THE MARINER'S PRACTICAL STAR FINDER (1).

by

CAPTAIN G. T. RUDE, U. S. COAST & GEODETIC SURVEY.

While navigator of a troop transport during the World War, the author conceived the idea of a graphic means of star identification to replace the ponderous identification Tables which at best are far from satisfactory; the Tables, furthermore, require observing by compass the bearing of the star at the time of observing its altitude by sextant. Navigators realise the difficulty of obtaining a star's bearing by compass even under conditions satisfactory for observing; this operation is rendered more difficult and at times even impossible when scudding clouds allow only time for observing the star's altitude.

Upon return of the author to survey duty at the close of the war, the choice of a suitable projection for such a purpose was discussed with Messrs. Charles H. DEETZ and Oscar S. ADAMS, coauthors of the U. S. Coast and Geodetic Survey Special Publication No. 68, *Elements of Map Construction*, which deals with the various kinds of projections. The stereographic projection, which is a conformal projection (2), was selected as the one best adapted to the purpose. The writter is further indebted to Dr. ADAMS for his assistance in arranging the projection to suit the problem involved and for his advice in the construction of the two types of stereographic projections used — the polar and the horizon.

The stereographic projection is one of the oldest recorded projections, dating to ancient Grecian times; it was used by HIPPARCHUS before the birth of Christ.

In this projection the eye is assumed to be at the surface of the sphere and in the hemisphere opposite the projection; that is, for the north polar projection of the star finder, the eye is supposed to be at the south geographic pole, projecting the celestial bodies on a plane tangent to the north geographic pole and vice versa. For the horizon projection of the identification templates for various latitudes, the eye is assumed to be at the surface of the sphere at the selected latitude of contrary name for which that particular projection is intended for use, projecting at five-degree intervals on a plane tangent to the opposite pole, the plane of the horizon and of the almucanter circle planes parallel to the horizon.

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(1) The patent rights to the "Mariner's Practical Star Finder" have been transferred by the author to the United States Navy and the device is now issued by the Hydrographic Office as the RUDE STAR FINDER AND IDENTIFIER.

(2) The term "conformal" implies that all angles between intersecting lines or curves are preserved; and that for any given point (or restricted locality) the ratio of the length of a linear element on the earth's surface to the length of the corresponding map element is constant for all azimuths or directions in which the element may be taken.

The results obtained from the use of this projection justified its selection; the accuracy of altitudes and azimuths, read by inspection from this device, compared favorably with computed values and is well within the limits of practical requirements. In addition, the fact that almucanter circles could be introduced admitted of identification by altitudes only. The use of almucanter circles also made possible another application of the instrument besides identification. This operation, which, for lack of a better term, may be called "star spotting", permits the easy determination of the locations of stars and planets in azimuth and altitude before they become readily visible to the unaided eye; the navigator is thus assisted in actually "spotting" the star in the sextant telescope and therefore able to obtain his observations before the horizon has become indistinct — immediately after sunset.

Two applications of the stereographic projection were employed — the polar projection on which the celestial bodies were permanently plotted by means of their right ascensions and declinations as tabulated in the "*Nautical Almanac*", and the horizon projection on which were projected the zenith of the observer, and azimuth and almucanter circles for the latitude of the observer. The two polar projections, one for each hemisphere, are printed on chart paper and mounted on heavy cardboard; the eleven horizon projections, one for each six degrees of latitude from the equator to latitude 66°, are printed with special ink on thin sheet celluloid.

By the locating of the zenith and meridian of the observer on the polar projection and the superimposing upon these of the zenith and meridian of the horizon projection, the two projections are combined in practice. The altitude and azimuths of celestial bodies for the terrestrial position of the observer may be determined by inspection from their relation to the azimuth and almucanter circles of the horizon projection which is constructed on transparent material.

Figure 1 illustrates on reduced scale the construction (1) of a horizon projection, eleven of which are required for the device. These have been called "Templates". The construction lines are shown broken; the full lines are of the projection itself. The construction illustrated is for latitude 63° and for illustrative purposes is only partly completed. The almucanter circles, the lower of which corresponds to 15° altitude, are shown completed; the lines radiating from the centre of the template are azimuth circles and the showing of the remainder of these circles would require the lengthening of line *L C* (line of centres) beyond reasonable limits for an illustration. This fact is obvious when consideration be given that the azimuth circles gradually approach the meridian line, which is a straight line and therefore has its centre for projection at an infinite distance.

In general, problems which lend themselves to solution by tabular values are also subject to graphic determination. The degree of accuracy obtainable is largely dependent of course upon the scale selected for the graph. A

(1) For explanation of the construction of stereographic projections and for a discussion of the theory and various problems of these projections, see U. S. Coast & Geodetic Survey Special Publication No. 57, *General Theory of Polyconic Projections*, Oscar S. ADAMS, Geodetic Mathematician.

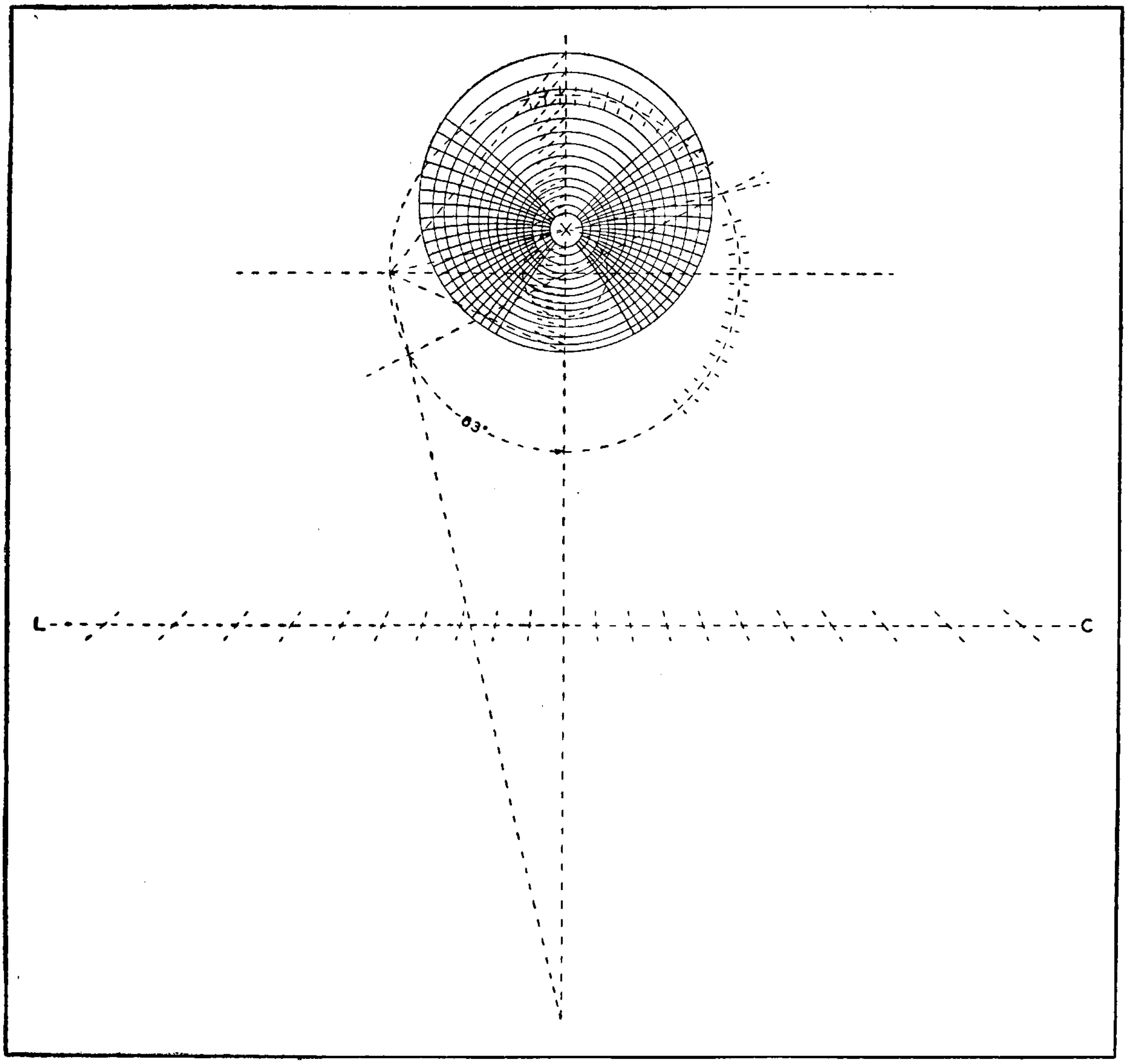
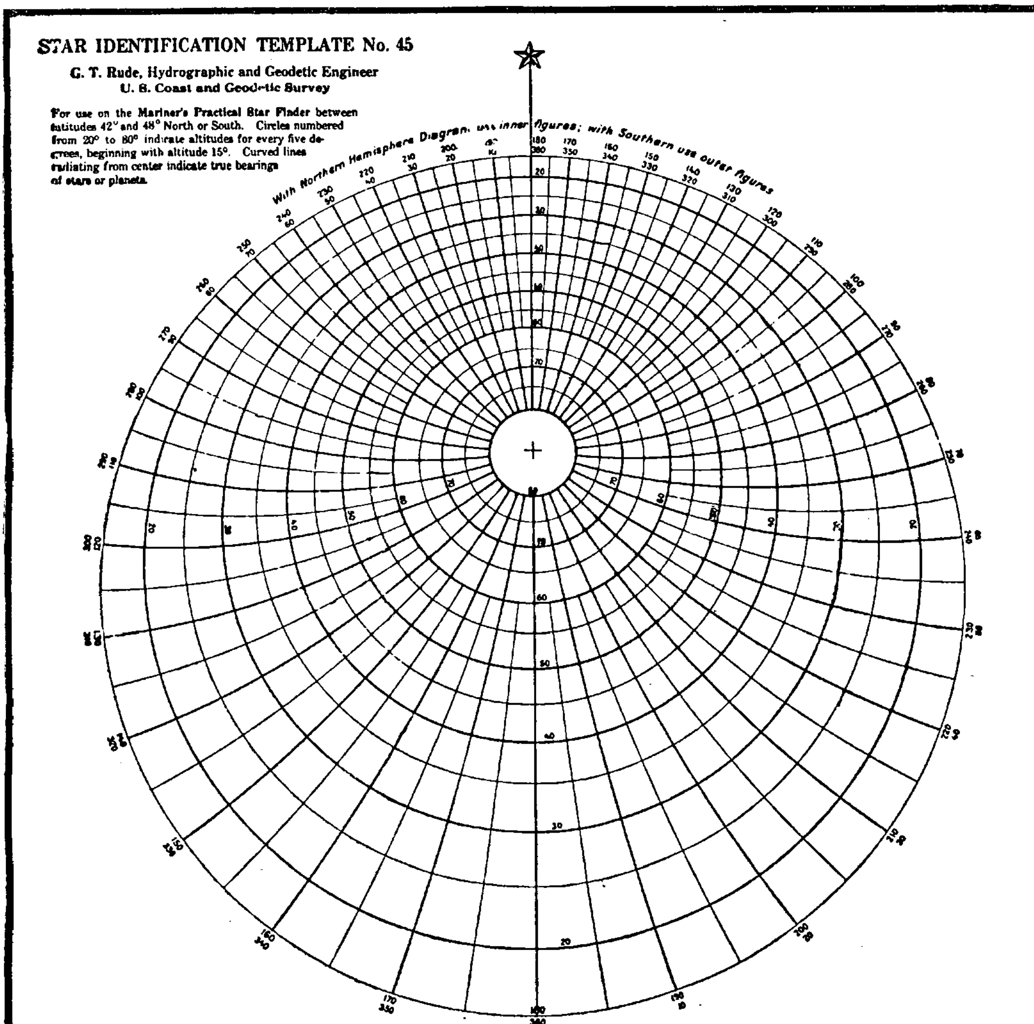


FIGURE I

diagrammatic solution has the advantage, too, of facility of use and further that the various steps are more easily understood; the diagram tends to transform an abstract problem into concrete form.

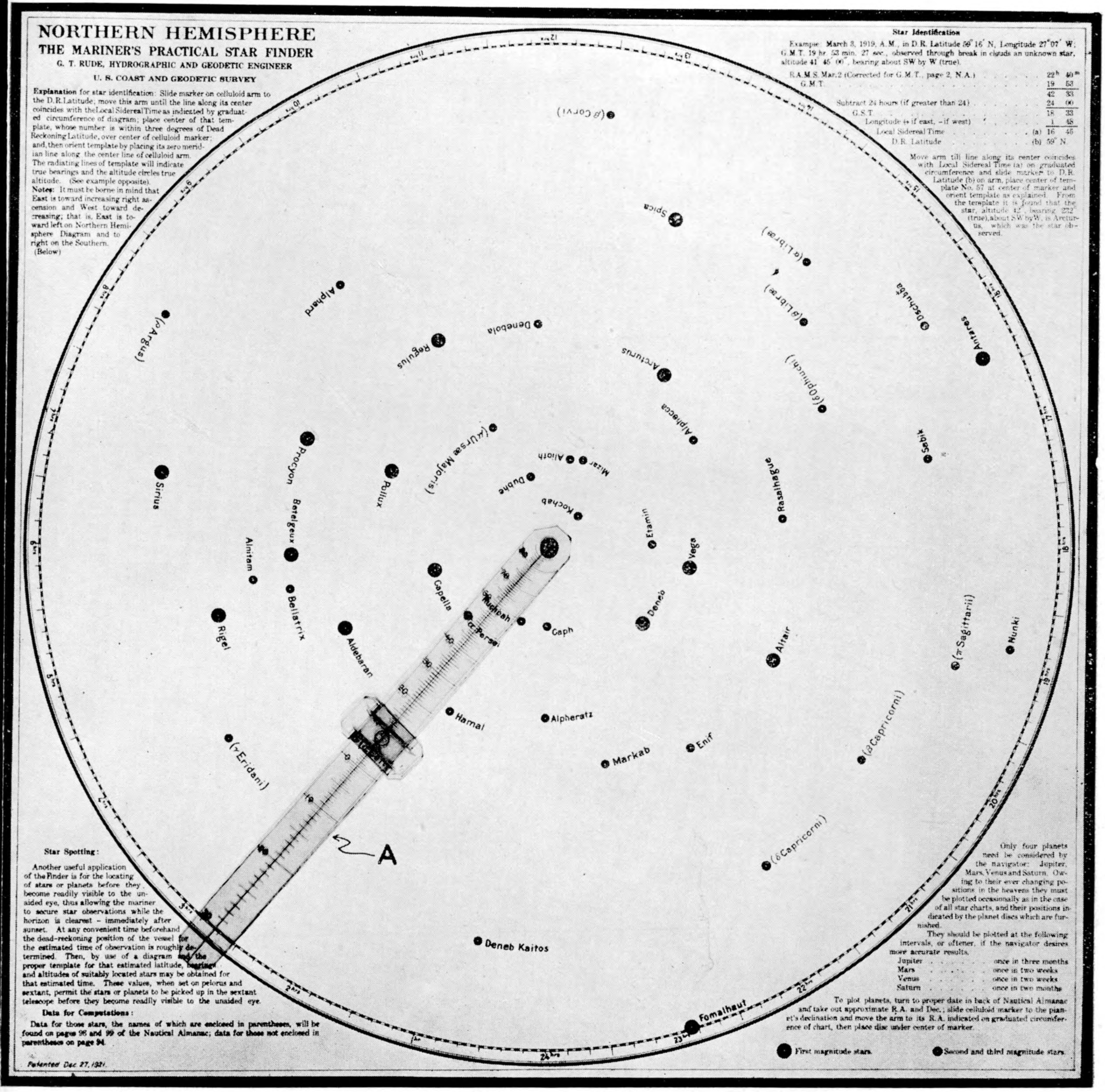
The original drawings of the projections of this star finder were made to an arbitrary scale, considered at the time more than large enough to furnish values of an order of accuracy sufficient for the purpose intended. Later, when preparing the projection for photographic transfer to plates for printing, the scale was decreased thirty-eight per cent to bring the projections to a scale so that the eleven templates could all be printed on a single sheet of stock size commercial celluloid twenty by fifty inches in size. The final scale proved ample for furnishing values of the necessary accuracy, with the accepted size of the polar projection sixteen inches square, a convenient size for practical use.

Figure 2 illustrates the polar stereographic projection of the northern celestial hemisphere reduced in size, extending from the celestial pole to declination thirty degrees south. To eliminate confusion in actual use, when combining the polar and horizon projections, the declination circles were omitted from the drawing of the former; the necessary graduations for declinations were supplied by means of a graduated revolving transparent arm (*A*, Figure 2). The periphery of the polar projection is graduated for right ascension in hours, subdivided into ten- and two-minute divisions. First magnitude stars, and some of second and third magnitude, are permanently plotted on this projection by means of their declinations and right ascensions. The planets are also plotted on the projection in a temporary manner as their movements, in their apparent wanderings in the heavens, require so as to have the accuracy furnished by the scale. For the southern hemisphere a similar projection is used;



Patent applied for

No. 45
Latitudes 42° to 48°
FIGURE 3



NORTHERN HEMISPHERE
THE MARINER'S PRACTICAL STAR FINDER
G. T. RUDE, HYDROGRAPHIC AND GEODETIC ENGINEER
U. S. COAST AND GEODETIC SURVEY
Explanation for star identification: Slide marker on celluloid arm to the D.R.Latitude; move this arm until the line along its center coincides with the Local Sidereal Time as indicated by graduated circumference of diagram; place center of that template, whose number is within three degrees of Dead Reckoning Latitude, over center of celluloid marker; and, then orient template by placing its zero meridian line along the center line of celluloid arm. The radiating lines of template will indicate true bearings and the altitude circles true altitude. (See example opposite).
Notes: It must be borne in mind that East is toward increasing right ascension and West toward decreasing; that is, East is toward left on Northern Hemisphere Diagram and to right on the Southern. (Below)
Star Identification
Example: March 3, 1919, A.M., in D.R. Latitude 59° 16′ N, Longitude 27° 07′ W; G.M.T. 19 hr. 53 min. 27 sec., observed through break in clouds an unknown star, altitude 41° 46′ 00″, bearing about SW by W (true).
R.A.M.S. Mar. 2 (Corrected for G.M.T., page 2, N.A.) 22h 40m
G.M.T. 19 53
42 33
Subtract 24 hours (if greater than 24) 24 00
G.S.T. 18 33
Longitude (+ if east, − if west) 1 48
Local Sidereal Time (a) 16 45
D.R. Latitude (b) 59° N.
Move arm till line along its center coincides with Local Sidereal Time (a) on graduated circumference and slide marker to D.R. Latitude (b) on arm, place center of template No. 57 at center of marker and orient template as explained. From the template it is found that the star, altitude 42°, bearing 232° (true), about SW by W, is Arcturus, which was the star observed.
Star Spotting:
Another useful application of the Finder is for the locating of stars or planets before they become readily visible to the unaided eye, thus allowing the mariner to secure star observations while the horizon is clearest – immediately after sunset. At any convenient time beforehand the dead-reckoning position of the vessel for the estimated time of observation is roughly determined. Then, by use of a diagram and the proper template for that estimated latitude, bearings and altitudes of suitably located stars may be obtained for that estimated time. These values, when set on pelorus and sextant, permit the stars or planets to be picked up in the sextant telescope before they become readily visible to the unaided eye.
Data for Computations:
Data for those stars, the names of which are enclosed in parentheses, will be found on pages 98 and 99 of the Nautical Almanac; data for those not enclosed in parentheses on page 94.
Patented Dec 27, 1921.
Only four planets need be considered by the navigator: Jupiter, Mars, Venus and Saturn. Owing to their ever changing positions in the heavens they must be plotted occasionally as in the case of all star charts, and their positions indicated by the planet discs which are furnished.
They should be plotted at the following intervals, or oftener, if the navigator desires more accurate results.
Jupiter once in three months
Mars once in two weeks
Venus once in two weeks
Saturn once in two months
To plot planets, turn to proper date in back of Nautical Almanac and take out approximate R.A. and Dec.; slide celluloid marker to the planet's declination and move the arm to its R.A. indicated on graduated circumference of chart, then place disc under center of marker.
First magnitude stars.
Second and third magnitude stars.
(β Corvi)
Spica
(α Librae)
(β Librae)
Dschubba
Antares
Alphard
(ρ Argus)
Denebola
Regulus
Arcturus
(θ Ophiuchi)
Alphecca
(μ Ursae Majoris)
Alioth
Mizar
Dubhe
Kochab
Procyon
Sirius
Pollux
Sabik
Rasalhague
Etamin
Betelgeux
Alnitam
Bellatrix
Capella
Vega
Deneb
Mirfak
α Persei
Caph
Rigel
Aldebaran
Altair
(π Sagittarii)
Nunki
Hamal
Alpheratz
Enif
Markab
(β Capricorni)
(γ Eridani)
A
(δ Capricorni)
Deneb Kaitos
Fomalhaut

Fig. 2.

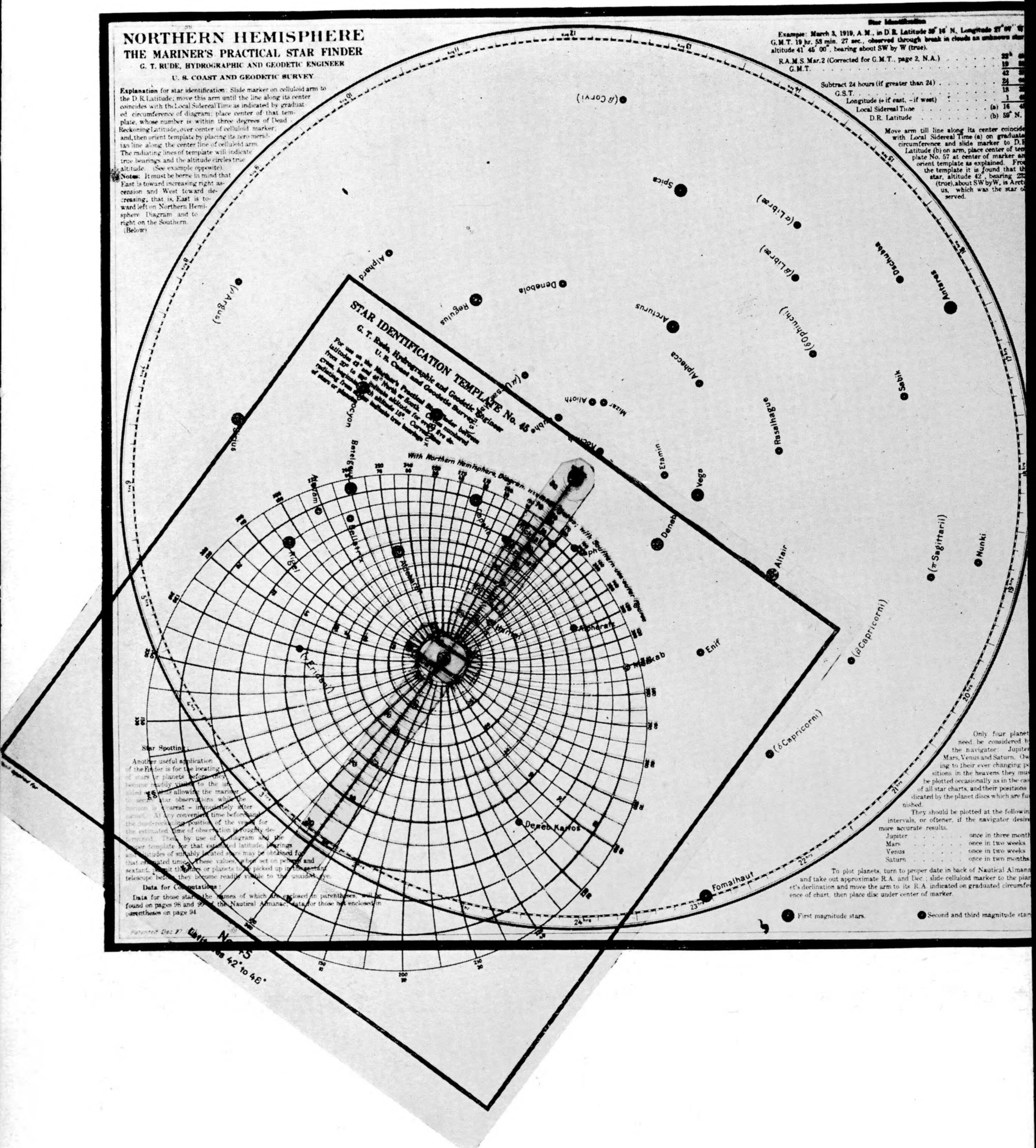

NORTHERN HEMISPHERE
THE MARINER'S PRACTICAL STAR FINDER
G. T. RUDE, HYDROGRAPHIC AND GEODETIC ENGINEER
U. S. COAST AND GEODETIC SURVEY
STAR IDENTIFICATION TEMPLATE No. 45
First magnitude stars.
Second and third magnitude stars

Fig. 4.

this projection extends from the south celestial pole to declination 30° North, thus allowing an overlap of sixty degrees of declination on the two projections.

Figure 3 is the stereographic horizon projection printed on transparent celluloid, constructed for latitude 45° N. or S. This particular template is used in practice between latitudes 42° and 48°; results of sufficient accuracy foı practical purposes are obtained three degrees either side of the parallel for which the template is constructed. Eleven such templates therefore are required to cover the earth between latitudes 66° N. and 66° S., for practical purposes the whole navigable world.

The cross near the centre, Figure 3, is the projection of the zenith of the observer; the "starred" straight line represents his meridian, the curved lines radiating from the central circle are azimuth circles for each five degrees, the heavier lines indicating the even tenth degree and the lighter five degree intervals; the nearly concentric circles numbered from 20° to 80° are almucanter or altitude circles, parallel to the horizon, for each five degrees, the even tenth degree being accentuated by a heavy line as with the azimuth circles.

In use (Fig. 4) a celluloid template for the latitude of the observer is superimposed upon the polar projection on which the celestial bodies are plotted; the azimuth circles of the template will indicate true bearings of these bodies for the position of the observer, and the altitude circles will indicate true altitude, starting with altitude fifteen degrees, which is the lowest almucanter circle constructed. If the position of the celestial body falls between the lines of the template, its altitude and azimuth may be readily estimated to the nearest degree. The figures at the extremities of the radiating azimuth lines indicate actual values of azimuth, the inner figures for the northern hemisphere and the outer for the southern.

The star finder furnishes with facility the following data for any dead reckoning position over practically the whole world : the azimuths of celestial bodies with ample accuracy for plotting MARCQ ST. HILAIRE position lines; furnishes in advance the approximate altitudes and azimuths for any given time of stars and planets ("star spotting"); shows the navigation stars and planets which will be visible at twilight or dawn, and identifies any star or planet, the altitude of which has been observed and its bearing roughly estimated only, without actual bearings by compass.

The templates furnish values of altitude and azimuth very close to computed or observed values when used on or near their parallels of construction; as departure is made by the observer from this parallel for which the template is constructed, the determination of altitudes and azimuths will differ generally not more than a degree from the absolute values, even when departure of three degrees in latitude is made from the parallel of construction.

For "star spotting" the probable dead reckoning position of the vessel for the estimated time of observation is roughly approximated; this may be done at any convenient time beforehand. Altitudes and azimuths of suitably located stars may then be read by inspection from the star finder for that estimated time. These values may be set on the sextant and pelorus and will bring the selected star within the field of the sextant telescope as it is trained on the horizon in the direction indicated by the pelorus.

For star identification, no compass bearing is necessary; the general direction of the body from the observer may be estimated. The identification is made absolute from the observed altitude by means of the almucanter circles of the horizon projection.