

**TABLES FOR AZIMUTHS, GREAT-
CIRCLE SAILING, AND
REDUCTION TO THE MERIDIAN,
WITH A NEW AND IMPROVED
"SUMNER" METHOD**

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T A B L E S
 FOR
AZIMUTHS, GREAT-CIRCLE SAILING,
 AND
REDUCTION TO THE MERIDIAN,
 WITH A
NEW AND IMPROVED "SUMNER" METHOD:

LATITUDES - - - - - 90° N. TO 90° S.
 DECLINATIONS - - - - - 90° N. TO 90° S.

Azimuths through Tables A, B, and C (or separately through Table D) for all the Heavenly Bodies at any Time the Body is above the Horizon; and Great-circle Sailing-courses for all Latitudes.

Also other Useful Navigational Tables, with Numerous Examples of
 Double Altitudes, Equal Altitudes, Azimuths, &c.

BY
H. S. BLACKBURNE (Extra Master),

Principal Examiner of Masters and Mates in New Zealand, and Nautical Adviser to the Government.

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PREFACE.

THE tables and problems here published are a reprint, for the most part of the azimuth tables which have been published in the first three years' issues of the "New Zealand Nautical Almanac."

Tables D and G are now reprinted and brought up to date from the writer's original tables published in 1883, and Tables A, C, and D have been extended from 60° to 85° of latitude. This will meet the needs of Arctic and Antarctic explorers, as well as the traders to such places as Archangel. Some years ago the writer promised Captain Liddle, who was then trading to Archangel, that he would extend his tables to latitude 72° to meet the needs of those trading in these high latitudes, outside the limits of the ordinary azimuth tables. With this extension they now constitute the most complete and comprehensive azimuth tables yet submitted to the seafaring community, giving with great simplicity sufficient accuracy to meet even the requirements of the extra-masters' examination. By the aid of Tables A, B, and C (when the hour-angle is known) the true bearing of the sun, moon, planets, and fifty-one of the brightest stars may be found in a couple of minutes at any hour of the day or night by the use of only about half a dozen figures.

As requests have been made from candidates for examination for permission to use these A, B, and C tables for solving some of the problems in the examination for masters and mates, and recommendations have been made for their use in the local examinations in New Zealand, these tables are now published separately, and, for the sake of giving the azimuth with greater precision for examination purposes, the factors are given in Tables A and B to three places of decimals when hour-angles are between four and eight hours, except in the very high latitudes, where so many decimals are unnecessary.

The comprehensiveness of the A, B, and C tables for azimuth purposes is simply marvellous. They cover only forty-two pages, and give not only all the azimuths of the above-mentioned heavenly bodies comprised in the four large tables of inspection (which cover several hundred pages), but also a considerable number of azimuths which are outside the limits of the larger tables. They are therefore especially valuable for use in the "Sumner" and "double altitude" problems, where the large azimuth tables omit to give the azimuth when the body is near either the upper or lower meridian. It was this omission (which is especially felt in low latitudes) which first led the writer to calculate and publish his original A and B azimuth tables. When the price of the large azimuth tables is taken into consideration (Burdwood's and Davis's for the sun, and Davis's and Goodwin's for the higher-declination stars), amounting altogether to £1 13s, the boon to navigators in the

price only, apart from the much greater extent of limit comprised in these small tables, must, I think, be recognized and appreciated by those who have only moderate means.

In the writer's old A and B tables the factors throughout were given to three places of decimals for the sake of being able to show that these tables would give the azimuth as accurately as the large tables of inspection. He has, however, often regretted having given the three places of decimals in the smaller hour-angles, as it makes interpolation at sight more difficult, and the azimuth is obtained with sufficient accuracy for practical purposes without it. In this edition three places of decimals have been given wherever necessary to give sufficient accuracy for examination purposes. Even in the Board of Trade extra-masters' examination any azimuth tables which give the azimuth correctly within half a degree may be used in the time-azimuth problem. These tables will nearly always give the azimuth correctly within 0.1° of the truth. To insure the most rigid accuracy in the second place of decimals, whenever the third place of decimals in the writer's old table came to 5 a fresh calculation has been made. In the parts where three places of decimals have been given, new calculations have been made and compared with the old tables.

In Table B all the stars not less bright than 1.0° magnitude have been computed separately for their actual declinations for the epoch 1910; and, as their annual change of declination is so small, these factors will be sufficiently accurate for all practical purposes for the next thirty or forty years, and no interpolation for declination will be needed.

The whole of Table C has been newly calculated on the lines of the late Mr. W. H. Rosser's table published in "Norie's Epitome," but this table (including latitudes to 85°) contains more than eight times the number of his computations, for the sake of giving greater accuracy and less interpolation. This plan will, I believe, be more popular with most navigators than that previously given in the writer's old table, as the azimuth is taken out more directly, and quite accurately enough for all practical purposes.

Tables A and B have been worked to five places of decimals where necessary, and Tables C and C², though only given to the nearest decimal of a degree, have been calculated throughout to the nearest decimal of a minute for the sake of accurate checking by differences.

Table D has also been checked from the writer's old calculations, and, where necessary, seven-figure logarithms have been used to determine fine points; otherwise, with the exception of changed heading and the addition of two pages, giving latitudes from 61° to 85° , it remains the same as when first published in 1883.

Table A, from latitude 61° to 82° , was calculated with great care by Captain Thomas Liddle, who very kindly sent to the writer the whole of his work. This was carefully compared by the writer with his own calculations. Throughout the compilation of the whole of these tables such minute care has been taken and rigid accuracy aimed at that the writer has good reason for believing that not one factor in a thousand will be found in the slightest degree in error.

An important feature in this work, which the writer believes he was the first to introduce, and which should prove a boon to navigators,

is the method here presented of working the "Sumner" problem on a plane chart in connection with these tables. This method is much shorter than that usually taught in the navigation schools in preparation for the Board of Trade examinations, and at the same time it gives greater accuracy, especially when the plan which is here advocated is adopted, of combining the ex-meridian and chronometer observations when one of the bodies observed is near the meridian; and it has the great advantage of only requiring one chart, instead of having to carry about "Sumner" charts for every change of latitude N. and S. of the Equator. The Marine Department of the New Zealand Government has published some very accurate charts on a convenient scale for this purpose.

As the request from the New Zealand Government to the Board of Trade to allow the use of these tables, and improved "Sumner" method for solving the "Sumner" and "double altitude" problems, in the New Zealand examination for masters and mates was not granted, two examples have been clearly worked and plotted on the chart (see pages 104 and 110)—one of two observations of the sun as given in the masters' and mates' examinations, and the other of observations of two different stars as given in the extra-masters' examination. These examples illustrate the possible errors that may arise from the old method. This error is especially aggravated in low latitudes, where in the summer months one of the altitudes must always be great, and often within half an hour of the meridian. The error in such cases would sometimes amount to 6 or 7 minutes of latitude. The summer months, too, in these latitudes are generally the rainy season, when double altitudes are most needed. We trust that after further perusal and trial of these tables and the methods here advocated the Board of Trade may see fit to alter their decision, especially as the tables are now printed separately from the "New Zealand Nautical Almanac."

Although the examples above mentioned are purposely exceptional ones, for the sake of better illustration, smaller errors will often arise if the method at present used by the Board of Trade for the masters' and mates' examinations is always adopted. Many an opportunity of determining the ship's position is lost owing to the impression among many navigators that the "Sumner" method is not of value when one of the observations is within, or a little outside of, the ordinary ex-meridian limits. At other times a false confidence is encouraged about the accuracy of the ship's position by trusting too implicitly to the latitude by ex-meridian following a chronometer observation for longitude, without due regard to the bearing when the first observation was taken.

An example from "Norie's Navigation" (the best-known epitome of navigation in the world) will illustrate both these contentions. On pages 368 and 369 of the 1900 edition an example is given of a longitude by chronometer at 8 h. 45 m. a.m., and an ex-meridian at 11 h. 30 m. a.m. At the close of the work the editor says, "Since by reference to the table, page 309, the hour-angle of the second observation is within the limits of the reduction to the meridian, it follows that the latitude found will be the *correct* latitude, unless the latitude and longitude used in the calculation are both very erroneous." He seems to have ignored the fact that when the first observation was taken the sun was not on, or even near, the prime vertical (and never is in the winter months in high

latitudes), and therefore the time resulting from this observation was more than 1 minute in error; and, although the sun was only $8\frac{1}{2}^{\circ}$ from the meridian when the second observation was taken, the resulting position was over 2' in error in the latitude and about $2\frac{1}{2}'$ in error in the longitude from the position given, and which the reader might naturally infer was correct. The editor afterwards goes on to say that "if the second observation had not been within the limits of the table on page 309, and the azimuth had been small, or if the estimated latitude and longitude had been very erroneous, neither the latitude nor the longitude could have been found with any degree of accuracy by the ordinary methods. Now what is termed the 'new navigation' may prove useful." As this closes the chapter in "Norie" on the "Sumner" method, in which is included the above-mentioned example of finding position by chronometer longitude and an ex-meridian, it is presumed that these are what are referred to as the "ordinary methods."

Now, the author maintains that if the "Sumner" method is dealt with in a practical way, either as advocated in these pages by numerous examples, or as given in the "American Practical Navigator," by Bowditch, revised by Lieut. G. W. Logan, U.S. Navy, the "Sumner" position will give quite as accurate results as by the method which is termed the "new navigation," and he ventures to believe that this method, too, will be easier for most men to grasp. He guarantees that he will take any of the double-altitude or simultaneous-altitude problems out of the numerous examples given in Captain Thompson's "Navigation Simplified" (which we may presume are fair specimens of the problems given at the Board of Trade examinations) and by the methods here presented, by the aid of these tables, either with or without the aid of a chart, will find the position of ship with similar accuracy to that obtained by the most rigorous methods of trigonometry, and well within the limit of accuracy required in the extra-masters' examination. His contention is that the papers set in the examination-room should above all things tend to make men better practical navigators, and he believes that any impartial judge must admit that the methods advocated in these pages for the "Sumner" problem are superior in many points to that which is at present encouraged by the Board of Trade examinations. The advantages may be thus summarized: (1) Greater accuracy; (2) fewer figures, and consequently less time required for the work; (3) one chart does for any navigable latitude; and (4) many observations which would be considered useless for the ordinary "Sumner" give excellent results with even fewer figures by combining ex-meridian and chronometer observations together, as illustrated in this work by various examples. Most officers pass the examination for master many years before they get command, and it is hardly to be expected that they will keep a supply of "Sumner" charts for the various latitudes that they trade in; consequently the practice of this method, which they have learnt for their examination, is sure to be neglected. The writer, speaking for himself, can testify that he never used it at sea, though, much to his regret, for more than ten years he has had to teach it or examine candidates in their knowledge of it.

Very shortly after the publication of the writer's first edition of the A and B azimuth tables the late Mr. W. H. Rosser published abridged A, B, and C tables for the same purpose, and afterwards slightly ex-

tended them for publication in "Norie's Epitome." They are excellent tables, and very concise, but even as enlarged in "Norie" require in most places considerable interpolation, the time-interval being sometimes 20 minutes and 30 minutes apart, which naturally could not admit of as much accuracy as a fuller table. A few years later Captain Lecky asked and obtained the writer's permission to publish the A and B azimuth tables in his famous "Wrinkles." Captain Lecky then extended and improved them, and later on published them in a separate book with further extensions and improvements, showing how the tables can be used for quite a number of navigational problems.

In closing, the author has much pleasure in acknowledging the kind help voluntarily tendered to him by Captain Thomas Liddle, and in thanking him for his disinterested labours in the calculation of much of the extension of these tables. But for his perseverance in continuing to urge the writer to extend his tables it is very improbable that they would ever have been published in their present revised form. He would also like to thank the Hon. Mr. Hall-Jones, Minister of Marine, and the New Zealand Government for valuable clerical assistance in the compilation of a portion of these tables, for the confidence they have reposed in him, and for their liberality and public spirit in the interest of navigation all over the world in thus publishing an extension of navigational tables far beyond the limits of New Zealand's own trade.

H. S. BLACKBURNE.

April, 1905.