TECHNICAL MANUAL No. 1-206

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CELESTIAL AIR NAVIGATION

Prepared under the direction of the
Chief of the Air Corps

SECTION I

GENERAL

1. Purpose and scope.—*a.* The purpose of this manual is to provide in convenient form an elementary text on celestial air navigation.

290277°—41——1

is 57°33.1′ and the table is entered with a declination of 57°30′, the declination difference is 3′.1. Since Δd represents the change in altitude due to a change of 1′ of arc of declination, if Δd is multiplied by the declination difference, the correction to the altitude for declination is obtained. The table inside the back cover provides a means of multiplying Δd and declination difference by inspection. This correction is then applied with + or − sign to the tabulated altitude according to instructions previously given in *b*(3)(*e*) above, and the result is the correct H_c for arguments of integral degree of latitude, integral degree of LHA, and the *exact* declination of the body.

(6) *Example.*—Solution of the following problem is shown in figure 28:

(*a*) The navigator of an aircraft in DR position 25° 15′ N.–75° 13′ W. observed the star Betelgeux with bubble octant at $06^h\ 55^m\ 40^s$ GCT on January 1, 1941. H_s is 46° 49′; bubble correction 0′; altitude of airplane 5,000 feet. Required, the H. O. 214 solution for altitude intercept and clockwise azimuth; use Δd correction only.

(*b*) It will be noted that the above sight must be plotted from position 25° 00′ N.–75° 27′ W.

c. Advantages.—(1) Line of position solution is equally applicable to sights on all navigation bodies.

(2) Method is short and simple when only the Δd correction is used.

(3) Azimuths extracted from the tables are sufficiently accurate to use for aircraft compass swinging. No corrections are necessary. Although the assumed position may not coincide with the location on the earth where the swinging is to take place, the difference in azimuth between the assumed position body and actual position body may be disregarded. The navigator is justified in disregarding the error because it is insignificant when the body is low on the horizon as it must be for compass swinging. The assumed position can and should always be picked so that it is within 30′ of latitude and 30′ of longitude of the swinging location.

(4) Method of star identification is simple.

(5) Tables may be used to compute great circle course and distance. However, all three corrections, Δd, Δt, and ΔL are involved.

d. Limitations.—(1) Tables are bulky and consist of several large volumes.

(2) Existing volumes extend only to latitude 50° N. or S. Until the remaining latitude bands are published the method cannot be used in higher latitudes.

(3) Solution is inconvenient when worked with the DR position as the assumed position. Three interpolations are usually required to perform this operation. It is likewise inconvenient if the navigator

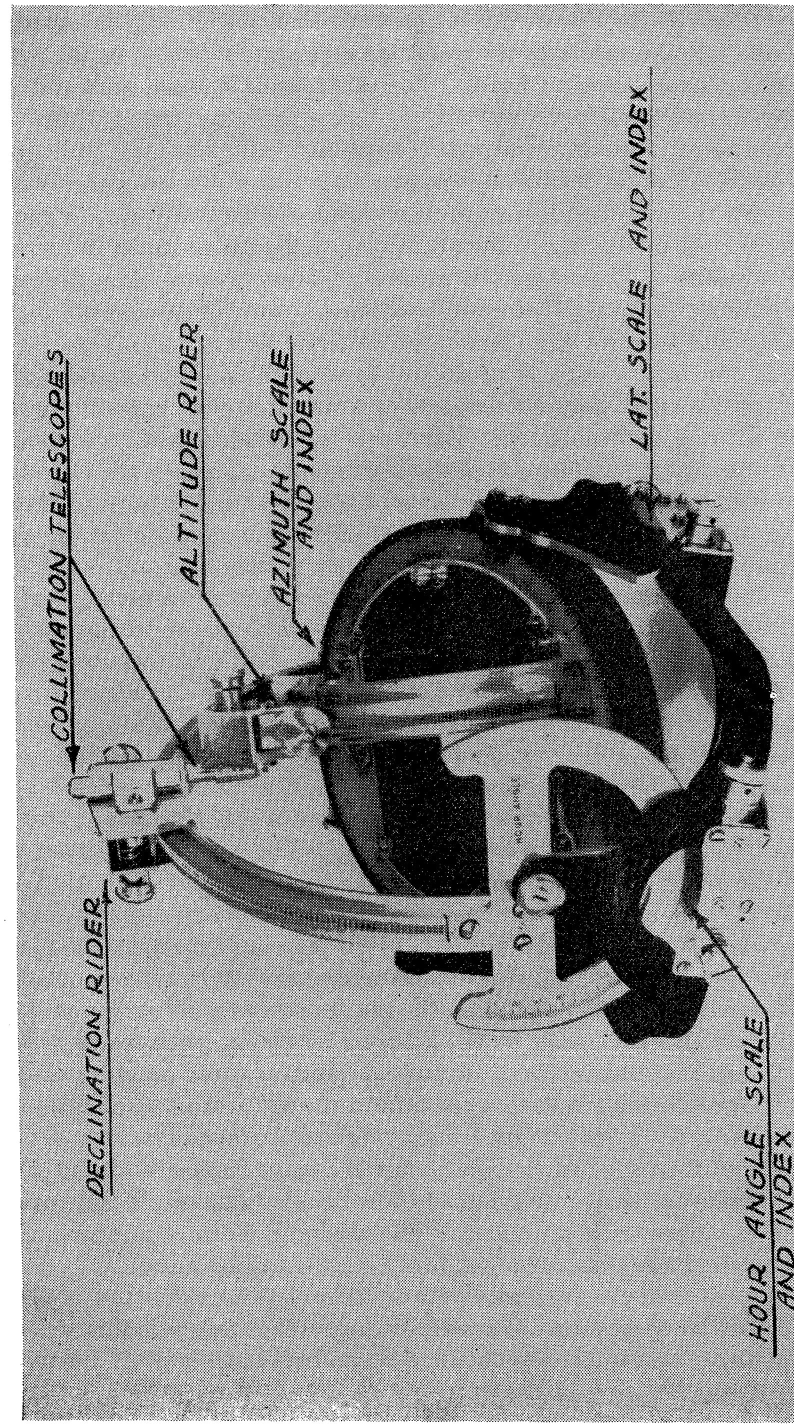

FIGURE 29.—Line of position computer, A-3 (Hagner).

desires to use as the assumed position any other place than that which is located on integral parallel of latitude and at a longitude which will give an integral degree of LHA. For this reason it is not well suited for precomputing altitude curves.

50. Line of position computer, type A–3 (Hagner) (fig. 29).—*a. Description.*—(1) The Hagner position finder is a mechanical device for solving the astronomical triangle without the necessity of reference books other than the Air Almanac. It actually reconstructs in metal the conditions that exist at the instant of observation. In addition to solving for a celestial line of position, it may be used as a star identifier and to work problems in great circle flying.

(2) It consists essentially of several arcs; each arc is provided with a degree scale and a micrometer scale for reading to the nearest minute of arc without interpolation. Each arc is provided with a locking device. In setting an element of the astronomical triangle, the locking device is unlocked and the scale set to the nearest degree or so. The locking nut is then locked and final adjustment made with the micrometer tangent screw.

(3) The center of the earth (observer) is considered as being at the center of the azimuth ring and the largest arc is used to represent the position of the body with respect to the zenith of the observer, that is, it represents the hour circle of the body. In addition to having a protractor scale at one end for the purpose of setting local hour angle, it has a declination scale and rider so that the position of the body on its hour circle may be set.

(*a*) The hour angle protractor is graduated so that hour angles to include 110° E. or W. may be set thereon. The hour angle index is fixed; the scale moves with the arc. The black scales on both the protractor and micrometer drum are used for setting easterly hour angles when the north pole is the elevated pole and the red scales for westerly hour angles. The scales are reversed when the south pole is the elevated pole. When reading the black degrees scale care must be taken to use the black scale on the micrometer drum; when reading the red degrees scale, the red scale on the micrometer drum must be used.

(*b*) The declination scale is graduated to ±60° so that declinations of same name or opposite name to observer's latitude may be set. The black scale is used when declination is the same name as observer's latitude; red scale if opposite name. The declination scale is fixed and the index moves with the rider. The declination rider is equipped with a telescope for use when collimating as described below.

(4) The latitude scale, graduated to 70° only, is used to set in the latitude of the observer's assumed position. It is not a double scale, red and black, as are the HA, declination, and azimuth scales. Setting

this scale sets the plane of the horizon which is the plane upon which the azimuth scale is engraved. The latitude protractor moves, the index being fixed.

(5) The altitude rider which travels along the altitude arc gives the altitude of the body. The altitude scale is a single one, graduated from 0° to 90°. The rider is equipped with a telescope for collimating with the declination telescope.

(6) The azimuth of the body is indicated on the azimuth ring. It is graduated from 0° to 180°, one half of the 360° circle being in black graduations and the other half in red. The micrometer drum is provided with red and black minute of arc graduations to match with the degrees scale. The index is fixed, the scale movable. A few later models of the Hagner computer have azimuth graduated to 360°. On these models the azimuth indication should be labeled with the name of the elevated pole and be considered as being measured clockwise in the northern hemisphere, counterclockwise in the southern. It corresponds to Z_n.

b. Orientating instrument.—No confusion will arise as to whether to set the various elements on a red or black scale if the instrument is oriented so that the axis of the LHA arc is placed with the protractor end pointing at the elevated pole of the observer. Then to set off an hour angle the HA arc will be swung toward the position the body occupies in the heavens and the proper scale will be indicated by visual inspection of the HA protractor. If working in the northern hemisphere and the body's declination is N., the declination rider must be set on that part of the declination scale which lies between 0° and the protractor end of the HA arc; if the declination is S. and the elevated pole is north, the declination rider must be moved so that the scale between 0° and the opposite end of the axis is used. If the elevated pole of the observer is the south pole, south declinations will be set off between 0° and the protractor end of the hour angle axis; north declinations toward the opposite end of the axis. The degrees and minutes indicated on the azimuth scale are labeled to conform to the elevated pole and the hour angle; thus, if the elevated pole is the north pole and the HA is east, the azimuth will be N. so many degrees E.

c. Use.—The two ways in which the instrument may be used to solve the celestial triangle are first, solution by assuming both latitude and longitude, and second, solution using H_o and assumed latitudes or longitudes.

(1) *Solution for line of position by assuming both latitude and longitude.*—(*a*) Observe body, note GCT, correct H_s to obtain H_o, and extract GHA and declination of the body from the Air Almanac.

(*b*) Select an assumed position; it may be the DR position or one near it.

(*c*) Find LHA of the body for the assumed longitude.

(*d*) Set this LHA on the HA scale.

(*e*) Set declination rider to the declination.

(*f*) Set assumed latitude on the latitude scale.

(*g*) Two elements remain which have not been set, altitude and azimuth. These are the two unknowns for which the solution is being made. These elements are procured by moving the azimuth circle and the altitude rider until the altitude and the declination telescopes are collimated. Collimation is effected when the two engraved circles seen through the telescopes are exactly concentric. Do *not* move the HA, the declination, or the latitude verniers when collimating.

(*h*) When collimation is effected, read on altitude scale the computed altitude H_c of the body as it appears from the assumed position.

(*i*) Read the azimuth from the azimuth ring.

(*j*) Compare H_o and H_c for the intercept and plot line of position from the assumed position in the orthodox manner.

(2) *Solution for line of position using H_o and assumed latitudes or longitudes.*—By this time, it will be seen that if any three elements of the triangle are known or are assumed and set into the computer, the other two elements may be solved by collimating the telescopes provided the collimation is effected by adjusting the two remaining scales only. In the method about to be described, the points where the observer's actual position circle intersects two whole degree parallels or two whole degree meridians near his DR position are found. These intersections definitely fix the direction of the position line. In this method the azimuth is not recorded, although the azimuth ring is used to effect collimation as will be seen.

(*a*) Observe body, note GCT, correct H_s to obtain H_o, and extract the GHA and declination of the body from the Air Almanac.

(*b*) Keeping in mind that the position circle is perpendicular to the bearing of the body, estimate whether the position line when plotted will run more nearly east and west, or more nearly north and south. If the position line will run east and west, select two whole degree meridians in the vicinity of the DR position; if the position line will run more nearly north and south, select two whole degree parallels near the DR position. If the direction of the body is such that it appears that the position line will cut the meridians and the parallels obliquely, say at an approximate 45° angle, select either two whole degree meridians or two whole degree parallels. It does not matter which are chosen.

(*c*) *If two whole degree meridians have been selected.*—Compute the LHA of the body with respect to each of the meridians, combining the GHA of the body with the longitude of each of the meridians in turn. Now set up the Hagner computer as follows: set in either of the two above computed LHA's, set declination, set H_o on altitude scale. Collimate the telescopes by varying the azimuth and latitude scale settings. When collimation has been effected, read on the latitude scale the latitude at which the position circle will intersect the meridian whose LHA was used in setting up the computer. Mark this point on the chart. Leaving declination and the altitude settings undisturbed but changing LHA setting to read the LHA which was not used in the first set-up, again collimate by adjusting the azimuth and latitude scales only. Read on the latitude scale the latitude at which the position circle will intersect the meridian whose LHA was used in setting up the computer the second time. Mark this point on the chart. Draw a line through the two marked points. This is the position circle.

(*d*) *If two whole degree parallels have been selected.*—Set up the computer as follows: set in either of the whole degree latitudes, the declination and H_o. Collimate by moving only LHA and azimuth scales. Record the LHA. Now set in the other whole degree latitude and recollimate by moving LHA and azimuth scales only. Record the second LHA. Now combine each of the LHA's with the GHA of the body as extracted from the Air Almanac to find at which longitude the line of position will cut each of the parallels which was assumed in setting up the instrument. Mark each of the longitudes thus determined on its proper parallel and draw a straight line through the two points. This is the line of position.

(*e*) Analysis of the foregoing procedure will make it apparent that whole degree latitudes or longitudes need not have been assumed. Any two latitudes or any two longitudes in the vicinity of the DR position would have served the purpose. The whole degrees are used for convenience only.

(*f*) The reason for estimating the direction in which the position line will run is as follows: assume that a body bears north and by mistake it has been chosen to find where the position circle will cut two whole degrees of latitude. Since the resultant position line will run generally east and west, it is apparent that the two parallels will be intersected by the position line at two widely separated longitudes. In fact, it is entirely possible to have one or both of these intersections fall off the chart, in which case the point or points cannot be plotted. Furthermore, even though the intersections fall on the chart, the position line itself will not be as accurate as would be the case if the whole degree of longitudes had been selected. This is due to the fact that when the computer is set up the wrong way (that is, assuming latitudes by mistake), the hour angle arc must be moved through several minutes of arc before any change in collimation is perceptible. Hence it is difficult to know just what position of the HA arc is the correct one. Similar plotting and collimation difficulties will result if whole degree longitudes are selected when the body bears to the east or west.

(*g*) When solving for a line of position using H_o and assumed whole degrees of latitude or longitude, there are two possible solutions for each set-up of the finder. This is due to the fact that every parallel passing through the circle of position is a chord of the circle and will intersect the circle twice. Likewise, two intersections fulfill the conditions when a meridian is assumed. A knowledge of the approximate DR position of the aircraft will indicate the proper solution, as one of the intersections usually will be at least several hundreds of miles away from the DR position.

d. Operation, handling, and maintenance.—(1) It is highly desirable that the navigator adopt proper methods of handling the Hagner position finder. Some difficulty may occasionally be experienced when seating the worm drive of the micrometer verniers in the respective teeth of their arcs. This occurs when the worm drive has been lifted completely from the arc teeth for an approximate or "rough" setting. When this occurs, under no condition must the worm drive be forced to seat with the drive resting on the arc teeth. It is obvious that any attempt of this kind may result in injury to the parts concerned and consequently impair accuracy of the instrument. A slight shifting of the arc or rider with the worm drive lifted will almost immediately result in proper engagement. If care is taken to set the reference index on riders between the degree marks on the arcs when making a rough setting, the possibility of jams will be practically eliminated.

(2) Setting of arc riders should be accomplished by pushing them in the desired direction. These are all important in the final alinement of the finder and therefore under no circumstances must any undue force be applied that would tend to offset their optical centers.

(3) All moving parts of the finder are machined with maximum precision, and therefore a firm, even pressure will insure easy settings.

(4) Before replacing the position finder in its case, the arcs, ride[illegible] and the azimuth plate must be set at 0° values (90° for altitude [illegible] This will insure proper suspension of the instrument by its bas[illegible] eliminating any possibility of stress on the arcs themselves. [illegible] of the finder should be grasped firmly in both hands and the [illegible]

ment inverted and set carefully in its cradle. Under no condition should the instrument be lifted by either the altitude or HA arcs. If either of the aforementioned arcs are compelled to support the weight of the computer (10 pounds) for any length of time, their precise curve will be subject to distortion which will affect the accuracy of their relationship and consequently the perfect alinement of the riders.

(5) An occasional application of a slightly oiled cloth to the unpainted portions of the finder will insure protection against oxidation, preserve its neat appearance, and facilitate operation of the instrument.

(6) Due to dust or dampness, the optical system of the finder may require an occasional cleaning. This should only be done with a good grade of clean chamois or a well-washed linen handkerchief. Particular care should be exercised when cleaning the objective or altitude lens to avoid possibility of applying pressure that may tend to affect its precise alinement with the rest of the instrument. When cleaning, the slight pressure required should be parallel to the surface of the lens rather than against it.

(7) Good common sense in handling the instrument is all that is required. Its accuracy will be maintained indefinitely if reasonable care is taken while handling and using the instrument.

(8) Obviously, adjustment of the instrument may be checked by working an Ageton or H. O. 214 solution of a typical problem, and then setting the same problem on the computer. The solution by Hagner should be correct to within ± 2′ or 3′ when the verniers are carefully set.

e. Advantages.—(1) Solution is equally applicable to all celestial bodies.

(2) No arithmetical calculations are necessary except for LHA. The only book necessary is the Air Almanac.

(3) Line of position may be solved using DR position or any other assumed position near it.

(4) Unknown stars may be identified quickly.

(5) Great circle courses and distances may be computed rapidly.

(6) Permits an LOP to be found without using any altitude intercept (the method described in *c*(2) above).

(7) Is very useful when precomputing altitude and azimuth curves.

(8) Gives a graphic portrayal of celestial triangle, hence it is an [illegible]cellent classroom device.

[illegible] *Limitations.—(1) Will not solve the astronomical triangle when [illegible]bserver's latitude exceeds 70°, when the LHA of the body is [illegible]han 110° nor when its declination exceeds 60°.*

[illegible]nconvenient to operate in flight. The scales are difficult to [illegible]ad, especially in a poorly lighted navigator's compartment.

When setting the scales, consideration must be given as to whether to use red or black scale and micrometer readings. The micrometer drums often develop considerable back lash, that is the tangent screws can sometimes be rotated through several minutes of arc without affecting collimation.

(3) Is a precision instrument and subject to derangement if mishandled.

(4) Is difficult to operate in flight.

(5) Is heavier and bulkier than tables.

(6) No written record of the solutions remains for a later check.

(7) Is more expensive than tables.

51. Line of position computer, type A-4 (Fairchild-Maxson) (fig. 30).—*a. Description.*—(1) The A-4 computer is a mechanical computer for solving the astronomical triangle. The formulas upon which the mechanical solution is based are old ones; it is in the ingenious method by which these formulas are solved by a system of cams, grooves, and gears that the device is unique. The computer does not solve the triangle for azimuth and the known azimuth of a body cannot be set into the instrument. The line of position is orientated by finding where the position circle cuts two parallels of latitude or two meridians in the vicinity of the DR position. In this respect, the general procedure is similar to that which has been described for computing an LOP by Hagner using H_o and two assumed latitudes *or* longitudes as entering arguments.

(2) As is true of other methods, it will compute problems in great circle flying and may be used for star identification.

(3) The Air Almanac data for the sun are fed into the computing mechanism from a cam on which are cut the data for a 3-month period. The cam with its cam followers and accessory gearing is mounted in a subunit, four of which are supplied with each instrument, one being mounted on the computer proper and the other three supplied in individual containers each marked with the quarter and year to which it applies. This subunit is called the *quarterly almanac;* it is not to be confused with the Air Almanac. Provision is made in the carrying case for storing the computer with current unit and one extra unit.

(4) Figure 30 shows the face of the instrument with the operating controls numbered for reference.

(5) The computer can solve for lines of position for all latitudes north or south, for all longitudes east and west, using bodies of any declination north and south, and with right ascensions from zero to 24 hours.

(6) For problems involving fixed stars, planets, and the moon, the declination and right ascension of the observed body are set on the

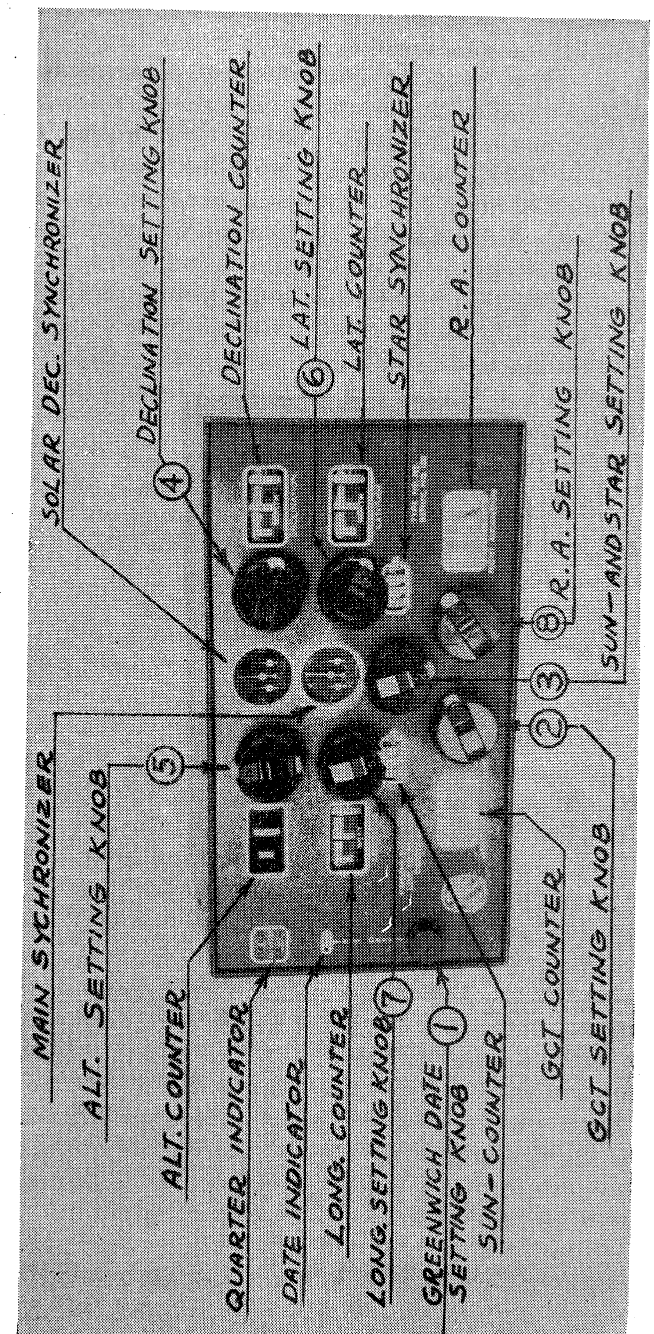

FIGURE 30.—Line of position computer, A-4 (Fairchild-Maxson).