AZIMUTH TABLES, CHARTS AND DIAGRAMS FOR AZIMUTH DETERMINATION.

From articles by A. WEDEMEYER and K. SCHÜTTE
in the *Annalen der Hydrographie,* pamphlet XII, 1942, pp. 375 and 361.

By means of the sextant measuring of altitude h of a heavenly body, the three side of the position triangle : $\frac{\pi}{2} - h$, $\frac{\pi}{2} - \delta$ (the complement of the declination of the heavenly body), $\frac{\pi}{2} - \varphi$ (the complement of the latitude of the observing spot), may be known and it is possible to calculate the azimuth Az of the heavenly body. This measuring and this calculation, however, must be frequently repeated for the determination of the compass variation and that of the radio fix. Moreover, this measuring operation requires two people, one for measuring the altitude, the other to read off the compass.

It is more convenient now that chronometers give time with sufficient accuracy, to use tables or diagrams giving the azimuth directly in terms of latitude, declination and time.

John Burdwood in 1852 (1), subsequently J.E. and P.L.H. Davis in 1875, produced tables published in many editions, which give the azimuth for each degree of latitude, with accuracy within one minute of arc for each value of the vertical argument δ, from degree to degree, between $-23°$ and $+23°$, and of the horizontal argument t (true time) from 10 to 10 minutes.

The necessity of interpolating for the three azimuths, however, makes these tables inconvenient. It is moreover necessary to avoid small hour angles for which azimuth variation is too rapid.

Labrosse (Paris, 1868) also published tables for which he adopted the azimuth as a vertical argument, given from minute to minute. Such accuracy made them unserviceable.

Julius Ebsen's tables (Hamburg, 1896) were a great improvement. They gave the azimuths within 0°,1 for all latitudes between 0° and 70° and for all declinations from 0° to 29°. Interpolation was made easier and the volume of the tables was substantially reduced.

The fact that radiogoniometric bearings are more and more frequently used for fixing position and have the advantage of being resorted to even in thick weather, has brought azimuth tables into fresh favour. Those already in existence, however, were badly set out for such a purpose.

Captain Weir's diagram, published in 1890, transforms curves of equal azimuth into straight lines. His system which is made up of ellipses for parallels and hyperbolas for meridians, was mentioned by Karl von Littrow in his chorography, in 1868, as a conformal projection system (2). It is necessary to draw a straight line by means of a protactor on this diagram which is inevitably on a fairly small scale. This cannot be done with great accuracy on a paper which may have been warped and aboard a ship with inadequate facilities. Moreover, this diagram cannot be used in polar region. Still, another diagram has been obtained from it by inversion, which can be used in these regions.

In 1925, A. Wedemeyer gave new azimuth tables for the 15 largest radiobeacons in Europe and along the east coast of North America. He uses the azimuth from degree to degree as a vertical entry and, according to cases, with latitude as a horizontal entry, the difference in

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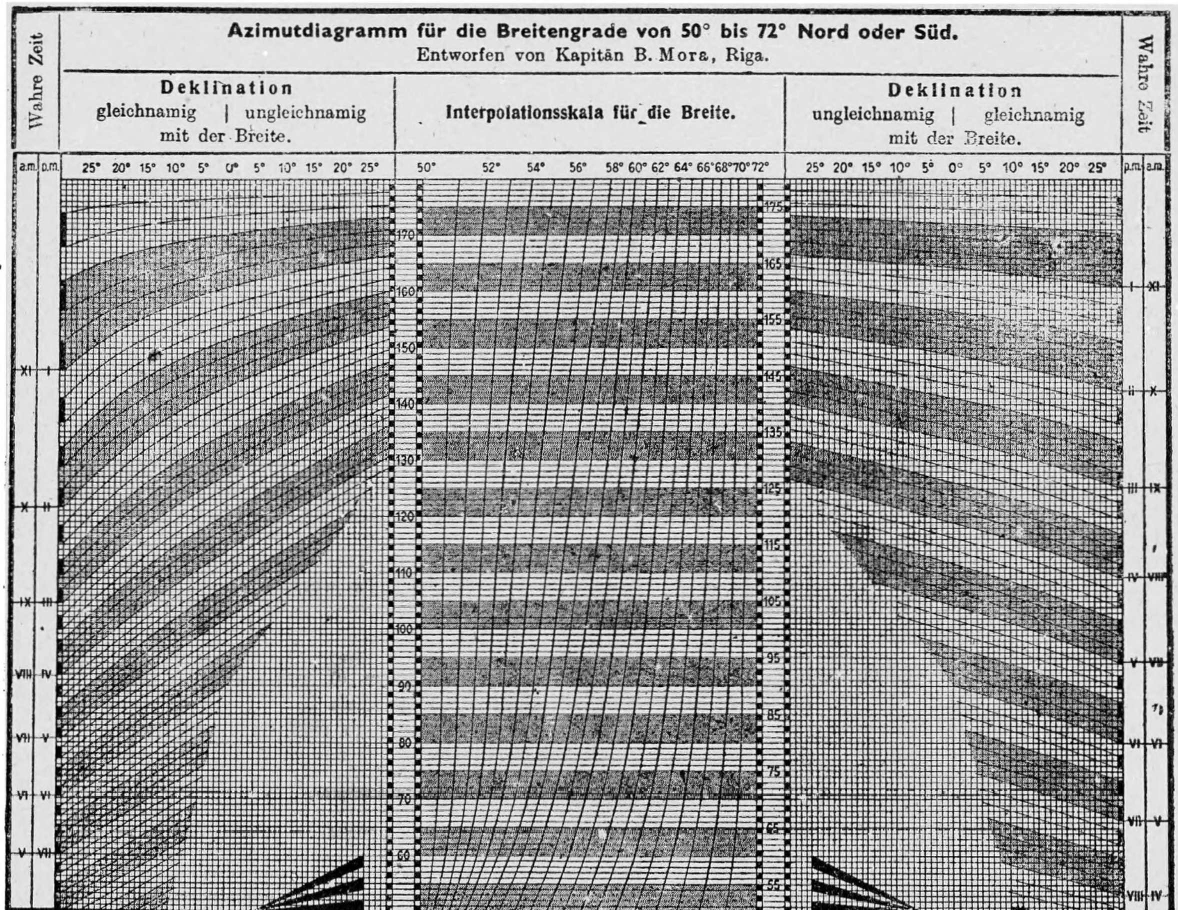
(1) THOMAS LYNN had published azimuth tables as early as 1829. (See : *Hydrographic Review,* n° XX, page 114.)

(2) See : A. WEDEMEYER, *Annalen der Hydrographie* 1918, p. 209. — W. IMMLER, *Annalen der Hydrographie* 1931, p. 462.
Hydrographic Review, vol. IX, n° 1, 1932, p. 251 ; vol. X, n° 2, 1933, p. 98 ; vol. XIV, n° 1, 1937, p. 61.

corresponding longitude, from minute to minute, or with the difference in longitude as an horizontal entry every other degree or from degree to degree, the corresponding latitude. In a more recent edition, the azimuth interval is only 0.1°, which does away with tiresome interpolations.

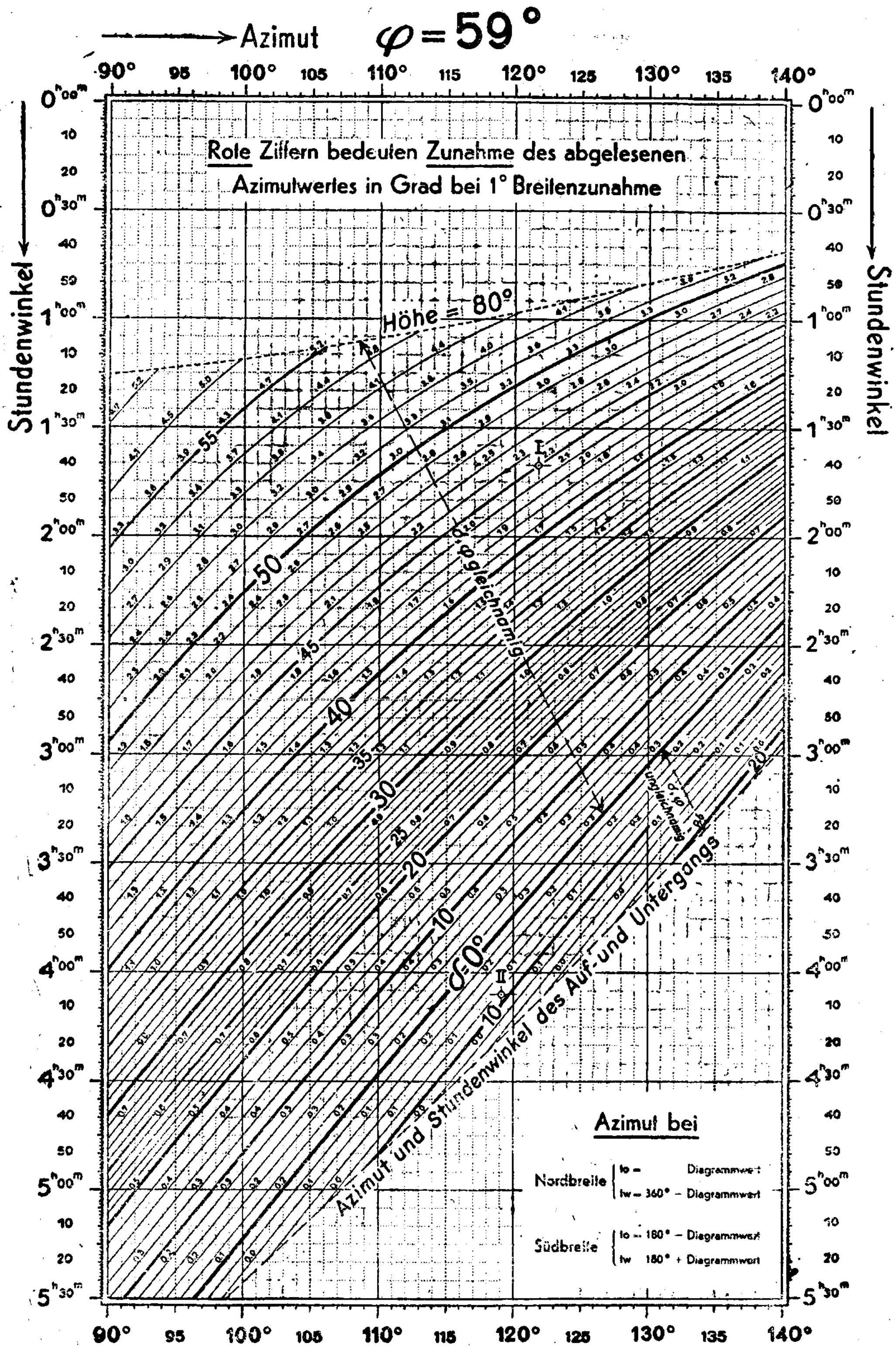
Many other tables or diagrams have been published, compiled or suggested ; they do not seem to have been quite satisfactory, in practice.

Captain B. Mora, a professor of navigation at Riga, constructed two diagrams, before 1914, which gave the azimuth within 1/2°. They are based on new principles and are a great improvement, which does not seem to have been sufficiently noticed. Interpolation being obtained by a new method, is made easy and paper warping is of no importance. One of these diagrams is designed for latitudes between 30 and 50° ; the other for latitudes between 50° and 72° (we only reproduce the second, after reducing it by half ; the darker portions are in yellow on the original). Each of these diagrams comprises three parts, the middle one being for latitude interpolation. If the latitude is between 30° and 50°, the azimuth for true time *t* and for latitude 30° is sought on the left part of the first sheet, by following the curves from time *t* up to their termination ; then, if necessary, by following a horizontal up to the inner part of column *a* in which the azimuth is entered.



The same procedure is followed for the right hand part of the diagram for the latitude of 50°, the azimuth being found in the inner part of column *b*. The two points obtained are joined by a straight line or by application of a ruler and the azimuth is read off on the horizontal of the point of intersection of the straight line or ruler with the curve corresponding to the latitude.

If the latitude is between 50° and 72°, the same procedure is followed with the second diagram.


Azimut
φ = 59°
90° 95 100° 105 110° 115 120° 125 130° 135 140°
Stundenwinkel
Rote Ziffern bedeuten Zunahme des abgelesenen Azimutwertes in Grad bei 1° Breitenzunahme
Höhe = 80°
φ, δ gleichnamig
φ, δ ungleichnamig
δ = 0°
Azimut und Stundenwinkel des Auf- und Untergangs
Azimut bei
Nordbreite
to = Diagrammwert
tw = 360° − Diagrammwert
Südbreite
to = 180° − Diagrammwert
tw = 180° + Diagrammwert

In the *Annalen der Geographie* for 1942, p. 361, K. Schütte, after considering the various diagrams which may be obtained by leaving constant one of the elements of the positions triangle, comes to the conclusion that the most favourable for giving the azimuth is the one in which φ is constant on each diagram and the declination constant on each curve drawn thereon ; the azimuth being shown as an abscissa and the hour angle as an ordinate. It is therefore the one which he selected. For each latitude in rounded off degrees ; the diagram comprises three parts whose first two are set out on opposite pages, the azimuths varying from 0° to 180° for hour angles of 0 h. to 6 hours. On the back of the sheet are found hour angles from 6 to 12 hours. Curves of equal declination are drawn every degree, except when they are too close, in which case a wider interval has been adopted. Hour angles can be read off at the minute of time. The diagram scale makes it possible to obtain the azimuth within 0.1°.

In order to facilitate interpolation between two latitude values differing by 1°, the author plotted in red, on the declination curves, the variation for a difference of latitude of 1°. These numbers, all positive, are to be added to the value of the azimuth for an increase of 1° of latitude.

There are no lines to be drawn on these diagrams ; the warping of the paper is therefore of no importance. They allow the solution of radiogoniometric bearings problems on board ship as well as ashore.

It generally happens that bearings have not been taken at the same time. It will therefore be necessary, before taking the intersection of two loci, to displace one of them in a direction parallel to itself, by a quantity corresponding to the distance run by the ship during the time elapsed between the takings of two bearings, as this is done when fixing position by two altitude position lines.

We reproduce herewith one page of K. Schütte's diagrams, on the same scale as the original.

P. V.