or above the sea in cases where there is no tide. (5 ft high) (350)
Towns, Villages or Houses
Villages or Houses
Roads
Track or Footpath
Railway
Tramway

Churches or Chapels
Temples
Windmill
Triangulation Station
Beacon, Chimney, Flagstaff or other fixed points
Lights, Position of
* Rocky Ledges & isolated rocks, dry at Mean Low Water Springs — Dries 2 ft., Dr. 3 ft, Dries 2 ft.
* Sandy Beach & Banks, dry at Mean Low Water Springs — Dr. 1 ft., Dries 1 ft.
* Stones, Shingle or Gravel, dry at Mean Low Water Springs — Dr. 2 ft., Dries 2 ft.
* Mud Banks, dry at Mean Low Water Springs
* Sand & Gravel or Stones, dry at Mean Low Water Springs
* Sand & Mud, dry at Mean Low Water Springs
* The Underlined Figures on the Rocks & Banks which uncover, express the Heights in feet above the datum of the chart, unless otherwise stated.

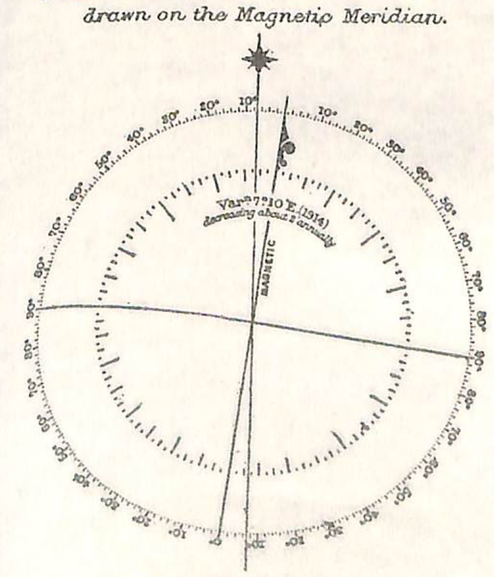
Signifies 1 fathom line, 2, 3, 4, 5, 6, 10, 20, 50, 100
Coral Reefs
Rock awash at Mean Low Water Springs * or ⊛
Rock with less than 6 feet of water over it at Mean Low Water Springs + or ⊕
On small scale charts, this symbol is used for rocks with greater depths of water over them.
Rocks with limiting Danger line
Rock or Shoal, the Position of which is Doubtful — P.D
Reported Rock or Shoal, the Existence of which is Doubtful — D, E.D
Breakers along a shore
Overfalls & Tide Rips
Eddies
Kelp
Beds of Edible Sea Weed
Signifies no bottom found at the depth expressed — 70, 100

Anchorage for large vessels
Anchorage for small vessels
Fishing Stakes

Wrecks

Where depth over is known — Wreck (1911)
Partially or wholly submerged where depth over is unknown — Wreck (1911)

Pattern of Compass (prior to June 1911), drawn on the Magnetic Meridian.



The figures in brackets, either before or after the Variation, denote the year for which it is given.
All Bearings are Magnetic, except when otherwise stated, and are referred to the nearest compass on the chart.

Tides and Tidal Streams

H.W F. & C. IX^h 25^m ...... High Water Full & Change. The hours are expressed in Roman Figures, except 2^h

Equin^l	Equinoctial	m.	minutes
Fl. fl.	Flood	Np.	Neap Tides
*H.W.	High Water	ord.	ordinary
†H.W.O.S.	Ordinary Springs	Q^r	Quarter
h.	hour, hours	Sp. Spr.	Spring Tides
kn.	knot, knots	(arrows)	Current
*L.W.	Low Water	(arrow)	Flood Tide Stream
†L.W.O.S.	Ordinary Springs	(arrow)	Ebb
M.H.W.S.	Mean High Water Springs		
M.L.W.S.	Mean Low Water Springs		

* H.W. or L.W. always refers to Mean High Water or Mean Low Water of Spring Tides, unless otherwise stated.
† These terms will not appear on new charts or new editions of charts published subsequent to June 1914

The period of the tide, at which the streams are running in the direction of the arrows is denoted as follows:-

1. 1st Q^r 2nd Q^r etc. for the Quarters of each Tide ...... 2nd Q^r 2nd Q^r
2. I^h, II^h, III^h, etc. for 1st 2nd 3rd hours after High or Low Water ...... II^h III^h
3. Black dots on the arrows, the number of hours after High or Low Water. (The reference being to High or Low Water in the locality, unless otherwise stated on the chart)

3 hours after High Water, and 3 hours Ebb are both indicated by ......
4 ...... Low ......, and 4 hours Flood ......

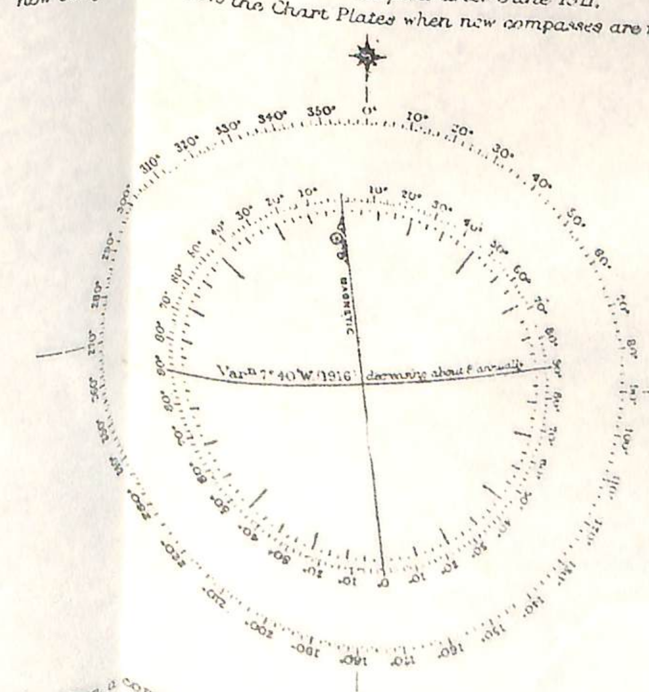
The Velocity of Currents and Tidal Streams is expressed in knots, thus:- ...... 1 kn 5 kn
The Rise of Tide is given above the Datum of the chart.
The Datum to which soundings are reduced, unless otherwise stated, is approximately Mean Low Water of Spring Tides

General Remarks

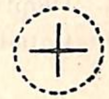
Charts are generally drawn on the True Meridian; if otherwise, a True Meridian is given on the chart.

Soundings are expressed in Feet or Fathoms, as stated in the title of the chart.
1 Fathom = 6 Feet = 1·828766 Metres.
Underlined Figures, on Rocks and Banks which uncover, express the Heights in Feet above the Datum of the chart, unless otherwise stated.
All Heights (except those expressed in underlined figures as above) are, unless otherwise stated, given in Feet above Mean High Water Springs, or, in places where there is no tide, above the Level of the Sea.
The Natural Scale is the proportion which the scale of the chart bears to the actual distance represented, and is shown thus:- $\frac{1}{12,150}$
A Sea Mile is the length of a minute of Latitude at the place, and a Cable is assumed to be a tenth part of a Sea Mile.
The Figures in Brackets in the bottom right-hand corner of a chart, thus:- (38·43 x 25·49) are the dimensions of the plate in Inches between the innermost graduation or border lines.
All Longitudes are referred to the Meridian of Greenwich.

Pattern of Compass adopted after June 1911, now being engraved on the Chart Plates when new compasses are required.

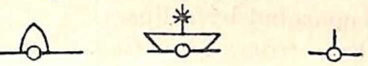


Note:- When a Compass of the above pattern is shown on the Chart Bearings are given both True and Magnetic thus 298° (N 54° W Mag) and this is stated in the Title.
The figures in brackets after the Variation ...

will dry at low water. Rocks awash at low water are shown thus , the dots indicating the points sticking up above the water and the dotted circle the boundary line of the danger. Rocks with less than six feet of water are shown . The positions of these should be carefully noted. From the air a swell gently surging over a rock just submerged might easily suggest a submarine and be so reported if the presence of a rock was not known to the observer.

Heights.—These are given in feet above mean high water springs (M.H.W.S.). Heights of lights in lighthouses and lightships are given from mean high water level and the water-line respectively to the centre of the lantern.

Bearings.—When laying off bearings to or from light-vessels, beacons, or flagstaffs, they should always be laid off to or from the *bottom* of the object observed, as that is its true position on the chart. In the case of a light-vessel or buoy the bearing should be laid off from the centre of the waterline. The position is generally indicated by a small circle thus—



Variation.—The magnetic compasses on a chart show the variation at a certain date and the amount of annual change. The variation must always be corrected to date, *e.g.*, Magnetic Variation (1912) 14° 56′ W., decreasing about 9′ annually, will give 14° 20′ W. in 1916.

Use the magnetic compass nearest the position, or better still calculate the amount of the variation from the Isogonic line nearest the position on the chart and use the true compass.

Lights, Buoys, and Tides.—These will each be dealt with separately and in greater detail. Lights and buoys should be of the greatest value and assistance to the aerial navigator, and a knowledge of the tides, though not of such importance to him as to the sailor, will enable him to know when certain channels will be available for ships of a certain size, to what extent the speed of friendly or enemy ships will be affected, whether rocks, sandbanks, &c., will be covered or uncovered, and so forth.

Lights.

Full particulars of all lights round the shores of Great Britain or elsewhere may be found in the Admiralty Light Lists. Lights may show a continuous steady light or be varied by the introduction of flashes, eclipses, &c. They are generally divided into two classes, those which change and those which do not change colour. They are also distinguished by the character of their illuminating apparatus.

C.	Catoptric	- -	Metallic reflectors.
D.	Dioptric	- -	Refracting lenses.
C.D.	Catadioptric	-	Combination of C and D.

Abbreviations and Characteristics.

Lt.—Light.

(1) Lt. Alt.—*Alternating.* Red and white or other colour alternately at equal intervals without any intervening eclipse.

(2) Lt. F.—*Fixed.* A continuous steady light.

(3) Lt. Fl.—*Flashing.* A single flash at intervals. Period of darkness greater than period of light.*

(4) Lt. Occ.—*Occulting.* A steady light suddenly and totally eclipsed. Period of light greater than period of darkness.

(5) Lt. Rev.—*Revolving.* Light gradually increasing to full effect then decreasing to eclipse.*

(6) Lt. F. Fl.—*Fixed and Flashing.* Combination of (2) and (3).

(7) Lt. Grp. Fl.—*Group Flashing.* Two or more flashes in quick succession separated by eclipses.

(8) Lt. Grp. Occ.—*Group Occulting.* Same as (4) but with two or more eclipses.

(U) after the name of a light indicates that it is unwatched and is therefore not to be implicitly relied on.

Period.—Is the interval between successive commencements of the same phase.

Bearings.—All bearings of lights given in Light Lists are *true* and from seaward.

Distances.—The distance of visibility of a light is calculated from a height of eye of 15 feet above M.H.W. level. The glare of the light is visible much further.

Light Buoys.—These are always flashing, revolving, or occulting to avoid their being mistaken for small vessels at anchor.

Type in Light List indicates relative importance of the light.

Candle Power.—Indicated in Light List by a figure. The unit of candle-power is 1,000 candles. Thus, 22 will indicate

* At short distances and in clear weather a faint continuous light may be observed.

22,000 candle-power. If two figures are given, the first shows clear weather power and the second the maximum power in thick weather.

Colour.—Light-vessels in England are painted *red*, and in Ireland *black*. The name is painted on both sides in white letters. They are further distinguished by a *day mark* or *top mark*, which will be given in the Light List. This may be a ball at the masthead or a diamond over an inverted triangle, &c.

The day marks of all light-vessels in the area of patrol of an airship should be memorised.

Light Vessel off her Station.—By day she will lower her day mark. By night, lower her ordinary lights, show a red light at each end of the vessel, and a red flare every 15 minutes.

Fog Signals.—It is improbable that any of these will be heard in an airship, as the sound will be drowned by the noise of the engines. They may be explosive report, syren, trumpet, reed horn, bell, gong, whistle.

A gun or explosive report might be heard, or the flash seen. In any case, it will be well if the aerial navigator knows the fog signals of lighthouses and light-vessels in his vicinity.

Buoys.

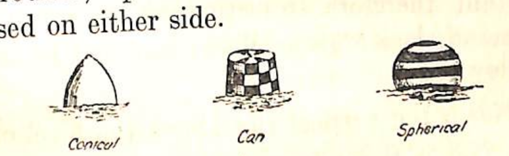
In the United Kingdom a uniform system of buoyage is established, all buoys on the starboard hand being of one shape and colour, and all buoys on the port hand of another distinctive shape and colour, shape being more important than colour.

First determine the direction of the main stream of floodtide. The term "starboard hand" then denotes that side which is on the right of the mariner, either going with the main stream of flood or when entering a harbour, river, or estuary from seaward. The term "port hand" denotes the left hand of the mariner under the same circumstances.

Shapes of Buoys.—Starboard hand buoys, *Conical.* One colour. England: red or black. Scotland and Ireland: red.

Port hand buoys, *Can.* One colour or particoloured. England: chequered, red and white, or black and white. Scotland and Ireland: black.

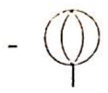
Middle grounds, *Spherical.* Horizontal stripes. These buoys can be passed on either side.



Special positions have special type of buoy.

Pillar buoys, generally light buoys; bell buoys, gas buoys, whistling buoys, wreck buoys.

Topmarks on Buoys.—Topmarks are placed on certain buoys or beacons in a channel to distinguish them.

Starboard hand buoys -	Staff and globe -	
Port hand buoys - -	Staff and cage -	
Outer ends of middle grounds	Staff and diamond	
Inner ends of middle grounds	Staff and triangle	

Light buoys.—Light buoys are not included in the Admiralty Light List. They must not be implicitly relied on as the lights are unwatched. As they are not far above the water-line and have not a powerful illuminating apparatus, they are not visible at any great distance.

Tides.

During the days following new and full moon, when the sun and moon are acting in conjunction, the tide rises higher and falls lower that at any other period of the month. These are *spring tides*. During the days following the first and third quarters, when the sun and moon are in quadrature, the tide has the least range. These are *neap tides*.

Lunar Day.—The moon appears to move round the earth once in 24 hours 48 minutes, which period is called a *lunar day*. The moon thus passes the meridian twice in a lunar day, and there are two high waters and two low waters in this interval.

Flow and Ebb.—The flow and ebb of the tide are due to the alteration of the level of the water caused by the tide wave.

When the water in a channel has been set in motion and a tidal current produced, the motion of the water does not immediately cease when it is either high or low water, but the momentum still continues to produce its effect.

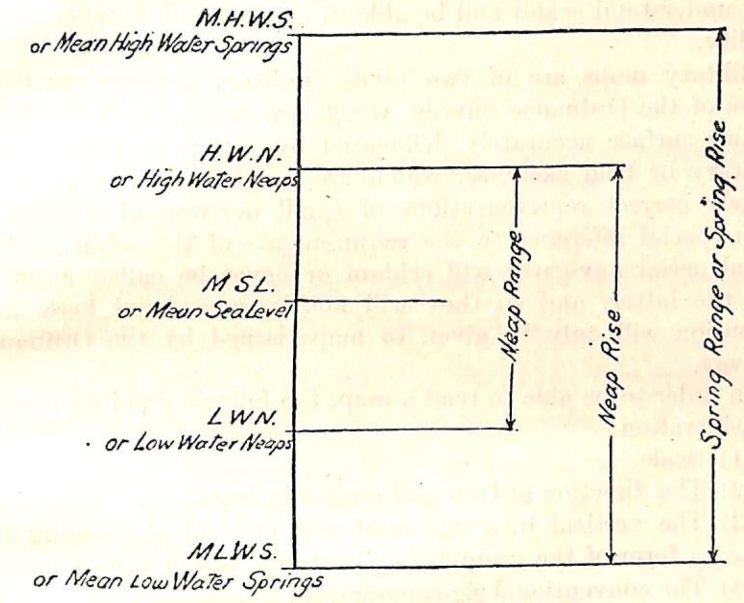
It is important, therefore, to distinguish between time of high water and time of slack water. Water may not be rising, but it may be still flowing.

Rise of a Tide is the vertical rise above the level of M.L.W.S.

Range of a Tide is the difference in height between low water of one tide and high water of the next following tide.

Mean Level of the Sea is the mean between the levels of high and low water of any tide.

These are shown in the diagram—



Spring rise will be seen to be the same as spring range.

Generally speaking—

Neap rise = $\frac{3}{4}$ or $\frac{5}{6}$ spring rise.
Neap range = $\frac{1}{2}$ spring range.

Lunitidal Interval is the interval of time between the moon's meridian passage at a place and the next high water.

H.W.F. & C. or the Vulgar Establishment of the Port is the interval of time in hours and minutes between the moon's meridian passage on days of full and change and the next succeeding high tide, *e.g.*, Port Natal, H.W.F. & C. IV.^{h} 30^{m}. It is the lunitidal interval on days of full and change.

Time of H.W.—To obtain the time of high water at any place refer to the Admiralty tide tables and obtain the time of H.W. at the nearest standard port. To this apply the tidal constant for the port required. Result—Time of H.W. at the place.

Maps and Map Reading.

Map reading is the art of grasping the topographical features or general appearance of the surrounding country from the inspection of a map representing it. To do this the observer must be able to picture in his mind what the representation of the country on a flat surface would look like in nature. The aviator has his task simplified in some respects, since the ground immediately below him appears quite flat as in a map, only the distant surrounding objects showing up more or less in profile.

In addition to reading the signs in his map, the aviator must also understand scales and be able to measure off distances with facility.

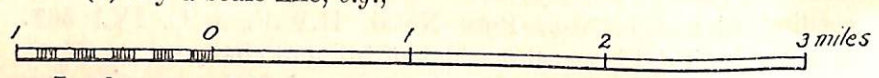
Military maps are of two kinds—military surveys, such as those of the Ordnance Survey, which are representations of the earth's surface accurately delineated by expert surveyors, and military or field sketches, which are rough and only approximately correct representations of small portions of a country with special reference to the requirements of the soldier. The naval aerial navigator will seldom or never be called upon to use the latter, and so they will not be considered here, and attention will only be given to maps issued by the Ordnance Survey.

In order to be able to read a map, the following points require consideration:—

(1) Scale.
(2) The direction of true and magnetic north.
(3) The vertical intervals used and method of showing the form of the ground, *i.e.*, contours, colour layers, &c.
(4) The conventional signs employed.
(5) The general character of the country, *i. e.*, undulating, flat, canals, agricultural, &c.

Scales.—Scale is the proportion between linear distance on the ground and the representation of that distance on the map. It may be denoted in three ways—

(1) By a *representative fraction*, known as the R.F., *e.g.*, $\frac{1}{63360}$.
(2) By words, *e.g.*, 1 inch = 1 mile.
(3) By a scale line, *e.g.*,



In the case of the representative fraction, or R.F., the numerator must always be unity, and the numerator and denominator of the same character, *i.e.*, both inches, feet, yards, centimetres, &c. The R.F. is one whose numerator bears to the denominator the same proportion that a distance on the map bears to the actual distance on the ground.

Thus, R.F. $\frac{1}{63360}$ means that 1 inch on the map equals 63,360 inches, or 1 mile, on the ground. The scale is then 1 inch to a mile. Maps in Great Britain have the inch as the unit. In French and Continental maps the unit is generally a centimetre, *i.e.*, $\frac{1}{100000}$, or 1 centimetre to 1 kilometre.

The advantage of the R.F. is that when it is given any Continental map scale can be immediately turned into a British scale and a scale line in British units constructed.

To find miles to the inch.—To find the number of statute miles to the inch for any map that has a R.F. Divide the denominator of the R.F. by 63,360:—

Thus R.F. $=\frac{1}{80,000}=\frac{80,000}{63,360}=1\cdot263$ miles to the inch.

To find inches to the mile.—To find the number of inches to the statute mile. Divide 63,360 by the denominator of the R.F.:—

Thus R.F. $=\frac{1}{80,000}=\frac{63,360}{80,000}=\cdot792$ inches to the mile.

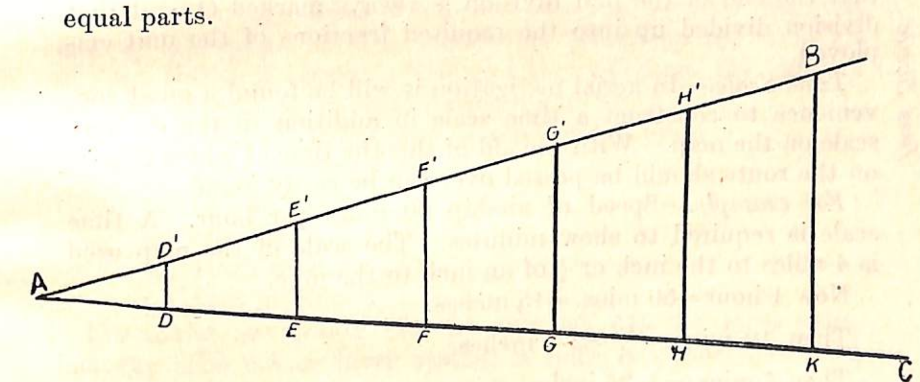
When it is miles to the inch the denominator is always greater than 63,360, *i.e.*, $\frac{1}{80,000}=1\cdot28$ miles to the inch.

When it is inches to the mile the denominator is always less than 63,360, *i.e.*, $\frac{1}{40,000}=1\cdot58$ inches to the mile.

Line Scales.—These are generally 4 to 6 inches long, and should show complete divisions of units; thus, scale in miles, showing tenths of a mile.

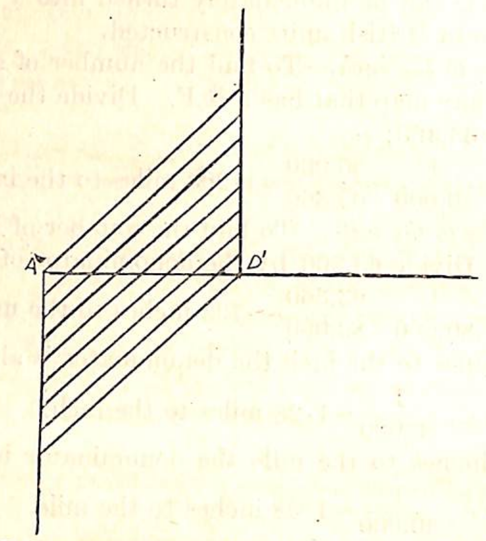
In order to be able to construct a line scale it is first necessary to know how to divide up a line into equal parts.

Take a line AB, 5 inches long, which is to be divided into six equal parts.



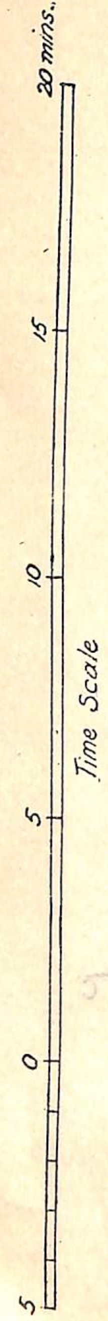
From A lay off AC at an angle of about 20 degrees. Along this mark off six equal distances about the size of the required divisions, *i.e.*, $\frac{5}{6}$ of an inch. Join the last division K with B, and through D, E, F, G, H draw lines parallel to KB, cutting AB at D′, E′, F′, G′ H′. The points of intersection will then divide AB into six equal divisions.

If it is required, the first division may be divided more accurately as follows:—



At A and D′ set up perpendiculars below and above the line. Mark off from A and D′ the number of divisions required, say, eight. Join A with the uppermost division, and by joining the other points so that they intersect AD′ the required division will be made.

The scale will then be marked in the required manner, noting that the end of the first division is always marked O, and that division divided up into the required fractions of the unit employed.



Time Scale.—In aerial navigation it will be found a great convenience to construct a time scale in addition to the distance scale on the map. With the aid of this the time at which objects on the route should be passed over can be easily found.

For example.—Speed of airship 60 miles per hour. A time scale is required to show minutes. The scale of the map used is 4 miles to the inch or $\frac{1}{4}$ of an inch to the mile.

Now 1 hour = 60 mins. = 15 inches.

Then 10 mins. $= \frac{15}{6} = 2 \cdot 5$ inches.

Then 5 mins. $= 1 \cdot 25$ inches.

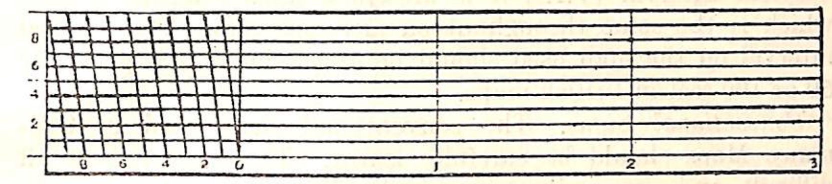
Scale will be as shown in margin.

The Protractor.—In cases where a line scale is not laid down on a map the diagonal scale on a protractor enables any distance to be measured to hundredths of an inch.

The protractor most commonly used is of boxwood or ivory, six inches in length by two in breadth.

On one side are several simply divided scales of 30, 40, 50, &c., that is to say those number of parts to an inch. Also graduations for laying off angles to 180°, and a scale of chords also for laying off angles.

On the other side is the diagonal scale as below.



To use this scale, and to take any number to three places of figures, the following is the general rule:—

On the parallel indicated by the third figure, measure *from* the diagonal indicated by the second figure, *to* the vertical indicated by the first. Thus—2·68. On the parallel of 8, at the point where it is intersected by the diagonal of 6, set the left leg of the dividers and extend the right leg to the point where the vertical of 2 cuts the same parallel.

Direction of True and Magnetic North.—In a chart the meridians are always based on the true meridian, but this is not the case in a map. It is therefore always necessary, when using a map, to find the direction of True and Magnetic North. As a general rule a compass diagram will be given somewhere on the map showing the direction of true North and the amount of variation when the map was published, with the annual change. If this is not given it may be that the position of the meridians are marked on the top and bottom marginal lines of the map. If these points are joined up the direction of true North is shown. Failing either of these the sides of the map must be taken as true North and South.

Relief on Maps.—Relief may be represented by—

(*a*) Contour lines.
(*b*) Colour layers.
(*c*) Shading.
(*d*) Hachuring.
(*c*) Spot heights.

For aerial navigation (*b*), (*c*) and (*d*) are the most satisfactory. The colour layer system is really contour lines with varying shades of colour added in order to aid visualisation of a considerable area. This system, though it is not usually resorted to in military maps, shows very readily inequalities in the surface mapped, and is therefore of great convenience to the airman.

Shading and hachuring effect the same thing, and, though perhaps not indicating relief so clearly, have the advantage of not making landmarks indistinct.

Spot heights, which are merely dots on the map with the height in figures near them, are useless for aerial maps.

The height of one contour above another is called the Vertical Interval (V.I.); it is always a fixed number of feet, which is the same throughout on any one map. The vertical interval on the map used should be ascertained; it is generally 50 or 100 feet in British maps.

Conventional Signs.—The conventional signs used in Ordnance Maps should be carefully learnt. These are not at all difficult and are easily memorised. These signs, as used in British Ordnance Survey Maps, are shown in Plate II.

The Continental conventional signs on maps are not quite the same as those used in Great Britain, and these should also be studied for differences. The key sheet (Plate III.) illustrates these.

CHAPTER VII.

PRACTICAL AERIAL NAVIGATION.

Selection of Landmarks and Seamarks.

In practical aerial navigation much can be done towards determining the position of the aircraft and in makeing accurate and speedy passages from place to place by rapidly recognising objects on the ground which are marked on the map.

The objects most easily distinguished are:—

Landmarks.

(1) *Water.*—This can generally be seen at a great distance. Shape is of importance. If a lake or pond, note whether there are buildings near it or something which enables you to identify it from a similar piece of water in the neighbourhood. Position over rivers or canals can be determined by the railway or passenger bridges over them.

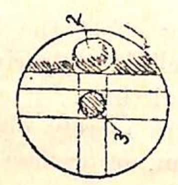
In wet weather and after a wet season, recollect that large areas of low lying country may be temporarily flooded, which will not be marked on the map.

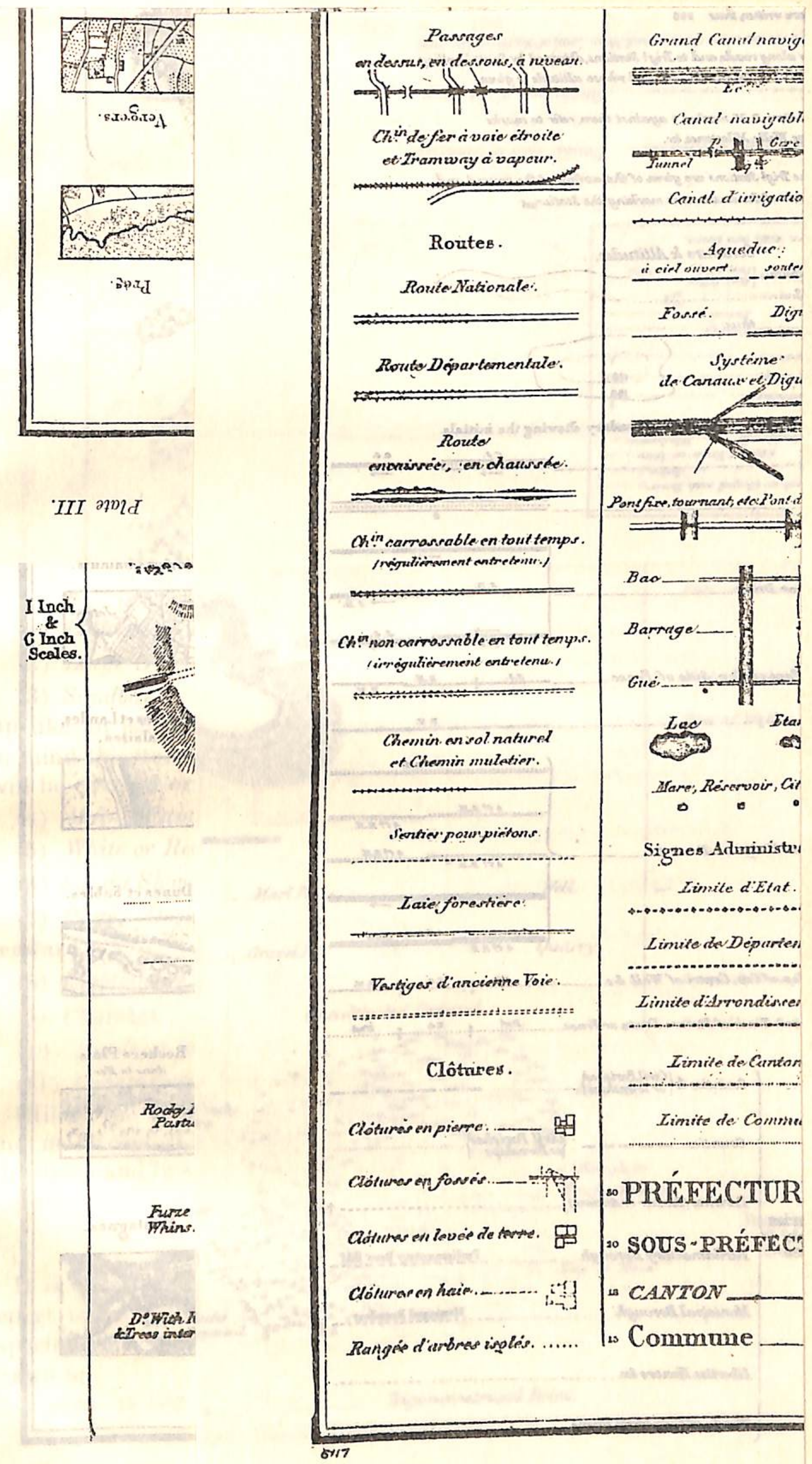
Small streams are generally hidden by trees and are of little use.

(2) *Cemeteries.*—These can be seen at some distance and are most distinctive and very useful landmarks.

(3) *Gasometers.*—These are generally good marks and their position, *i.e.*, north or south of a town, will help to identify the place.

(4) *Railways* (especially crossings or junctions).—If flying parallel to or over a straight stretch of railway line make use





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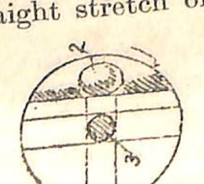

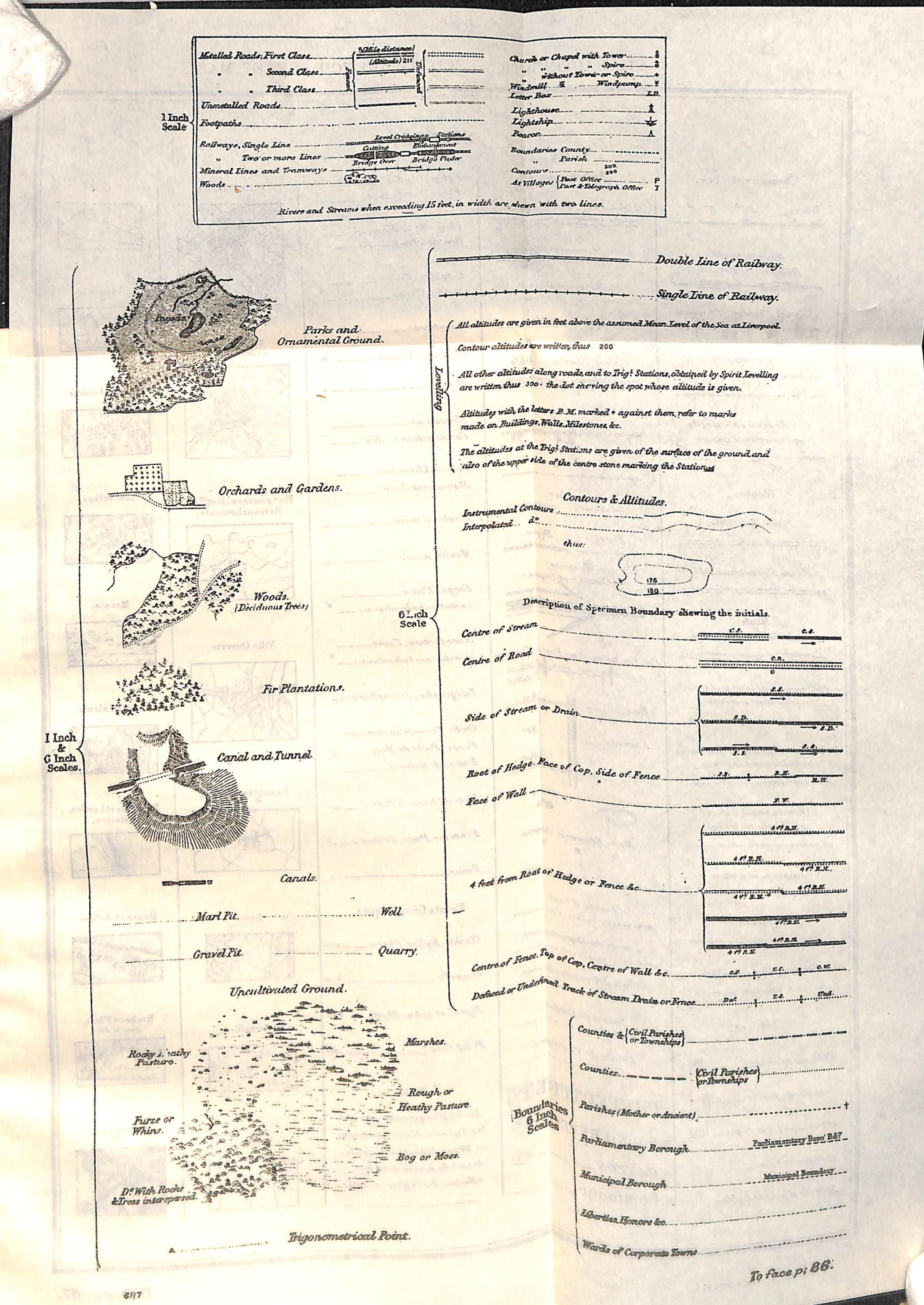

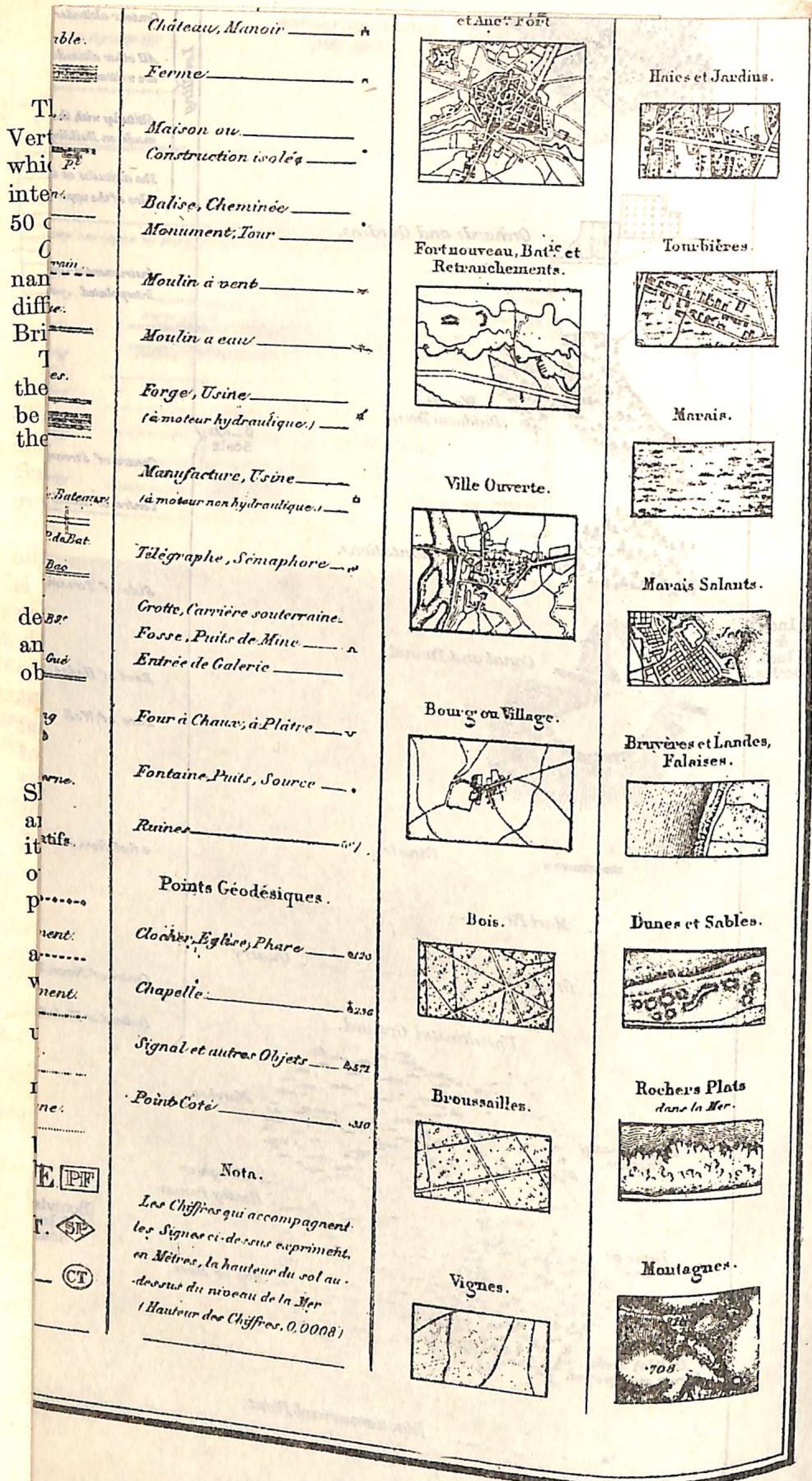

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of it to check the deviation of your compass. Take the magnetic direction of the line from your map and compare it with what your compass indicates. It will be useful also for checking your drift.

(5) *Woods.*—Shape is the first consideration.

(6) *Private Houses* surrounded by parks, especially those with ornamental water.

(7) *Golf Courses.*

(8) *Towns and Villages.*—Ascertain the position of the church.

(9) *Roads.*—As a rule all roads look much the same from above and it is difficult to distinguish a main road from an unimportant one. Moreover, main roads are frequently tarred and are then less conspicuous than the secondary roads and can be mistaken for railways.

(10) Windmills.

Seamarks.

(1) *Lightships.*

(2) *Large Buoys.*

(3) *Sandbanks, Rocks, Shoals.*—A good-sized rock will show up like an island and makes an excellent mark. Always have in mind the state of the tide so as to know whether these marks will be covered or uncovered.

(4) *Main Steamer racks.*

(5) *White or Red Cliffs.*

(6) *Sandy Shore.*

(7) *Piers, Docks, &c.*—When approaching the land from seaward.

(8) *Lighthouses.*

(9) *Churches.*

(10) *Hotels or large buildings.*

(11) *Conspicuous Towers.*

Utilise the leading marks given on the chart if available and make use of the views from seaward given in the sailing directions and in some charts.

Scouting Reports.

It is customary on every airship voyage for a short scouting report to be made out. Occasionally a flight should be made especially for scouting practice and a fully detailed report drawn up.

When flying over the land such a report should cover:—

(1) *Towns.*—The names of towns or villages passed over and whether defended or undefended.

If the former—*Nature of Defence:*—

(*a*) Permanent fortifications.

(*b*) Earthworks.

(*c*) Trenches. Give detailed sketch of these.

Troops and Barracks.

(*a*) Permanent barracks.

(*b*) Camps. Give position and number of huts, probable number of men accommodated, &c.

(*c*) Troops. State approximate strength of those seen and whether moving and in what direction.

(2) *Railways.*—Number and type of rolling stock seen, in what direction proceeding, whether track is double or single, length of sidings, termini and junctions, cuttings, embankments, tunnels, bridges and level crossings.

(3) *Roads.*—Type of roads, whether metalled or not, whether suitable for heavy transport or otherwise, whether open or fenced, and if fenced, how? Wood, iron rails, &c.

(4) *Canals.*—Barges or craft seen. Locks.

(5) *Rivers.*—Flowing in what direction, width at various places.

(6) *Bridges.*—Whether rail, passenger, &c.

(7) *Reservoirs and Lakes.*—Give approximate size.

(8) *Telegraph and Telephone Wires.*

(9) *Gasworks and large Buildings.*—Factories, whether working or not.

(10) *Districts passed over.*—Whether manufacturing, agricultural, &c., and general nature of the fencing, general contour, whether hilly or flat, wooded or grass land, giving general description.

When flying over the Sea.

(1) *Harbours.*—Describe the docks, if any, or harbour works, dry docks, basins, derricks, coaling quays and sheds; number of vessels in dock or in harbour; vessels proceeding in or out; vessels discharging or taking in cargo.

(2) *Shipping.*—Note all shipping seen, and mention whether man-of-war, merchantman, steam, sail, &c., and give accurate description, *i. e.*, battleship, battle-cruiser, submarine, mail steamer, barque, &c., and state nationality. Give bearings and time, also estimated distances and direction proceeding.

(3) *Light Vessels, Buoys, Beacons.*—Note those passed over and the times.

(4) *Rocks, Sandbanks, Shoals, &c.*—State whether covered or uncovered, and give state of tide. If wrecks seen, describe position and apparent condition.

In places where the charts or plans are not of recent date and only on a small scale, valuable information might be forthcoming from aircraft as to unsuspected pinnacle rocks, small shoals, &c., which could be seen from the air but have been missed over in the survey.

(5) *Always give the time of passing over or observing objects.*

CONNING THE AIRSHIP.

It is essential that the coxswain in an aircraft should understand clearly any directions received from the pilot as to alterations of course, and that there should be no ambiguity about the orders given.

The steering wheel used in an airship represents the wheel of a sea-going ship, and the same orders should be applicable. A recent order in the Royal Naval Air Service has, however, decreed that the terms "right" and "left" are to be substituted for "starboard" and "port"; the ordinary naval helm orders do not therefore hold good. Moreover, the coxswain in an airship labours under the disadvantage of being unable to hear any orders given from behind, and these must therefore be conveyed in such a way that he will understand what is intended. Every pilot will have his own ideas on the subject as to the best way of conveying his wishes to his subordinate, but it will be better for all concerned if there is some definite arrangement throughout the service.

At present it is customary for the pilot to touch the coxswain on the shoulder, and having thus gained his attention to indicate with the hand in which direction the wheel is to be turned, possibly showing by the number of fingers held up the number of degrees of the alteration, or by pointing in the required direction. The coxswain will then alter course, and in lieu of the word "steady" the pilot will again touch him on the shoulder when the craft is on her course, the coxswain carefully noting the degree of the compass indicated when he is so steadied. The operation of steadying is repeated two or three times and after short intervals until the pilot is satisfied that the coxswain is steering the correct course, the coxswain finally calling out the degree that he is attempting to steer.

In cases where the coxswain is able to hear the word of command, the orders given should be "Alter course — degrees to the right or left." As the craft's head comes near the new course, "Ease," in order that her swing may be checked as her head arrives in the required direction. If it is necessary for opposite helm to be given, the pilot will order, "Meet her," so that the swing may be checked as quickly as possible.

When the craft's head comes exactly on the new course, the order "Steady" will be given. This indicates that the craft's head must be kept in the direction it was at the instant "Steady" was called. After this order is received, and the craft finally steadied, the coxswain should steer the course indicated until a fresh one is given. At the word "Steady," the coxswain should call out the course as indicated by the steering compass, and he should always repeat any order.

Taking Station with the Fleet.

Since airships now have to work with the Fleet and take up definite stations, the aerial navigator should understand the terms "bow," "beam," "quarter," &c., used in fleet tactics.

It is customary to divide the two semi-circles formed on each side of the aircraft into points as in the compass, there being 16 points in the semi-circle of 180°. Thus each point has a value of 11° 15′ 0″.

The position immediately in front of the craft is "right ahead" or "ahead."

Four points on either side on the "Bow."
Eight points on either side on the "Beam" or "Abeam."
Twelve points on either side on the "Quarter."
Sixteen points on either side "Astern" or "Right Astern."

Any other intermediate positions are given by signal as compass direction, *i. e.*, Flagship steering north—"Take station N.E. by E.—1 mile."

The terms "starboard" and "port" are still used at sea and therefore they must be used also by the aerial navigator, in spite of the order referred to on page 89, to indicate the side on which station is to be taken.

Rule of the Road.

Until very recently it has been considered unnecessary for aircraft to observe a "rule of the road" as is the case in sea navigation, but conditions have of late become such that a code of rules is imperative, if dangers of collisions are to be avoided.

It is not at all uncommon to see reckless aeroplane pilots approaching dangerously close to airships and balloons, forgetful in the former case that the airship's aerial may be 200 feet below it, and the trail rope of the latter some 300 feet underneath. The first of these is certainly invisible to the aeroplane pilot, and probably the second also in bad or fading lights. In either case there is danger to all concerned.

(1) Two aircraft meeting each other end on, and thereby running the risk of collision, must always steer to the right. They must, in addition to this, pass at a safe distance between their nearest adjacent points.

A safe distance, in the case of aeroplanes, is considered to be 100 yards, and in that of airships at least 500 yards.

(2) When two aircraft are approaching one another in cross directions, then the aircraft that has the other on its right hand forward quadrant most give way, and the other aircraft must keep on its course at the same level till both are well clear.

(3) Any aircraft overtaking another aircraft is responsible for keeping clear and must not approach within 100 yards on the right or 300 yards on the left of the overtaken aircraft if it is an aeroplane or 500 yards if it is an airship, and must not pass directly underneath or over such overtaken aircraft.

The distance shall be taken between the nearest adjacent points of the respective aircraft. In no case must the overtaking aircraft turn in across the bows of the other aircraft after passing it so as to foul it in any way.

(4) In these regulations aeroplanes should always give way to airships, except as in paragraph (3), when they are the overtaken craft, and the airship should continue her course.

Note.—When observing the relative position of another aircraft it should be remembered that if the bearing of the other craft remains *constant*, the two aircraft will meet.

If the bearing draws ahead of you, she will pass ahead of you.

If the bearing draws astern, you will pass ahead of her.

Aerial Voyages.

The foregoing explanations of the meaning of navigational terms, of the methods of finding positions and use of navigational instruments, charts, and maps must now be compounded to make a connected whole. If the pilot has properly assimilated and practised the methods advocated he should be in a fair way to undertake any aerial navigational work which he may be called upon to perform.

The following concluding hints are by no means exhaustive, but are merely intended to serve as a framework to be covered by each pilot as his own special and personal experience teaches him.

Having been ordered to undertake a long voyage on the morrow the pilot will make all his preliminary preparations overnight, keeping in mind the fact that once started on his journey he will have no space for comfortable and accurate calculations nor time in which to do them. Everything that is possible must therefore be done beforehand.

Instruments.—Go over these and make sure that all are in good working order. See that you have a dependable watch or stop watch; that the compasses have been properly adjusted and that the deviation slips are in their places near the compasses ready for use. In S.S. ships where there is only one compass fitted the observer should carry a second one, preferably an "observer's" compass, in case of accidents. Care should be taken when using that it is held in a good magnetic position. Adjust the aneroid or altimeter by comparison with a standard barometer and test your air speed indicator for leakage, as instructed in the Airship Manual.

Those instruments included in the list on page 5 which are fitted on the instrument board will all be in place and if not will be easily missed, but any one of those which are not attached may be forgotten at the last moment. Make a list, therefore, of these, and also your charts, checking it before leaving.

(1) Charts and maps. Chartboard. Note-book with sectional ruled pages. Log book.
(2) Dividers, parallel rulers, protractors, Cust station pointer, india-rubber, pencils, knife. These should be fitted in a light handy case.
(3) Watch.
(4) Sextant.
(5) Aircraft course and distance indicator.
(6) Station pointer.

All of these should have their proper place so that they can be found easily.

First prepare maps and charts. Take a small scale chart covering your whole journey and on it lay down the direct route between your departure point and the objective. After studying this, select carefully the larger scale charts and maps you will require and put them in order. In your notes put down the numbers of the charts required in succession. Then decide on the best route to take to reach your objective, which may not necessarily be the most direct. Note all the principal landmarks or seamarks to be passed over, such as buoys, beacons, light-vessels, &c., and endeavour to memorise them. When making a long flight over sea be careful to record all stern leading marks which will assist you to start off from the coast in the right direction.

In your notebook put down the several directional marks, their distances apart in sea or land miles, and the approximate times at which you will expect to reach them. Also note the state of the tide at various times of the day so that you will know whether to look out for sandbanks, shoals, rocks, &c., as guides, and, if the journey will be partly at night, note the moon's phases.

Having laid down the track that you wish to make good, note the true course from place to place. Make out an approximate distance and time-table, giving times that objects should be passed over, and distance between them and the next. A rough scale or a card slip about 12 inches long, marked on one side for distance and on the other for time, will be found very useful.

Now you are well aware that your courses and speed must depend in great measure on the direction and force of the wind and the type of weather you will experience. You must, therefore, make a careful study of the meteorological conditions, and the forecast of the local meteorologist. From this you will know whether to anticipate wind, rain, fog, low visibility, &c., and you can make approximate calculations as to how your direction and speed will be affected thereby. You cannot calculate anything beforehand, as the weather conditions in the morning may not comply with the forecast, but you can at any rate have alternative distance and time scales in case of an adverse or fair wind.

Under the heading "Probabilities" and "Weather Prospects" in the Meteorological Report you will be able to get a good idea of the general type of weather you may expect on the morrow, and the likely winds at various heights. The altitude at which you will have to fly will largely be determined by the latter.

In order to determine approximately the height at which you will fly most economically, note the extreme height of any land that your selected route will pass over and arrange to fly at such a height as to give this reasonable clearance. Then consider the wind force and direction, and decide whether there is any advantage in flying higher or lower when going with or against the wind, bearing in mind that as a *rough general rule* the wind veers as you ascend, and also increases in force.

The height of flight is a matter of supreme importance, since it means economy or waste of gas. Endeavour, therefore, to arrange matters so that as nearly as possible a constant height is maintained, at the same time taking full advantage of the wind, arranging that it assists your speed rather than the reverse.

Petrol supply needs careful consideration. You will have drawn up a table before this showing your radius of action at varying speeds, and you will from this be able to determine whether the track to be made good and the probable wind will give you the greatest radius or the least. Be sure that you have a good margin of safety, so far as supply is concerned, to meet all contingencies.

Log Book.—Have this in such a form that your entries can be made rapidly and that the log is so kept that an accurate record of your voyage can afterwards be plotted on the chart. The usual form of a ship's log with columns for time, course steered, distance run, &c., should be equally useful for aerial navigation with extra headings to meet the case.

Before starting on a Voyage.—Have a last look at the meteorological report and modify your calculations as far as possible if the conditions are not quite what you expected.

Make sure that all your navigating instruments are on board.

Take care that at the last moment no magnetic substances such as iron or steel implements, *i. e.*, spanners, &c., are placed in the craft close to the compass.

Set your altimeter to record the height of your landing ground. Unless this is done and you are to land after dark at a place at a lower altitude than your own the instrument will be recording incorrectly and you will have trouble. Remember in any case when landing that your altimeter will show "creep," which may be 2 per cent. of the height attained.

En Route.—On starting make the aerodrome your departure point. Set your compass course, note the time by your watch and your estimated speed by the engine revolution indicator. When you have reached the altitude desired note the time and position. The track you have arranged should take you over one or two well-known landmarks and to a definite point on the coast, all in the direct path you wish to make good. Before leaving the land you should endeavour with the aid of these marks to determine your drift and ground speed and the velocity of the wind. First find your drift and ground speed as explained in Chapters III. and IV., then determine the direction and force of the wind. With these you can then find the necessary course to steer to make good the required track.

Do not forget when taking bearings, angles, or making any alterations of course to note the time.

Finally before losing sight of land, on passing from shore to sea and having no objects beneath you to give you your position, commence to fix by cross bearings or sextant angles, and continue to take these until landmarks are no longer available for the purpose. Cross bearings of objects taken abaft the beam are called "stern bearings" or "back bearings," and by some navigators these are considered of importance for giving the final positions before losing sight of the land. The important point, however, is the obtaining of a good fix or good departure point before the land is lost, and it is immaterial how such fix is obtained.

Leading Marks.—In the section on position finding it was pointed out how useful transits are for fixing position or giving a line of direction. Transits should always be sought for, and a transit steered on becomes either a leading mark or stern leading mark.

With Leading Marks Ahead.—Steer from the aerodrome to one of the special marks on your track, keeping this in line with a second and more distant mark, thus steering on a transit or leading mark. Whilst on this line the drift and wind can be calculated and so allowed for that when the leading marks are passed over the same track can be maintained towards the

objective, bearing in mind that the wind, as a general rule, over the *sea* at a height of 1,000 feet more nearly approximates in velocity to the gradient wind.

With Stern Leading Marks.—Having settled the course to be steered in order to make good the required track, just before leaving the coast the pilot looks astern and selects two objects in line which he finds from his chart will keep him in the proper direction. Whilst the coxswain attends to his compass course the pilot will keep an eye to these stern leading marks and by keeping them on will know he is making good what he desires.

An alternative way is to select two objects on the chart in the desired track and to keep these in line, the coxswain carefully noting his compass course whilst the pilot attends to the leading marks. The compass course steered will then be that necessary to maintain the required track, and any difference in velocity between the land and sea wind will be allowed for.

In concluding these remarks on navigation the attention of the aerial pilot and navigator is called to that most important of all directional instruments, the compass, which, if he understands it properly, will never fail him. He is specially cautioned to avoid falling into the error of allowing his coxswain to steer on distant clouds, smoke, or objects on the horizon in preference to the compass. "Eyes in the boat" should be the order. He has only to plot out on the chart the results of steering by such a method to see its faults. Finally, if good results are to be attained, direct and rapid passages made, and skilful navigation shown, the navigator must at all times give a strict attention to details.

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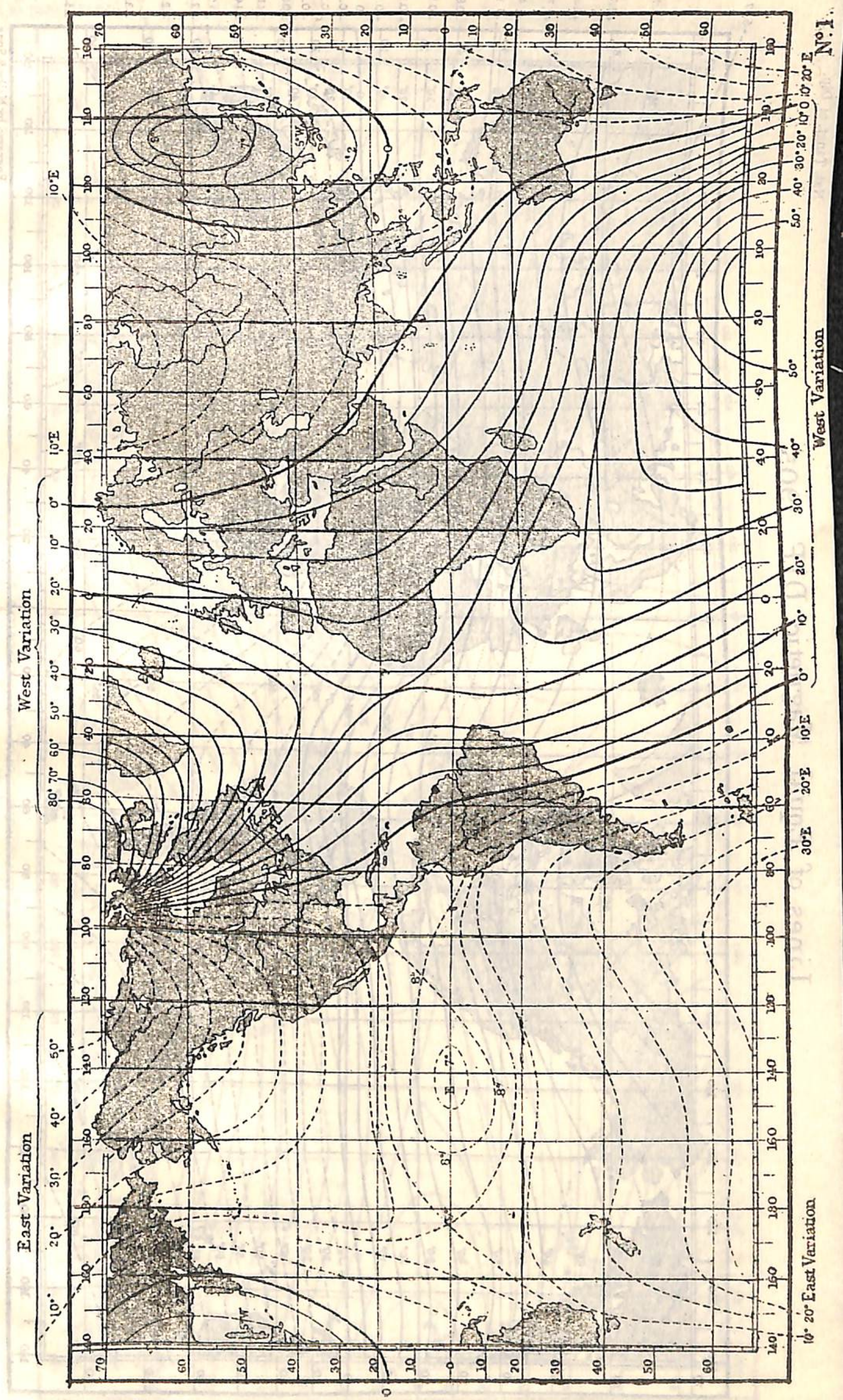

Lines of Equal Magnetic VARIATION. 1905.

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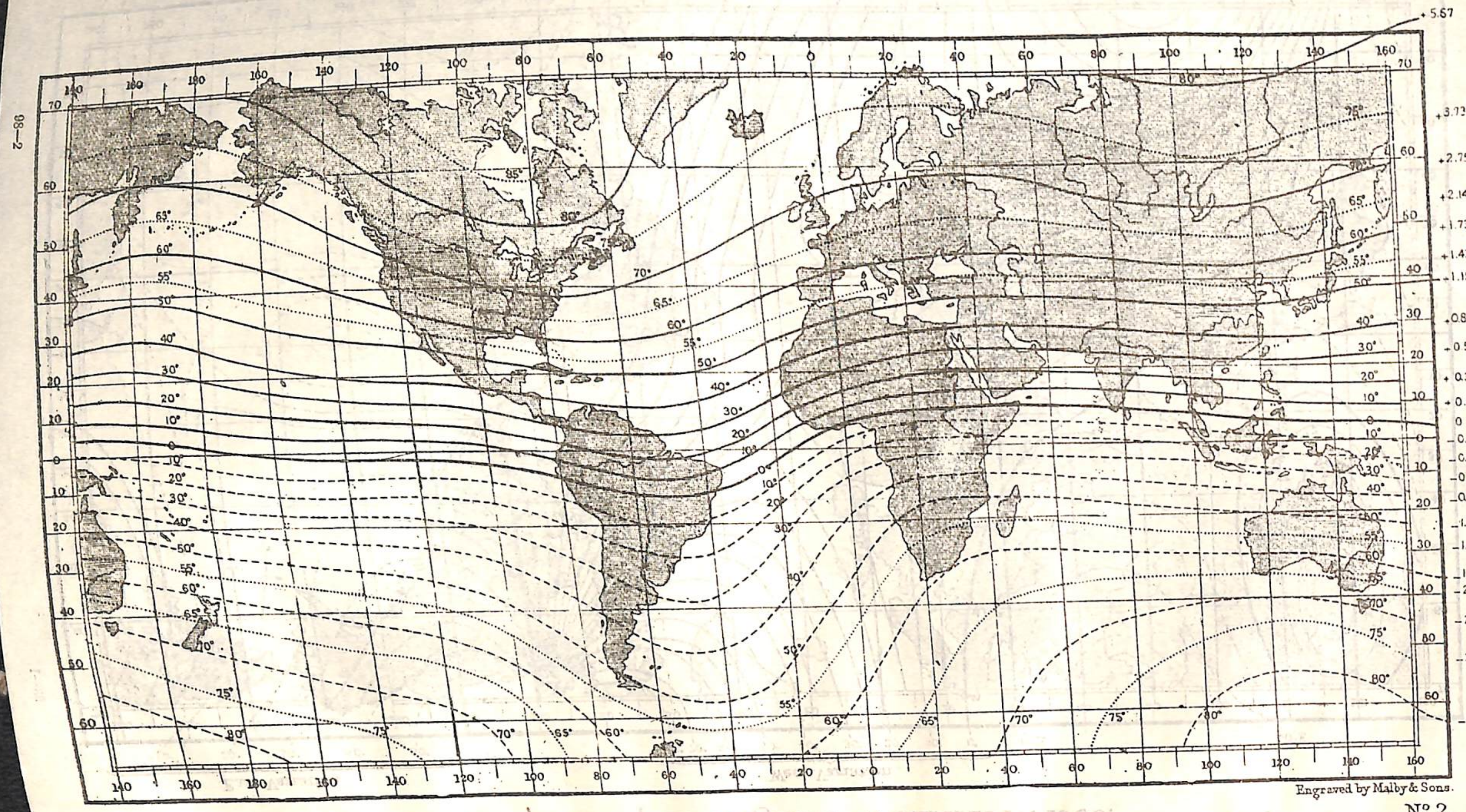

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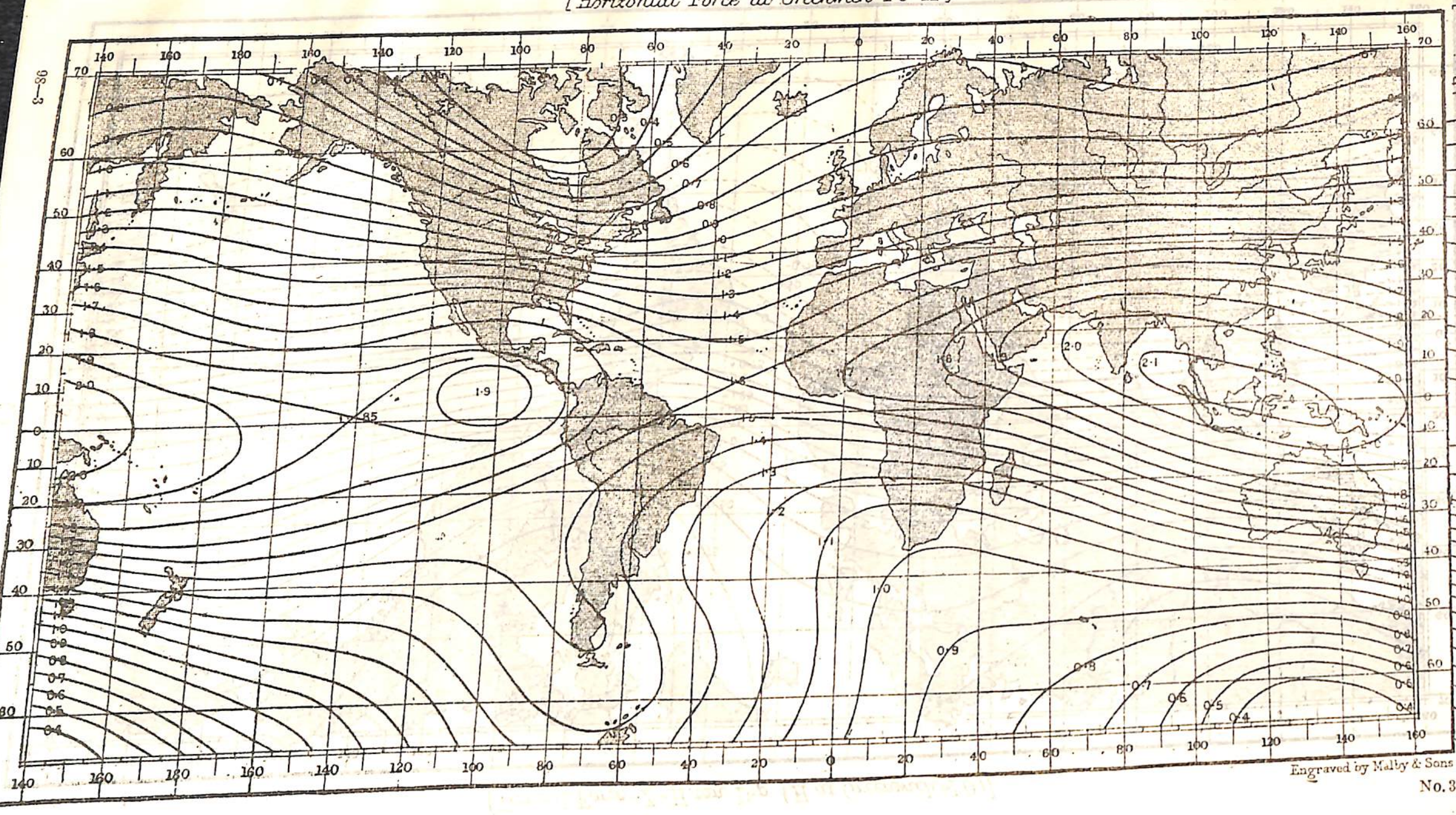
Nº 2.

Lines of Equal Horizontal Force 1905

[Horizontal Force at Greenwich-1·0·H]

Reciprocal of the Horizontal Force



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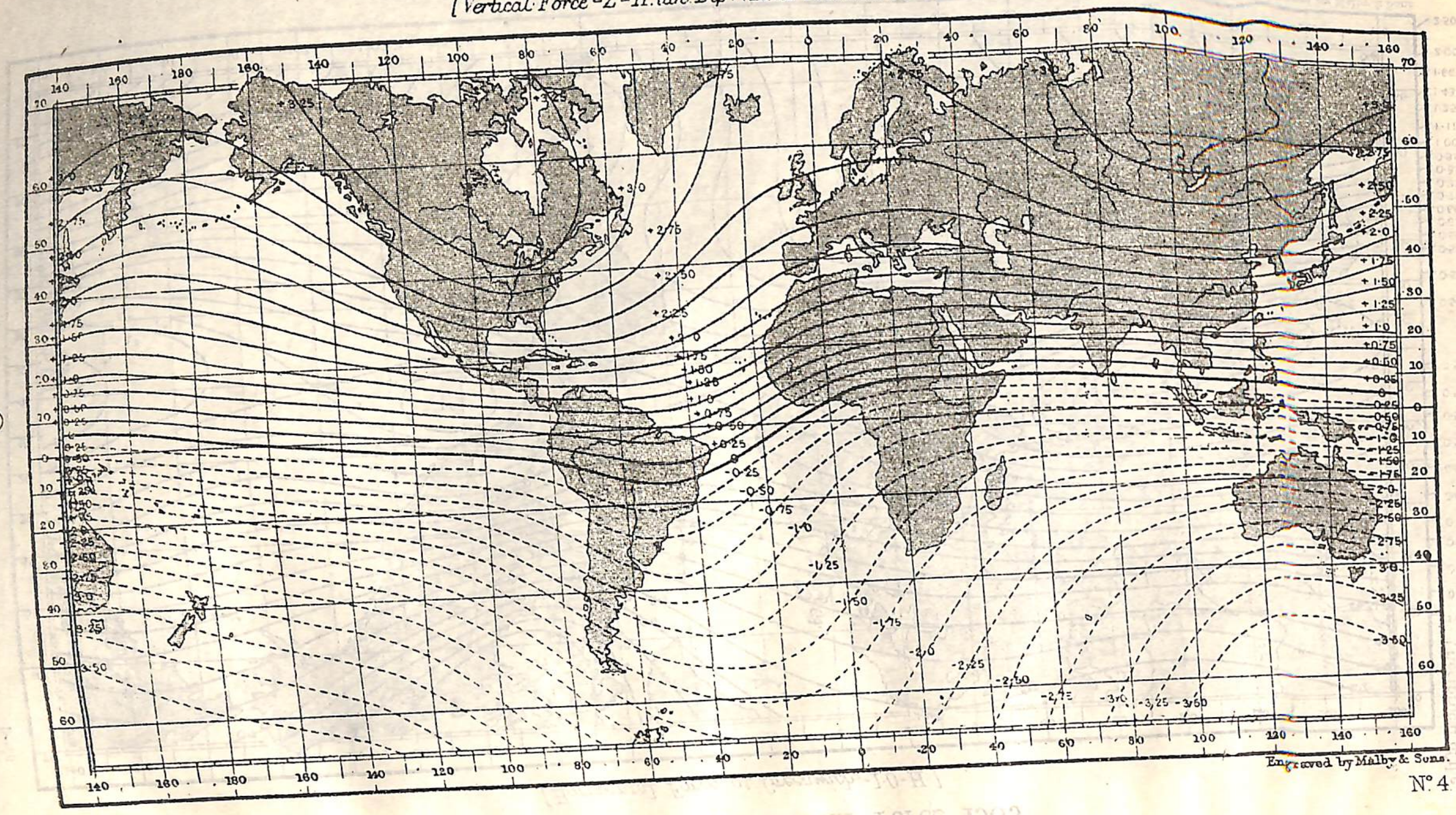
No. 3.

Lines of Equal Vertical Force 1905.

[Vertical Force = Z = H. tan. Dip (H. at Greenwich = 1·0)]



N° 4