

METHODS OF PLOTTING AND REDUCTION.

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I. - INTRODUCTION.

Hitherto it has been the practice to compute the altitude and azimuth of a celestial body either for a D.R. position or a chosen position in the vicinity of the D.R. position and to compare the computed altitude with the observed altitude, the difference (the *intercept*) being marked off along a line drawn in the direction of the computed azimuth from the position used for computing, either "from" or "towards" the object; a perpendicular drawn at the end of the intercept is the position line of Marcq St. Hilaire.

The time of observation and that for which the computation was made are either the same, or corrections are applied to make them the same. Further, it has always been the rule to keep the intercept short, if possible less than 60 n.m., in order to avoid error due to the position line being drawn as a straight line instead of a curve.

If the position line can be drawn correctly as a curve, the restriction on the length of the intercept may be relaxed with consequences which will be examined later.

2. - A NEW PROTRACTOR.

The Position Line Protractor has been constructed to enable positions to be obtained in which the intercept may amount to 300 n.m. or more, and the actual position may lie as much as 120 n.m. to one side of the computed line of azimuth.

The theoretical line of approach has been from the stereographic chart, using the horizontal stereographic projection, which has properties which are of importance in this problem in that the projections of great circles are very nearly straight lines, and that the projections of all small circles are other circles, the centres of which do not coincide with the projections of the original circles; also the scale is uniform for all practical purposes over the areas on any one sheet. Consequently, the circle of position to which the Marcq. St. Hilaire position line is a tangent (a useful approximation) will be a circle on the map, its radius being controlled by the scale of the map and the altitude of the body.

The protractor has been constructed to the horizontal stereographic projection to a scale of 1:3 000 000. The altitude circles are formed as slots through which a pencil can be run, and the slots are uniformly spaced at right angles to a central line of azimuth; at a suitable point on the line of azimuth is a small hole defining the centre of a circular scale of degrees, such that, when the hole is placed on a meridian, the circle reads against the meridian the azimuth of that end of the line of azimuth marked "towards"; the edges of the protractor parallel to the line of azimuth are scaled in nautical miles from 0 to 200 and 300 in opposite directions. The slots are about 120 nautical miles long on the scale and the altitudes represented have been selected so that the use of the slot named nearest to the observed altitude does not introduce an error exceeding 1 n.m. due to difference of curvature at a distance of 120 n.m. from the central line of azimuth. The protractor is not suitable for use on Mercator charts.

Unfortunately, the supply of charts and maps on the horizontal stereographic projection is practically non-existent, but the qualities of the projection required for

the protractor are present in maps made to the Lambert conformal projection ; consequently, the protractor may be used on maps made to the latter projection without serious error. The errors, as is usual in such cases, will be largest in high latitudes.

The following examples of the protractor's use with a Lambert conformal chart have been calculated on such a chart with standard parallels 63° N. and 77° N. :

Position	66° N. 25° E.	70° N. 16° E.
Chosen position	70° N. 30° E.	70° N. 30° E.
Body observed	SUN	DUBHE
Calculated altitude	32° $23'$	67° $13'$
Observed altitude	36° $20'$	71° $59'$
Intercept	$237'$	$286'$
Azimuth	S. 53° 4 W.	N. 71° $59'$ W.
Error	$1'$ approx.	$2'$ approx.

These errors do not exceed the errors of the bubble sextant or of the printing of the map, and are therefore of no significance. At lower latitudes they may be expected to be rather smaller.

The protractor is also suitable for use on the transverse Mercator projection which is expected to come into use on route maps.

The method of use is as follows :

- a. Place the protractor on the chart with the pinhole on the assumed position on a meridian.
- b. Rotate round the pinhole till the azimuth reads on the circle at the meridian to N. of the chosen position.
- c. Place a straight edge (or Douglas Protractor) against one of the long edges.
- d. Slide the protractor along the straight edge until the slot nearest the observed altitude is over the chosen position.
- e. Slide the straight edge till one corner or any convenient mark is opposite zero on the edge scale.
- f. Slide the protractor till the edge scale reads the intercept against the straight edge.
- g. Run a pencil along the slot nearest the observed altitude. This is an arc of the position circle.

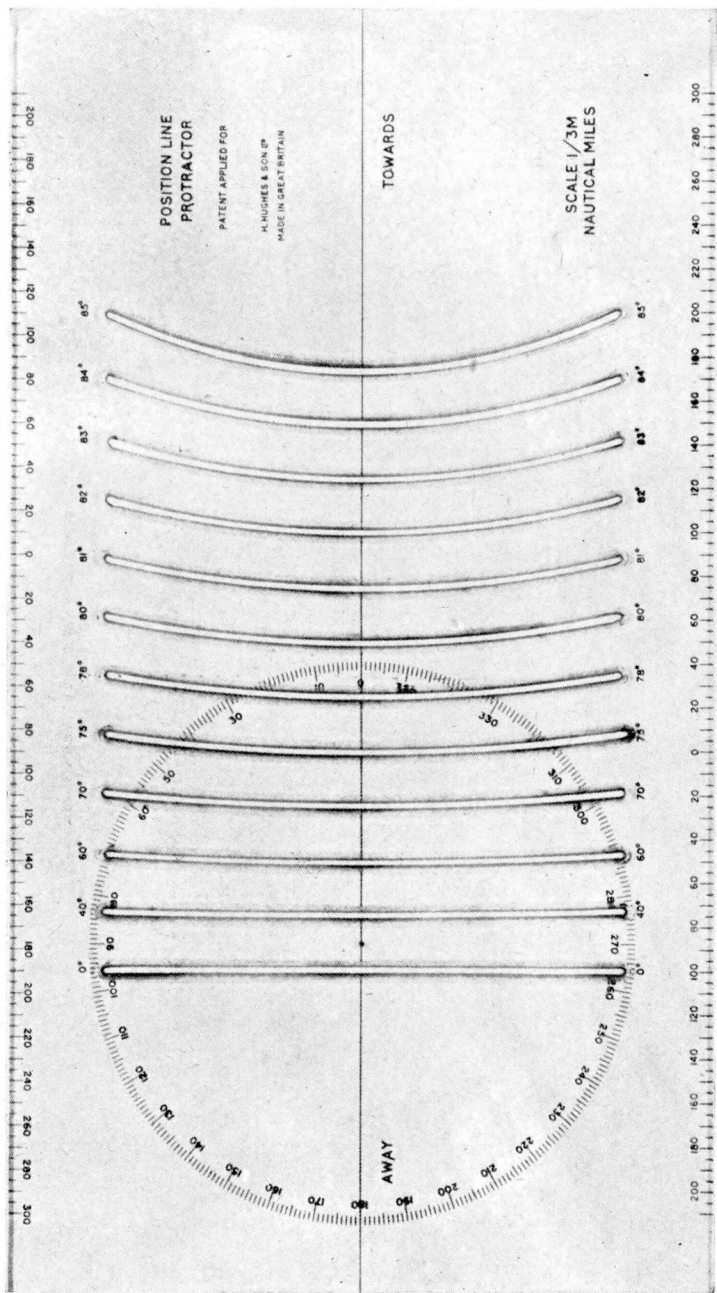
The protractor can also be used for radio bearings without having to apply correction for convergency. The bearing is merely set off from the position at which it is taken.

3. - EFFECT ON REDUCTION METHODS.

Using the protractor, position arcs can be drawn on the chart up to distances of 300 miles along the line of azimuth and up to 120 miles on either side, and these limits are capable of extension if required.

Examining the existing tables, such as A.N.T., H.O. 214, H.O. 249, etc., we see that these are constructed to a one-degree "mesh". This mesh can now be opened to three degrees, giving a ninefold reduction in bulk, so that 13 volumes of A.N.T. can be reduced to one volume of thickness half as much again.

Another advantage of the protractor's use is that the rather wearisome computing of altitudes and azimuths in the air can be transferred to the operations office on the ground, provided that the flight does not deviate from schedule by more than one to one-and-a-half hours. Transferring the computing work to the operations office would enable the work to be given to specially trained girls, in much the same way as other computing work, and also ensures its being carried out under more favourable conditions than when in the air. There is only one restriction ; it is an advantage for the computer to work to positions with integral degrees of latitude and longitude.



The Position Line Protractor.

Under the suggested scheme the air borne navigator or pilot navigator will :

- (i) Carry his own tables of much reduced volume to enable him to check any values handed to him, in case he has doubts as to their accuracy ;
- (ii) Observe his celestial objects within about 5 minutes of the G.M.T. for which he has been handed the computed altitudes and azimuths ;
- (iii) Correct his observed altitudes for
 - (a) ° difference of time,
 - (b) ° run during the difference of time resolved along the track ;
- (iv) Plot on a Lambert conformal or horizontal stereographic map or chart.

4. - ACKNOWLEDGEMENTS.

The assistance received from Messrs. Henry Hughes & Son, Ltd., who have made up a few of these protractors for trial, and also of Mr. R. W. Fish, M. Sc., on their staff, who was kind enough to compute the details of the circular slots on the protractor, is acknowledged.



(*) Tables for these corrections are given in A. N. J. T. and H. O. 249.