SECTION 3

CELESTIAL

REMEMBER—THE PROPER EXECUTION OF CELESTIAL NAVIGATION DEPENDS MORE UPON THE SKILL OF THE NAVIGATOR THAN ANY OTHER FORM OF NAVIGATION.

MOTIONS OF HEAVENLY BODIES

Solar System

The whole solar system is moving through space as a unit. While this motion is rapid as compared with the individual motions of the earth and other planets, it is slow in relation to the great distance from the solar system to the stars.

Although the stars have motion in relation to each other, they are at such great distances from the earth that their movement is imperceptible and their positions are considered fixed.

The Sun

The sun is a star whose axis revolves in a small orbit only 280 miles in diameter. This is an insignificant distance when compared with the distance of the planets from the sun, and the sun is considered fixed in relation to the earth and the other members of the solar system.

The Planets

The planets, of which the earth is one, rotate on their own axes and revolve around the sun.

The orbits of all planets lie nearly in the same plane, the maximum inclination being about 23°. The earth has a rotation from west to east on its polar axis once each day. The earth also revolves in a counter-clockwise direction (as viewed from the north) in an elliptical orbit around the sun.

The plane of the earth's equator is inclined at an angle of 23° 27′ to the plane of the earth's orbit. This inclination of the earth's axis causes the four seasons of the year.

The other planets are divided into the two general classifications of superior and inferior planets. The inferior planets are so named because their orbits are closer to the sun than that of the earth. Those farther away are called superior planets.

The Moon

Of the satellites which revolve around the planets, the only one of interest to navigators is the moon, which revolves around the earth. It is the only heavenly body relatively near the earth (average distance 239,000 miles). It gives no light except the reflection of the sun's rays. The moon in its orbit around the earth moves to the eastward and therefore moves in opposition to the rotation of the earth. Thus it is that the moon rises approximately an hour later on each succeeding night.

CELESTIAL DEFINITIONS

CELESTIAL AIR NAVIGATION IS THE ART OF DETERMINING THE POSITION OF YOUR AIRPLANE BY THE AID OF CELESTIAL BODIES

The zenith (Z) of an observer on the earth's surface is the point on the celestial sphere directly overhead. **The nadir** is the point on the celestial sphere directly beneath the observer.

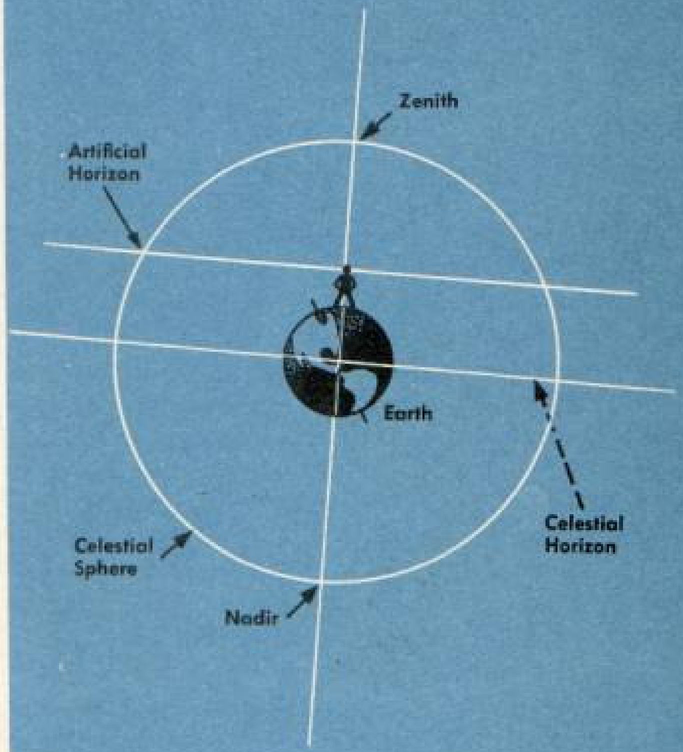
The celestial horizon is the great circle of the celestial sphere formed by passing a plane through the center of the earth perpendicular to the straight line joining the zenith and nadir. The celestial horizon is different from the **visible horizon,** which appears to mark the intersection of the earth and sky. The difference between the celestial and the visible horizon arises from two causes:

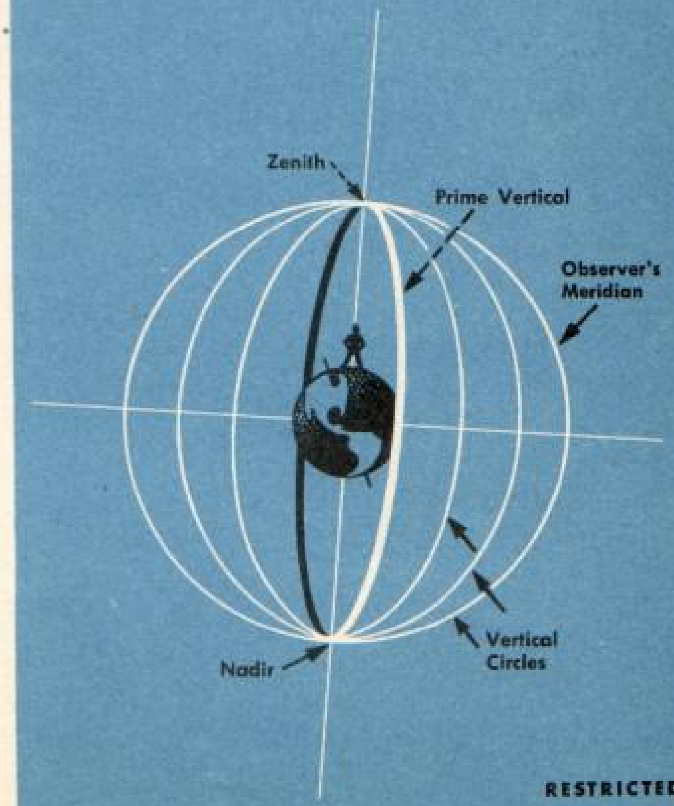
a. Your eye is always elevated above sea level. This gives you a range of vision exceeding 90° from your zenith. This range of vision exceeding 90° is called dip of the horizon.

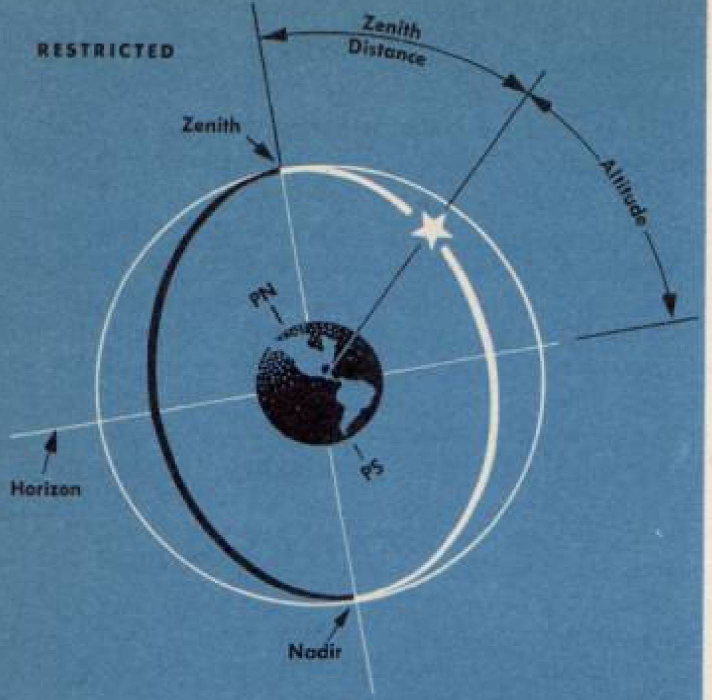
b. Your actual position is on the surface of the earth instead of at its center where the celestial horizon passes through the earth. This difference in horizon is called parallax.

An artificial horizon is the true celestial horizon determined by some mechanical device such as the bubble in your sextant. This is the horizon used in aerial navigation because the visible horizon is of no value to you. The artificial horizon is always assumed unless otherwise qualified.

Vertical circles are great circles of the celestial sphere which pass through the zenith and the nadir. Your **prime vertical** is the vertical circle whose plane is at right angles to the plane of the meridian on which you stand.

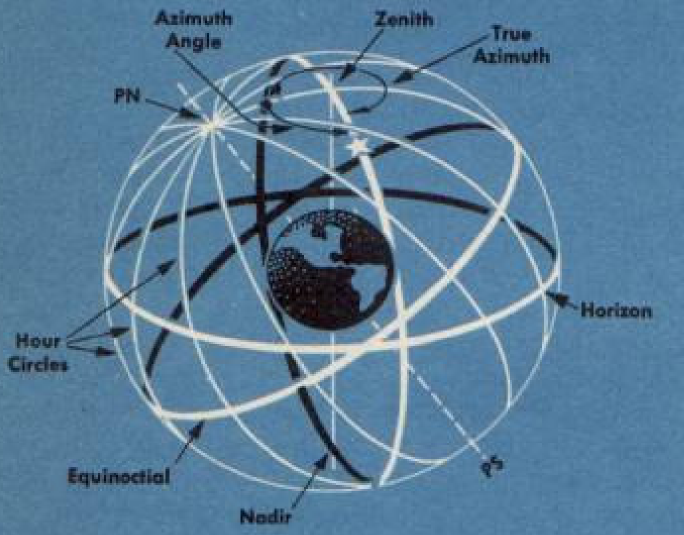






The altitude (H) of any point on the celestial sphere is its distance above the horizon, measured upon the vertical circle passing through the point in degrees of arc. When you calculate the altitude of a body as it appears from a point of known latitude and longitude by any one of the several trigonometric methods available, call it the computed altitude, (Hc). When you measure the altitude of a body with a sextant, name the reading of the vernier scale as the sextant altitude, (Hs). When you correct the sextant altitude (Hs) for all errors of observation you get the true observed altitude, (Ho).

The zenith distance of any point is its distance from the zenith, measured in degrees of arc upon the vertical circle passing through the point. The zenith distance of any point that is above the horizon is therefore equal to 90° minus the altitude.

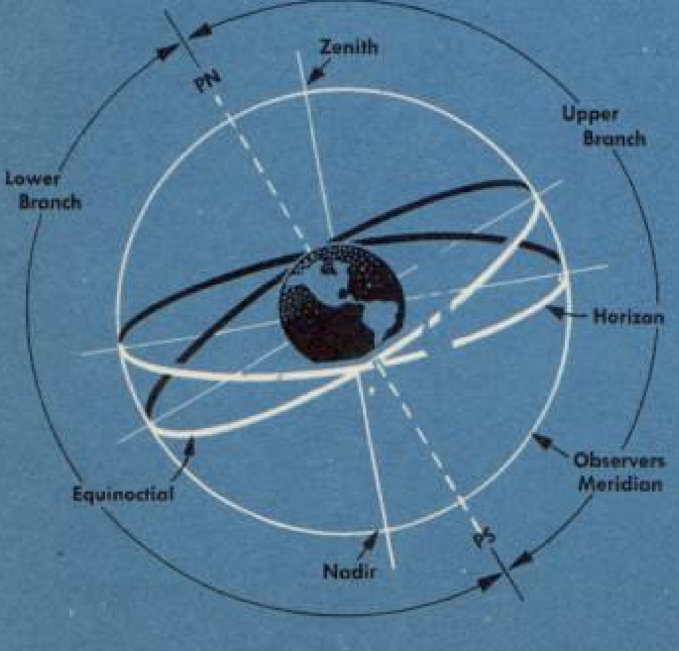


The azimuth of any point on the celestial sphere is the angle at your zenith between your meridian and the vertical circle through the point. Express the angle in degrees of arc. Measure it from either the north or south, to the east or west, to either 90° or 180°. Name it accordingly; N 50° E, or S 130° E. For convenience in plotting, if you are in the Northern Hemisphere measure the azimuth from the north to the right (clockwise) from 0° to 360°. Abbreviate this azimuth as Zn and do not precede it or follow it by directional abbreviations.

The equinoctial or **celestial equator** is the great circle formed by extending the plane of the earth's equator until it intersects the celestial sphere.

The celestial poles are the two points where the extended polar axis of the earth intersects the celestial sphere. Name the elevated pole the same as your latitude upon the earth.

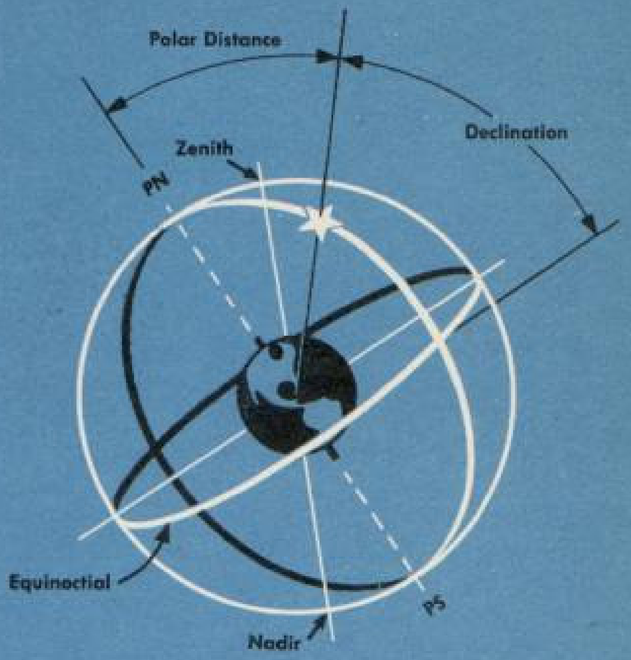
Hour circles or **celestial meridians** are great circles of the celestial sphere passing through the poles. Form them by extending the planes of the respective terrestrial meridians until they intersect the celestial sphere. Meridians and hour circles are identical. The hour circle containing the zenith is the **celestial meridian of the observer,** or your meridian.



The upper branch of the celestial meridian is that half which lies on the same side of the poles as your zenith. The lower branch is the opposite half.

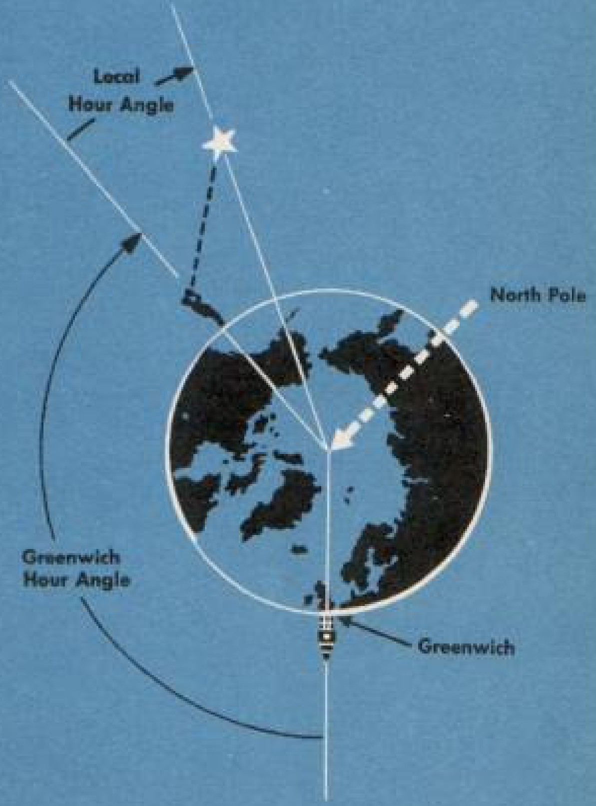
The declination of any point on the celestial sphere is its angular distance from the celestial equator measured on the hour circle which passes through that point. Designate it as north or south according to the direction of the point from the celestial equator. You can designate north declinations by a plus sign and south declinations by a minus sign; however, it is better practice to label declinations with the prefixes N or S, because the plus and minus signs are not meant to signify that N declination is always additive and S declination subtractive. Declination upon the celestial sphere corresponds with latitude upon the earth. By observing a celestial body at the instant it crosses your meridian you can determine your latitude. See Meridian Altitudes.

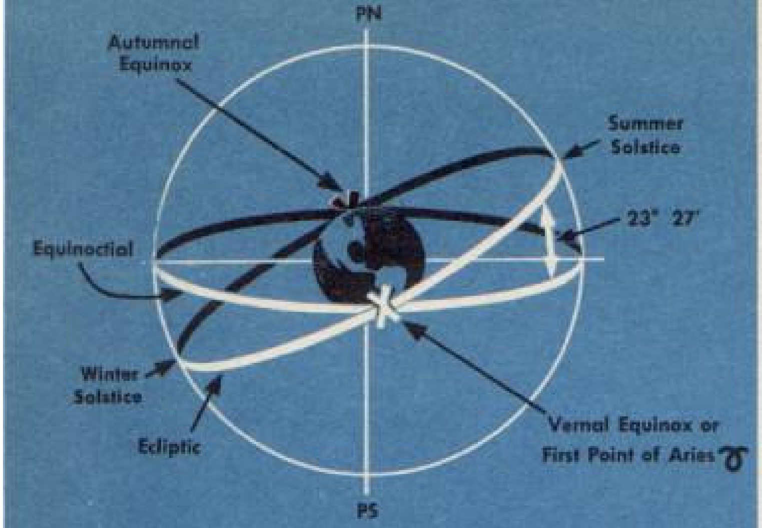
The polar distance of any point is its distance from the pole, measured upon the hour circle passing through the point in degrees of arc. It is equal to 90° minus declination, if you measure it from the pole of the same name as declination, or 90° plus the declination, if measured from the pole of opposite name. You can also refer to it as co-declination as it is equal to 90° minus declination.

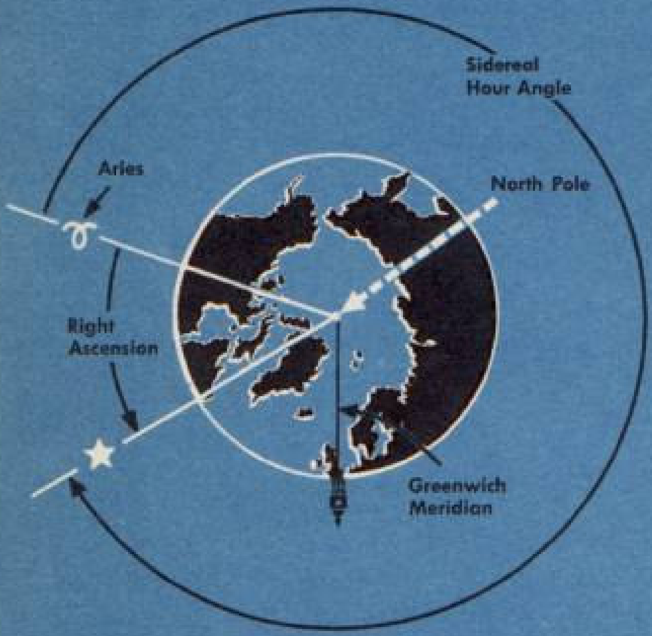


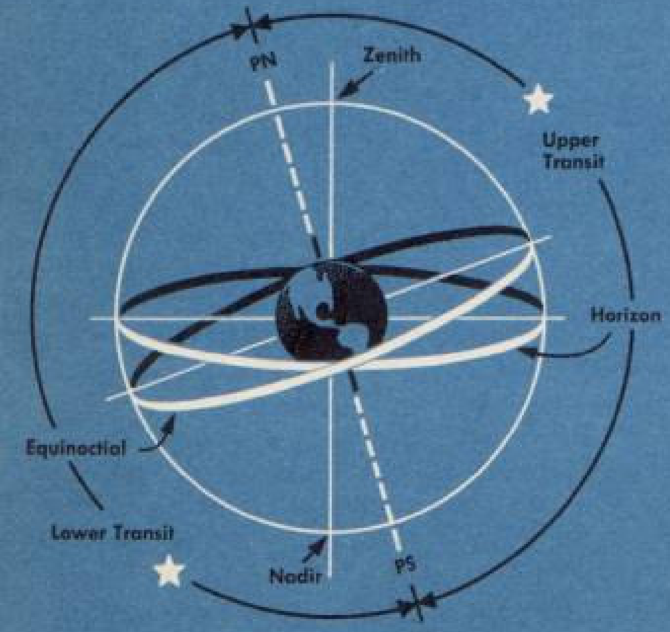
The local hour angle (LHA) of any point is that angle at the pole between the meridian of the observer (your meridian) and the hour circle passing through the point. Always measure it to the east or west from 0° to 180°. The principal exception to the 180° east or west method of measuring local hour angle is when you define the local hour angle of the vernal equinox. In this case measure the LHA from your meridian toward the west as a positive direction to 360°. The use of the Air Almanac has made it unnecessary for you to express hour angle in units of time. The local hour angle of a celestial body is merely the difference in longitude between your position and the celestial meridian through the body.

The Greenwich hour angle (GHA) of a heavenly body is the angle at the pole between the meridian of Greenwich and the hour circle of the body. Always measure it from the meridian of Greenwich to the west through 360°.









The ecliptic is the great circle representing the path in which the sun appears to move by reason of the annual revolution of the earth. The plane of the ecliptic is inclined to the plane of the celestial equator at an angle of about 23° 27′.

The equinoxes are the two points where the ecliptic intersects the celestial equator. The point where the sun appears to pass from southern to northern declination is called the **vernal equinox** or **the first point of Aries**, and designated by the sign of the ram's horn. Use the hour circle through the vernal equinox as the origin for locating stars on the celestial sphere, just as you use the meridian through Greenwich as the origin of longitude on the earth. The other point is called **autumnal equinox** and it is on the other side of the earth from the vernal equinox. The vernal equinox is a definite point in the heavens, even though it is not visible.

The solstices are points on the ecliptic at a distance of 90° or 6 hours from the equinoxes. In the Northern Hemisphere the **summer solstice** is the point where the sun appears to be at its greatest distance north of the equator, when the period of daylight is the longest. The **winter solstice** is the point where the sun appears to be farthest south of the equator, when the period of daylight is the shortest.

The right ascension (RA) of any point on the celestial sphere is the angle at the pole between the hour circle passing through the vernal equinox, and the hour circle through the point. It is measured from the hour circle of the vernal equinox eastward as a positive direction, from 0 hours to 24 hours. Always measure right ascension in hours and minutes and never in degrees of arc.

The sidereal hour angle (SHA) of any point on the celestial sphere is the angle at the pole between the hour circle passing through the point and the hour circle passing through the vernal equinox. Measure sidereal hour angle from the hour circle of the vernal equinox westward, from 0° to 360°. Sidereal hour angle is expressed in degrees whereas right ascension is expressed in units of time.

The instant at which any point of the celestial sphere is on your meridian is the time of **transit, culmination,** or **meridian passage** of that point. When the passage is over the half of the meridian which contains your zenith, it is in upper transit; when over the half containing the nadir, it is in lower transit. By observing a body as it passes over your meridian you can obtain your latitude.

ERRORS IN OBSERVATIONS

Errors

Learn how to compensate for all known causes of error. Remember, sextants are delicate and accurate optical instruments, and must be protected.

Never touch the index glass with your fingers or let any object strike it. Touching the glass leaves a film which makes it harder to see the bubble and celestial body while taking observations.

When making sextant observations in the air, you must take into account the following errors:

Sextant Error

There is an error in the instrument which is due to faulty adjustment of the bubble or the index prism. When you have found the error (see NIF 3-3-2), either apply it in reverse to the Hs (sextant altitude), or remove it by zeroing the sextant.

Atmospheric Refraction

This error in the observation is due to the light ray being bent toward the vertical by the earth's atmosphere. It is always a subtractive correction. This correction has been taken care of in the solutions by HO 218, Star Altitude Curves and Astrograph, for flight level of 5,000 feet. If the flight level differs greatly from 5,000 feet, or, if using one of the other solution forms to obtain the Hc, you must apply the correction for refraction to the Hs, using the tables at the back of the Air Almanac.

Dome Refraction

This is an error in observation introduced by shooting through a glass dome. This error usually increases with altitude, from about 0 to 10 minutes. To determine the error for your airplane:

1. Determine the sextant error accurately.
2. Shoot a series of observations through the glass dome. Use a range of altitudes.
3. Plot these shots against a computed curve in which refraction and sextant corrections have been applied in reverse.
4. The difference of altitude between your shots and the curve is the dome refraction. Make a critical table of the corrections similar to:

Hs	Correction
20°	
	-3′
25°	
	-4′
35°	
	-5′
50°	
	-6′
65°	
	-7′
80°	

Parallax

This error is introduced by assuming that you are at the center of the earth instead of at the earth's surface. This error is negligible except for observations of the moon. The parallax correction, which is always added to the Hs in observations of the moon, is determined from the tables in the Air Almanac.

Acceleration Error

This is an error in observation caused by the airplane movement which deflects the bubble so that it does not indicate true vertical. You can minimize this error by following these suggestions:

1. Notify the pilot when you are about to start shooting so he will hold the airplane steady.
2. Start shooting on an even minute and continue shooting for two minutes to average out acceleration errors which are due to the motion of the ship.
3. Use bubble about twice as big as the sun. A small bubble is sluggish and gives poor results.

CORRECTION FOR CORIOLIS ACCELERATION

LAT.	GROUNDSPEED						
	100	150	200	250	300	350	400
0	0	0	0	0	0	0	0
10	0.4	0.7	0.9	1.1	1.4	1.6	1.8
20	0.9	1.3	1.8	2.2	2.7	3.2	3.6
30	1.3	2.0	2.6	3.3	3.9	4.6	5.3
40	1.7	2.5	3.4	4.2	5.1	5.9	6.8
50	2.0	3.0	4.0	5.0	6.0	7.1	8.1
60	2.3	3.4	4.6	5.7	6.8	8.0	9.1
70	2.5	3.7	4.9	6.2	7.4	8.7	9.9
75	2.5	3.8	5.1	6.4	7.6	8.9	10.17

Coriolis Force

This error in observation is due to the rotation of the earth. This error increases with latitude and speed of the plane. Take care to determine whether the correction is enough to warrant the additional computation. Remember, the correction is at a maximum on beam shots.

Translate all lines right in Northern Hemisphere, left in Southern Hemisphere, perpendicular to track. Correction is in statute miles if your groundspeed is in statute miles, nautical miles if your groundspeed is in nautical miles.

Note explanation of "Z Correction for Bubble Sextant" which is combined with wander of the airplane caused by gyro precession. This correction is found in the rear of the Air Almanac.

You can overcome personal error only by constant, persistent practice.

Checking Sextant Error

Sextant error is the difference between what the sextant reads and what it should read if the instrument were in perfect adjustment.

1. The simplest and most accurate method of determining the sextant error is by using the collimator. Merely collimate the crosshairs or the star in the collimator with the bubble in the sextant and read the scale. If the scale reads above zero, the error is plus; if below zero the error is minus. Make certain that the collimator is level before checking the sextant.

2. If near a large body of water, you can use the natural sea horizon as a reference. Set the sextant on a stand, table, or place it in a clamp. Determine the height of the instrument above the water level. Split the bubble with the sea horizon. Apply dip correction to the sextant reading (you can find the amount of the dip correction from the back of the Air Almanac, but you must add it, not subtract it). The difference between the corrected sextant reading and zero is the sextant error.

3. If you know the altitude of the natural land horizon (determine it by means of a surveyor's transit or a sextant of known error) you can check the sextant on it. The sextant error is the difference between the sextant reading and the correct altitude of the horizon.

4. Construct a curve of the altitude of a celestial body. Plot Hc plus refraction, and minus parallax when shooting the moon. Compare with the sextant altitudes to obtain the sextant error. This method permits checking the error of the sextant at the altitudes which are most generally used.

5. If you set up a light or a pole at the same height as the sextant, 1,000 or more feet away, by means of a surveyor's transit or by a sextant with a known error, you can find the sextant error.

Remove the Error

After you have determined the sextant error you can remove it partially or completely by the methods described for each type of sextant. You should check the error frequently as it will change from time to time. Apply the sextant error mathematically in reverse to the Hs, if it is impractical to remove it. This is known as sextant correction.

It is a good idea to determine the altitude of some distant point from a place near the operations building and check your sextant just before takeoff.

Place a card with sextant number and error, date of check, and your name and rank in sextant case.

AIRCRAFT SEXTANTS

Know your sextant. The success of a vital mission, the lives of your fellow crew members, and the safety of your airplane are all dependent upon the accuracy of your calculations. They, in turn, depend upon the accuracy of your instruments and the skill with which you use them.

Tips

Always remove batteries from the sextant container as soon as your mission is completed. Corroding batteries ruin the rheostat and vernier-light battery case.

Keep the index mirror clean and free from greasy fingerprints. If the mirror does get dirty, clean it with lens paper or a well-washed handkerchief.

Severe changes of temperature may cause the index mirror to crack or break. Don't leave the instrument near a heating tube and then use it in a cold turret.

When you open the sextant case after a quick drop in temperature, moisture condenses on the sextant mirrors. To combat this, open the sextant case before you climb to a high altitude.

Batteries do not work well in extreme cold, so keep spares in a warm place, such as the pocket of your jacket, and replace them as often as necessary.

Always carry spare parts such as bulbs, batteries, and pencil leads in your sextant case.

Use a collimator tube, a precomputed curve, or a natural sea horizon to determine the amount of index error in your sextant. **Do not attempt to remove the error.** Note it and correct all subsequent observations by this amount. For any adjustments to your sextant consult an instrument specialist.

If your sextant requires the use of recording discs, be sure to keep them away from the heating tube of your airplane. If the case becomes hot, the wax on the discs melts and the whole supply sticks together.

If your sextant has a vapor bubble, be sure to release the bubble from the chamber during ascents, descents, and when you put the sextant away.

A-12 SEXTANT

Operation

There are two methods of using the sextant:

1. When you observe the sun, use the eyepiece and sunshades. You then are observing it indirectly, because the index glass reflects it to your eye.

2. When you observe the stars, use the direct method of sighting. This simplifies star finding and lessens the chance of observing the wrong star.

Median (Average) Sights

Take a series of shots, pressing the marking lever each time the body appears in proper position relative to the bubble. Take these shots only a few seconds apart.

It is good practice to observe a body for a period of one or two minutes in order to obtain the average time of the observation more readily.

Obtain the median reading in this manner:

1. If your shots are evenly spaced, use the middle mark on the rim of the drum. Rotate the drum until this mark is under the marking pencil. Then read the scale.

2. If your shots are not evenly spaced, rotate the drum until the visual average seems to be under the marking pencil. Your ability to estimate the correct median improves with practice.

Bubble

This sextant has a fixed bubble. The bubble assembly includes a bubble housing, two lenses with seals and locking rings, a filler hole, and xylene bubble fluid.

Optics

The index mirror is clear glass and optically flat. A clamp secures it on the same shaft that carries the sextant arm. With proper adjustment there is no lost motion between the arm and this mirror.

The lens tube assembly transmits the image of the bubble downward vertically from the bubble assembly and then up at an angle to the index mirror and your view.

The real field of the sextant is approximately 12°. See T.O. 05-35-15.

A-7 SEXTANT

Hold the instrument in both hands. Your right hand operates the micrometer drum while your left, besides furnishing additional support, operates the shade glass holder and the astigmatizer knob. When you use the artificial horizon, move the horizon shutter knob to its extreme position in the direction opposite that of the arrow. This keeps any direct horizontal light from entering the telescope.

Operation

1. Before taking a reading with this sextant, be sure to set the ratchet of the averaging device at 0 and adjust the pencil properly to give fine legible lines.
2. Sight through the instrument and bring the image of the celestial body into horizontal coincidence with the bubble.
3. To record the observation, press the trigger by moving your right thumb backwards without taking that hand off the sextant.
4. Repeat this procedure, without re-setting the ratchet, until you have recorded the desired number of observations.
5. Note the number in the ratchet and select the middle reading.
6. Having determined the middle reading, locate its pencil mark on the micrometer drum cover.
7. Align the pencil mark of the average reading with the end of the pencil.
8. Note the reading on the worm scale dial and micrometer drum scale. This quantity is the average angular altitude determined by the observations. The time of the observation is the median time between the start and finish of your observation.

Bubble

The bubble assembly which forms the artificial horizon consists of a field lens, bubble chamber, bottom glass, and diaphragm chamber with cap. A vapor bubble forms in the bubble chamber which, together with the diaphragm chamber, is filled with xylene. The bubble is formed and controlled in size by the deflection of a flexible diaphragm, which forms a wall of the chamber on the side of the bubble assembly. Control the deflection by turning the nut on the diaphragm cover. Radioactive luminous material, painted on a metal ring surrounding the bubble, amply illuminates it.

Before you put the sextant away in its carrying case, return the bubble control knob to neutral, loose on the shaft.

Optics

The instrument optics is so designed that the matching of the bubble's image with that of the body does not have to take place in the middle of the field. It is best to use the astigmatizer for accurate work because the way it flattens the image makes it easier for you to estimate the center of the bubble.

The real field of the sextant is approximately 12°.

See T.O. 05-35-4 for additional instructions on operation and care of this sextant.

A-8A SEXTANT

Operation

You can use this sextant for direct or indirect sighting.

1. Before you take any readings you must set the averaging device in the zero position. Do this by turning the vernier disc as far clockwise as possible. Then use the sextant in the usual manner.
2. As soon as you have taken a shot, place your right index finger in the concave portion of the handle and push it as far counter-clockwise as possible. Then return the handle to its original position. This operation moves the vernier disc counter-clockwise an amount equal to one-eighth of the total recording.
3. Repeat this procedure until you have taken a total of eight shots.
4. Then read the counter disc and vernier disc to obtain the average of these eight settings in degrees and minutes.

The average time is the time of the average altitude reading.

If the 0 line of the vernier disc points between two lines of the counter disc, read the lower of the two as the number of degrees. Add to this the reading of the vernier disc, expressed in minutes of arc.

In reading the vernier, follow the vernier disc counter-clockwise until a line of the counter disc appears to be a continuation of a degree line. The number of divisions in the vernier disc from 0 to the point where the lines coincide is the number of minutes you add to the scale reading.

A pencil averaging device is now available. To have your sextant modified, send it to any one of the following service commands:

Fairfield Air Service Command,
Oklahoma City Air Service Command, or
Sacramento Air Service Command.

Bubble

Use the dark field illumination of the bubble at night. This makes the bubble appear as a bright ring in a dark background. You can regulate the brightness of the bubble with the rheostat.

You can see directly through the center of the bubble to sight a heavenly body.

Optics

The focal length of the eye lens is equal to that of the objective lens.

The real field of the sextant is 9°.

See T.O. AN 05-35-7.

A-10 SEXTANT

Operation

Hold the sextant by its frame in the palm and fingers of your right hand. The control knob, which elevates the field prism, is down. Use your left hand to operate the control knob or to adjust the size of the bubble.

To register a line on the recording disc, move the plunger of the marker with your right forefinger.

The middle value of several readings in a series is the average of your observation. To obtain this reading, align the middle line of any group of readings with the index. Then read the counter to obtain this value in degrees and minutes.

If your observations are equally spaced, take a direct average. If they are not equally spaced, devise your own method of averaging them.

Bubble

Only the bubble itself is illuminated. This makes it easier for you to observe dim stars.

If the bubble disappears you can easily re-form it in this way:

1. Turn the sextant until the bubble-size knob faces downward.

2. Turn the bubble-size knob to its maximum INCREASE position, as indicated on the engraved diaphragm housing. Be careful not to force the knob past the limits of this position.

3. If the bubble is not visible, it may be formed in the diaphragm. Turn the knob to near its minimum position.

4. Hold the sextant firmly and snap your arm forward quickly, in order to release the bubble from the diaphragm housing.

5. An alternate method is to hold the sextant with the bubble chamber away from you and whip the sextant downward sharply.

Turn the bubble to maximum size when you put the sextant back in its case.

Optics

The auxiliary telescope and the eyeguard at the glass chamber housing are interchangeable. When you use the telescope you get a two-power magnification and your field is reduced approximately one-half.

The real field is approximately 14°.

The scales are illuminated. Replacement lights are provided, but in an emergency you can use the lamps out of the B-3 driftmeter, radio compass, or some other aircraft instrument.

See T.O. AN 05-35-12.

A-10A SEXTANT

This sextant is a modification of the A-10 sextant and includes the following new features:

1. An automatic marking device operated by a solenoid timing mechanism, which makes a mark on a plastic disc. You can operate the marker manually if the timing mechanism fails.

2. An air-reservoir bubble chamber which permits the bubble to form more easily and produces a bubble which is less affected by temperature changes than the previous vapor-type bubbles.

3. An improved lighting system for the marking disc and counters.

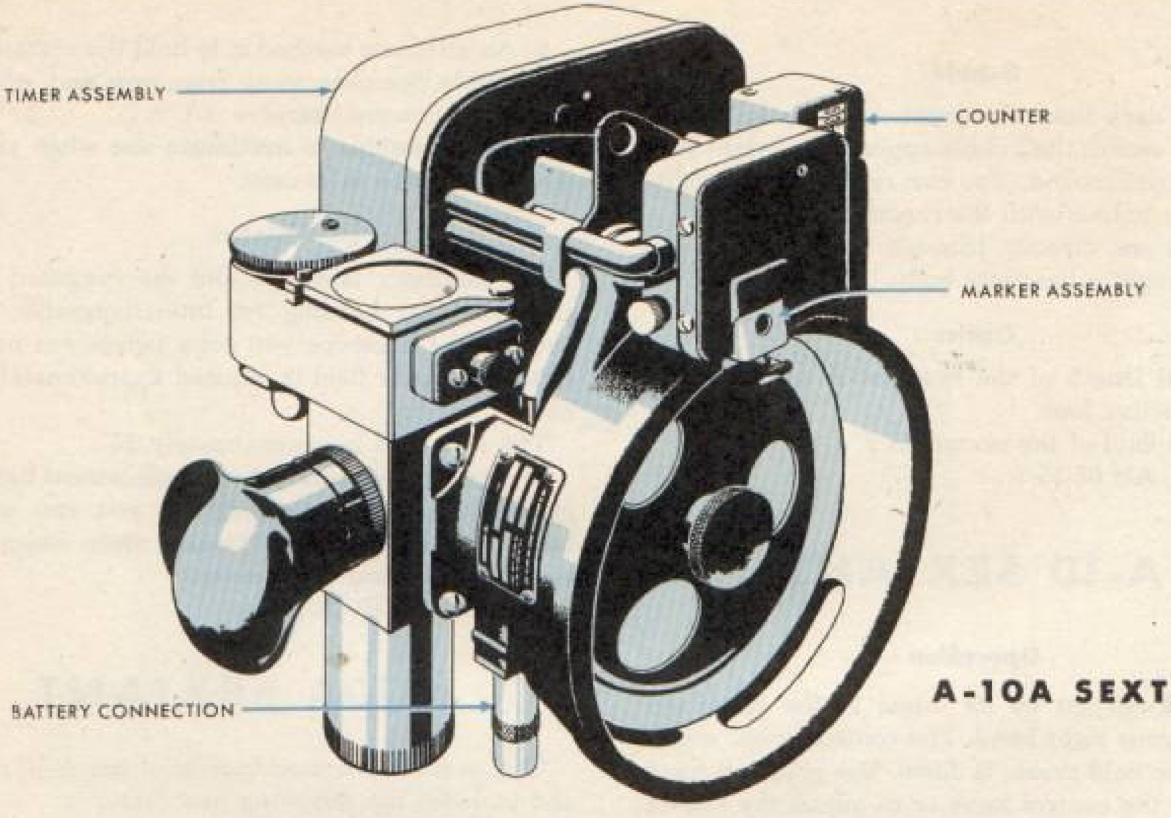
4. A 3-cell battery case which operates the electric timing mechanism and the lighting system.

5. The rheostat which controls bubble illumination is on the sextant instead of on the battery case.

Operation

You must use the battery case to operate this sextant, both day and night. The batteries provide power for a small electric clock in the housing on the left side of the sextant. Approximately once every second, so long as you press the trigger above the marking disc, this clock energizes a circuit which actuates the solenoid marker on the right side of the sextant.

Shake the sextant lightly to make sure that the clock has started; it does not always start when the battery case is connected. As soon as you complete your observations, disconnect the batteries to preserve them.



A-10A SEXTANT

Determine the number of impulses of the marking mechanism per minute. Normally this number does not vary greatly even with extreme changes in temperature. Once you know it, you need only to count the clicks of the solenoid to time an observation.

In the air it may not be possible to hear the click of the marking device, but by resting your right index finger lightly over the marker you can feel its movement and count the number of impulses. At night the bubble light blinks at each impulse and you can use this means of counting them.

The marking device requires careful adjustment of the pencil lead so that there is sufficient clearance between the lead and the disc at the beginning of the stroke to allow the solenoid to gain momentum before the lead strikes the disc. If this adjustment is too close the lead doesn't slide over the disc and, consequently, won't make a mark. If the pencil lead is too far from the disc the mark made is too short. If you adjust it correctly, the lead should last for the entire flight.

You can operate the marking device manually by pressing the flat side of the marker with your right index finger.

General

1. After looking at your hack watch at the start you can time your observation accurately by counting the aural or visual impulses of the marker.

2. You can concentrate on maintaining collimation with the body without having consciously to space your observations at even intervals.

3. The automatic marker makes more uniform marks and eliminates movement of the sextant which occurs when you operate the marker button manually.

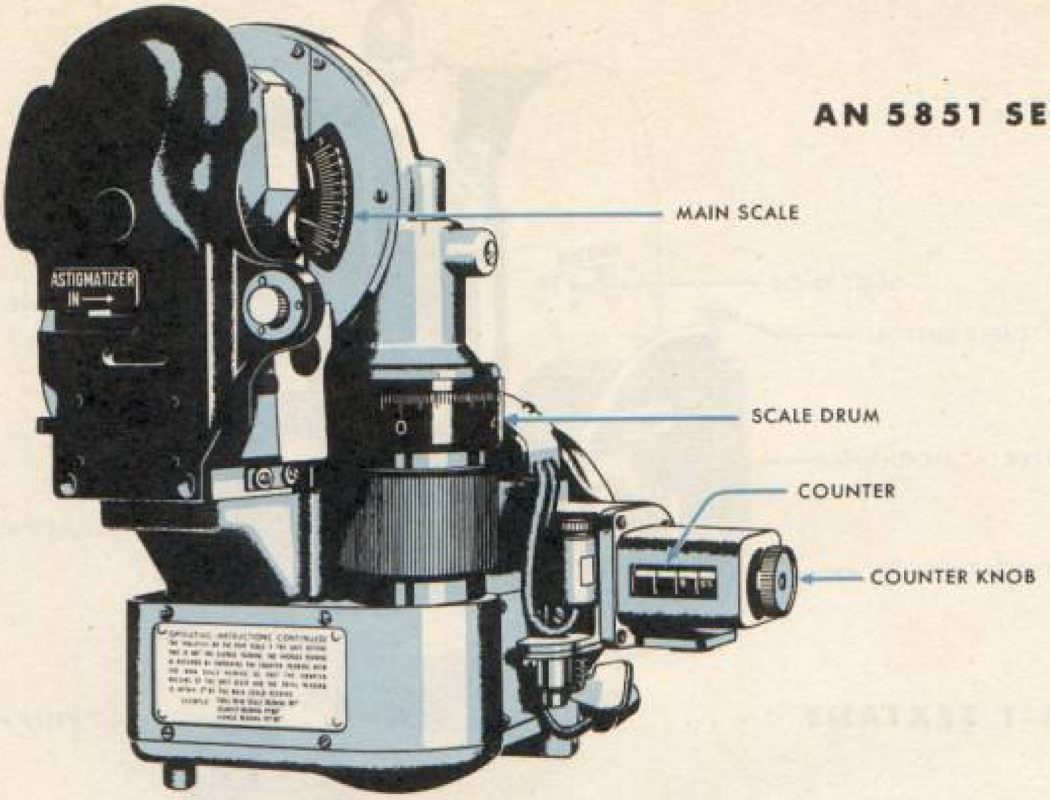
Bubble

The new bubble consists of a double chamber with a large air reservoir. Change bubble size by transferring air from one chamber to the other. The bubble never disappears except through deliberate operation of the diaphragm.

A large change in temperature produces practically no change in bubble size because the reservoir acts as a buffer. If you can't change the bubble size as you wish by rotating the diaphragm control to its extreme limit, level the sextant during the return stroke. You can rotate the diaphragm control back and forth any required number of times.

Optics

The real field of view varies between 12° and 14°, but is reduced one-half when you use the telescope attachment. You sometimes have difficulty in locating the desired star; it happens with all horizontal-viewing sextants. This procedure may help you:



AN 5851 SEXTANT

1. Set the instrument to 0° altitude.
2. Pick up the star by direct sighting.
3. Bring the sextant to operating position slowly, keeping the star in the field of view by rotating the index knob.

See T.O. 05-35-33.

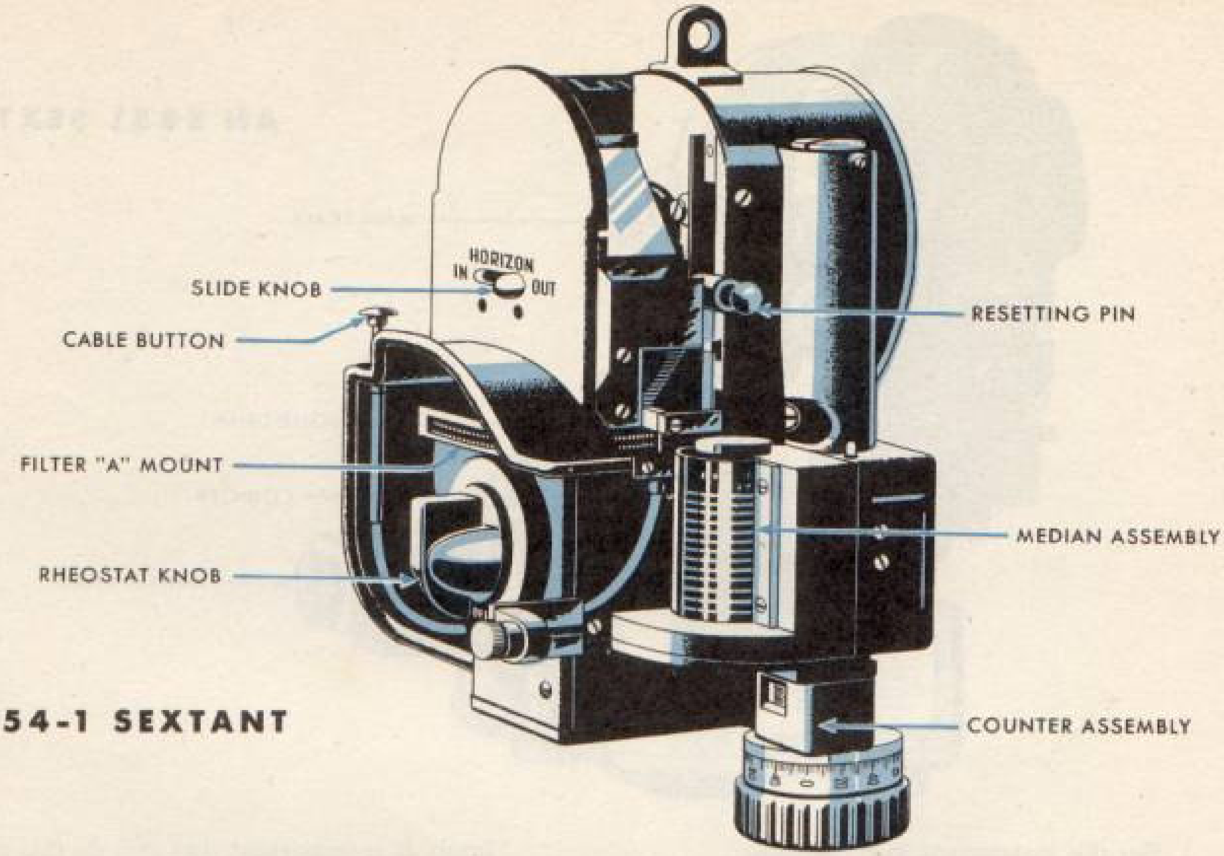
AN 5851 SEXTANT

Use the AN5851 sextant with the appropriate support arm. Like the A-10 and A-10A it is designed for horizontal vision. This sextant incorporates a chronometric, automatic averaging device which, at the end of a two-minute period, gives the average altitude on a counter.

The averaging mechanism picks off the setting of the instrument at two-second intervals and accumulates these values through a 60/1 gear reduction on the counter. Since a gear system does the averaging you must enter a full complement of 60 sights. You must, therefore, maintain collimation for a full two minutes. The reading on the counter is worthless if you stop observing before the two minutes have fully expired.

Operation

1. Set the counter to 0 by turning the counter knob. It is important that you do this accurately.
2. Wind the averaging device until you reach a solid stop.
3. Push lever 2 and rotate the scale drum to a stop. This operation engages the sextant with the averaging device and the stop indicates that the averager has been brought down to the base line.
4. Push lever 1 to engage lever 2. This operation disengages the averaging device from the sextant.
5. Take a preliminary sight. Push lever 2.
6. Again rotate the drum down to a stop, and if this amount of rotation is more than 2°, rotate the drum up to the sighted angle and collimate the star and the body.
7. If the amount of rotation is less than 2°, disengage the averaging device by pushing lever 1, rotate the drum down approximately one turn, push lever 2, and continue rotating the drum down to a stop. Then proceed with the sight. There is always a 15° spread between stops, which allows at least 2° on either side of the altitude of the body. This gives the drum room in which to rotate while the bubble is moving.
8. Push lever 3 to start the averaging device.
9. To obtain the average time, add 1 minute to starting time or subtract 1 minute from the time you finish your observation.
10. Maintain coincidence between the bubble and the celestial body. At the end of two minutes a



AN 5854-1 SEXTANT

shutter automatically moves into the field of view and obscures your vision.

11. To obtain the final average altitude, combine the counter reading with the main scale reading. (Do not read the scale drum; this indicates only the final altitude setting.) For example, if the counter reads 6° 35′ and the main scale pointer is between 4 and 5, the final reading is 46° 35′. Remember, the final main scale reading is within 2° of the average reading.

Bubble

In this type of sextant the star image and the bubble image are superimposed directly in the optical system and not by reflection, as in the A-10 series. You cannot see the star through the bubble, so use the cylindrical lens to astigmatize the star image, i.e., draw it out to a line instead of a point.

Optics

The real field of the instrument is 12°. Two-power magnification is built in.

Note that a rotatable polarizing filter in the eyepiece is designed to reduce horizontal (water) reflections of the sun at low altitude.

For general use, and always at night, remove this filter by pulling it straight out of the eyepiece. There is a finger ring attached to it for this purpose.

A horizon prism allows you to use the natural horizon.

See T.O. 05-35-22.

AN 5854-1 SEXTANT

Operation

Use the AN5854-1 sextant with the appropriate support arm. Hold the instrument by the handle, which is part of the sideplate, and by the graduated drum at the lower left side of the instrument. Operate the median averaging device with the index finger of your right hand. Press the cable button at each reading. Readings are recorded by the median assembly and are continued until the shutter automatically cuts off the field of view. Then, rotate the graduated drum until the median index is under the index line of the median assembly window, and read the angular altitude from the sextant scales.

To prevent any of the indexes from disappearing behind the median drum when you are determining the setting, the median drum is geared to turn half as fast as the graduated tangent screw controlling the sextant prism. This gear reduction also reverses the direction of motion of the median drum from that of the tangent screw.

Spread the series of observations over the particular oscillation cycle of your airplane. In normal flying conditions, space a series of 15 readings at intervals of approximately six seconds between readings. In extremely rough air, two series of 15 readings are recommended with an interval of approximately six seconds between series. Average the two medians to obtain an average of the 30 readings. The average celestial time for the series of 30 readings is the average time from the start to the finish of the observations.

Another method of using the averaging device is to rotate the series of indexes until they seem to be distributed evenly on both sides of the fiducial line. This reading is a good average.

Clear the median assembly and load the shutter for another series of readings by pressing the resetting pin and rotating the indexes back to the index fiducial line in the center of the window.

For use with the sun and bubble horizon, the instrument is equipped with five combinations of filters for various sun intensities or field brightness. With the real horizon reflector IN, you can use the astigmatizer lens to astigmatize the sun across the bubble.

You can view celestial bodies at night either through the clear openings or the astigmatizer lens in the filter mount.

Radium paint provides such adequate dark field illumination of the artificial horizon bubble at night that you rarely need electric light. However, variable electric light intensity is available to boost the level of illumination.

Optics

The shutter is a thin sheet of metal that automatically cuts off the telescope field at the end of the observation. The shutter drops on the sixteenth reading and not at the end of the fifteenth. The shutter is mounted directly above the objective lens and the filter mount assembly.

The real field of the sextant is 12°. Two-power magnification is built in. You sometimes have difficulty in locating the desired star, as is the case when you use any horizontal-viewing sextant. See procedure outlined under Optics, A-10A sextant.

All scales are illuminated. A red bubble filter is supplied to provide a red bubble for contrast against the sky. This is particularly suitable for use against a moonlit cloudy sky.

See T.O. 05-35-27.

WATCHES

In accordance with Technical Order 00-30-61-2 you are entitled to three watches: the A-11 hack watch, the A-8 groundspeed timer, and the AN5740 master watch. These watches are the best products the American watch industry can make in the quantity the Air Forces demand. The life of your watches and the performance they give you are largely a matter of the care you give them. You should take the following simple precautions:

1. Carry your master watch in the metal case provided. This protects the watch from shock and from large magnetic fields. Always try to carry the watch in a horizontal, face-up position.

2. Wind your master watch regularly and determine its rate so that you may gain confidence in its performance. This watch is one of the finest timepieces made today. It is adjusted for position and for temperature.

If you anticipate flying in extreme cold (below −20° C) it is advisable to carry the watch on a piece of string inside your flying clothing. The slight inconvenience which this causes in reading the watch is greatly outweighed by the improved rate of the watch.

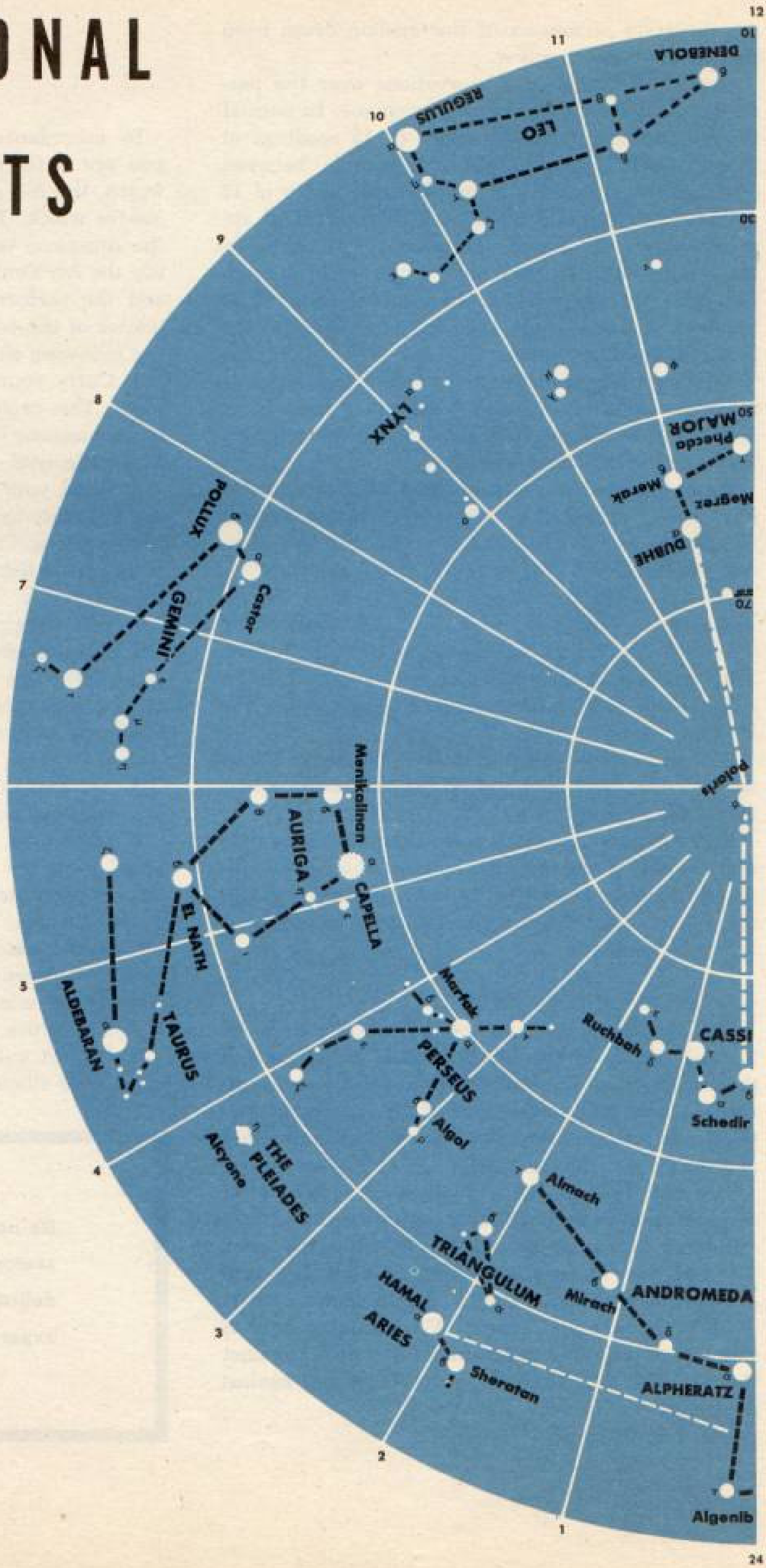
3. See that the screw-back and bezel of the watch are tightened securely at all times.

4. **Important: Your wrist watch is not waterproof,** so do not expose it to excessive moisture. The latest hack watches are supplied with a three-piece, dust-tight case. This simplifies maintenance and the rate of the watch is more constant. Take particular care to prevent water from running down your wrists after washing your hands; it collects around the stem of the watch.

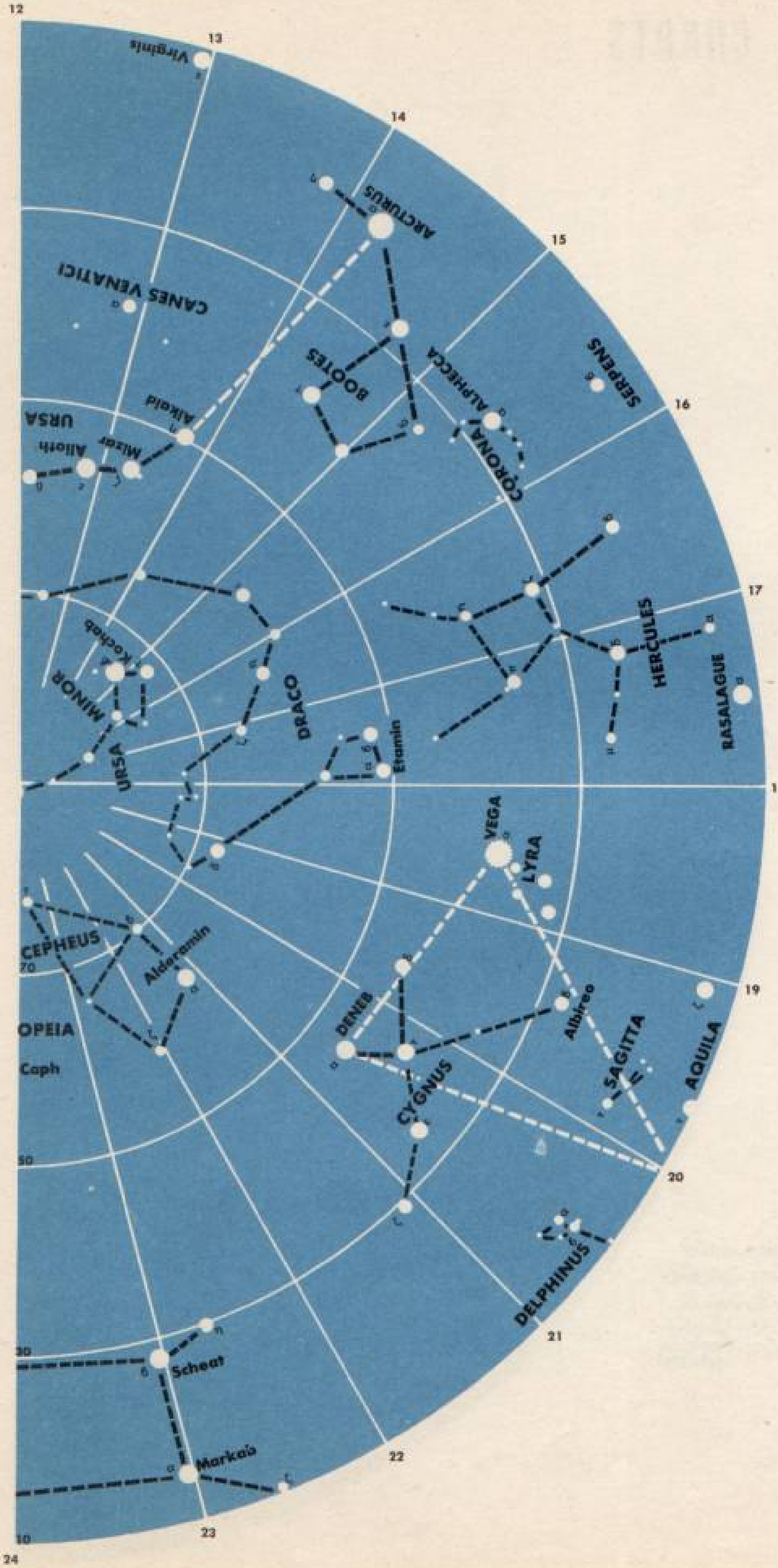
5. Inspect your watch strap and strap pins occasionally to eliminate any chance of losing the watch.

Do not attempt to repair sextants or watches. They are delicate instruments and require expert adjustments.

NAVIGATIONAL STAR CHARTS

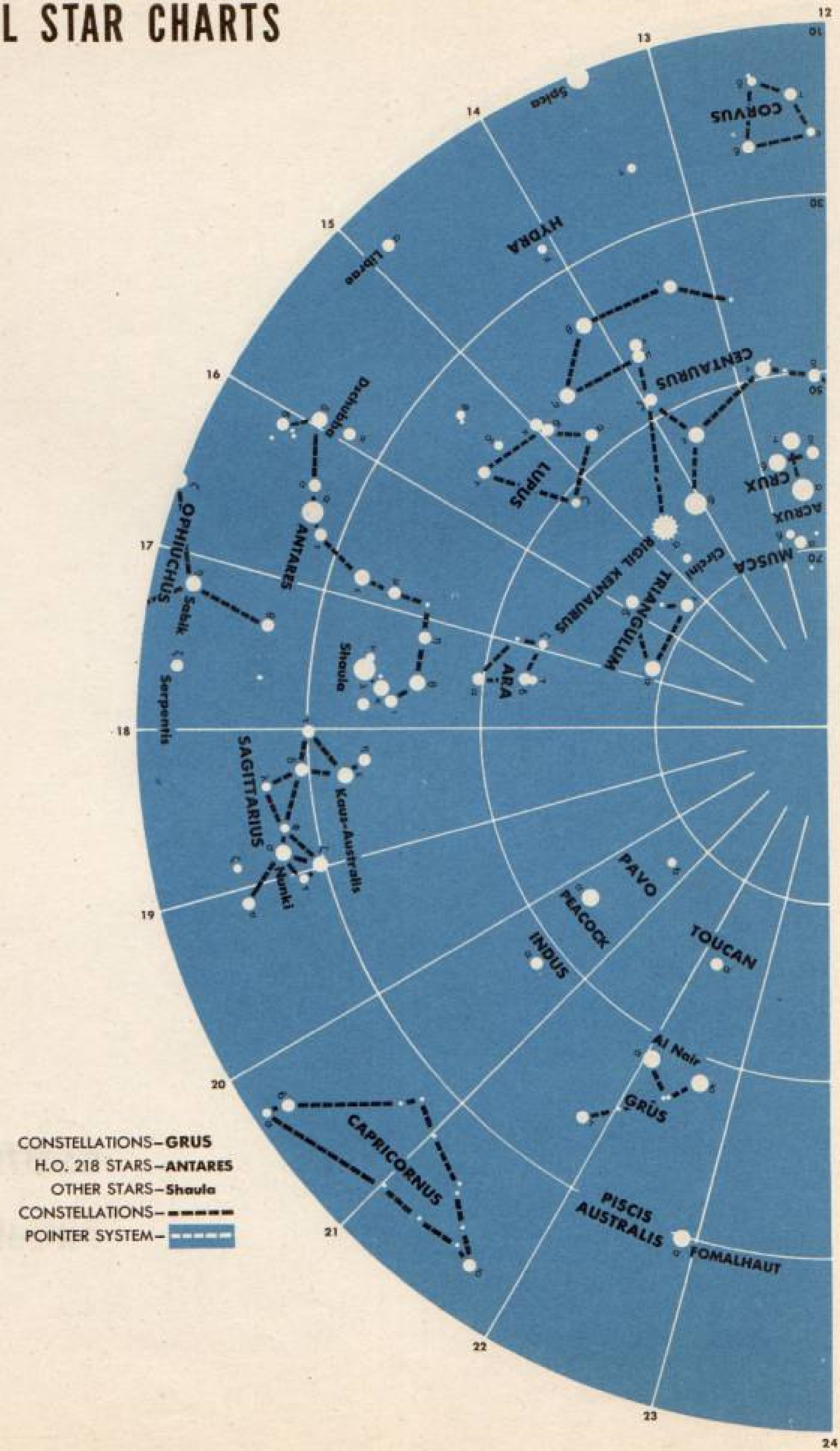


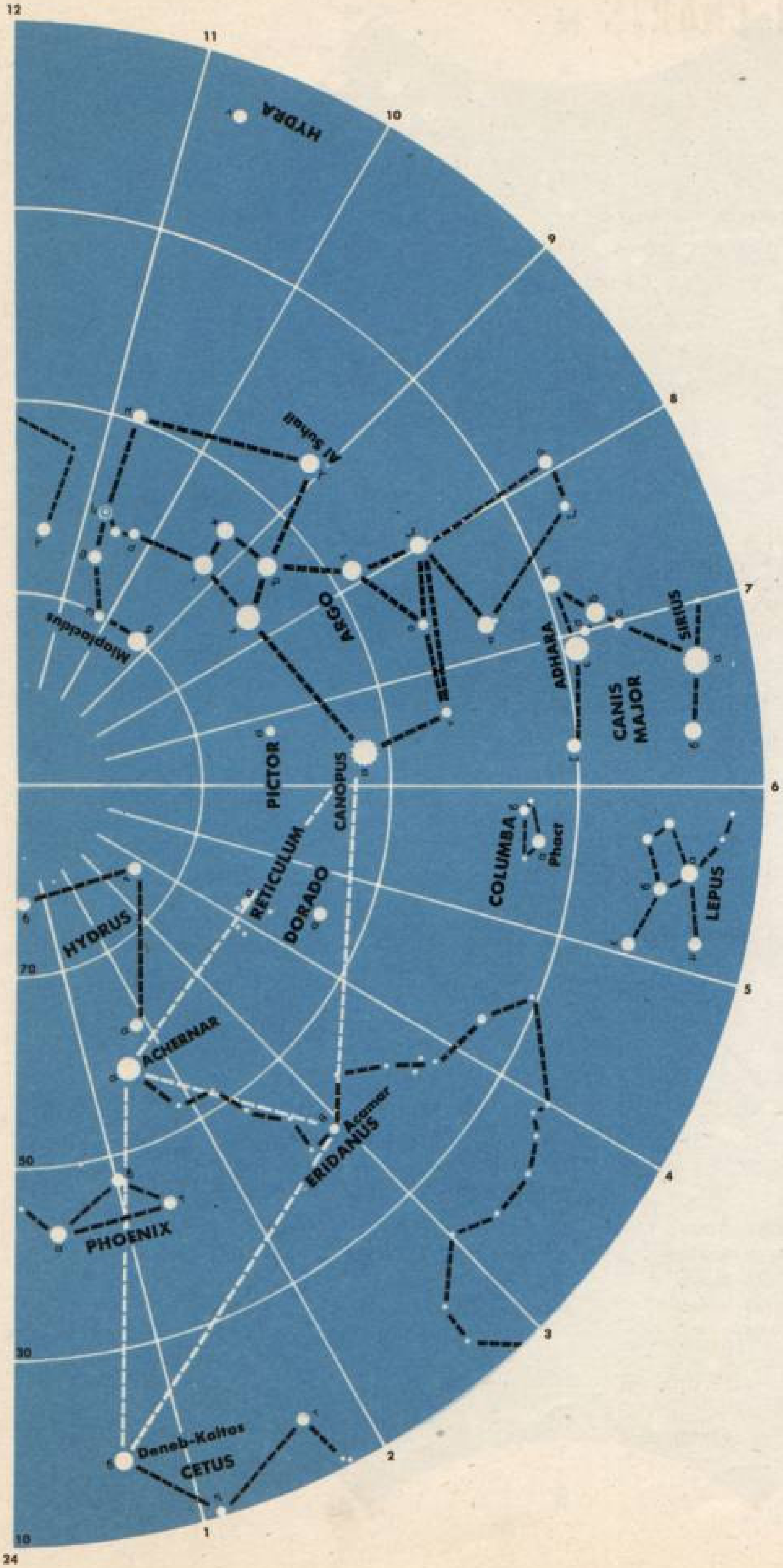
CONSTELLATIONS–**TAURUS**
H.O. 218 STARS–**CAPELLA**
OTHER STARS–**Almach**
CONSTELLATIONS–▬ ▬ ▬
POINTER SYSTEM–▭



NORTH POLAR PROJECTION

NAVIGATIONAL STAR CHARTS

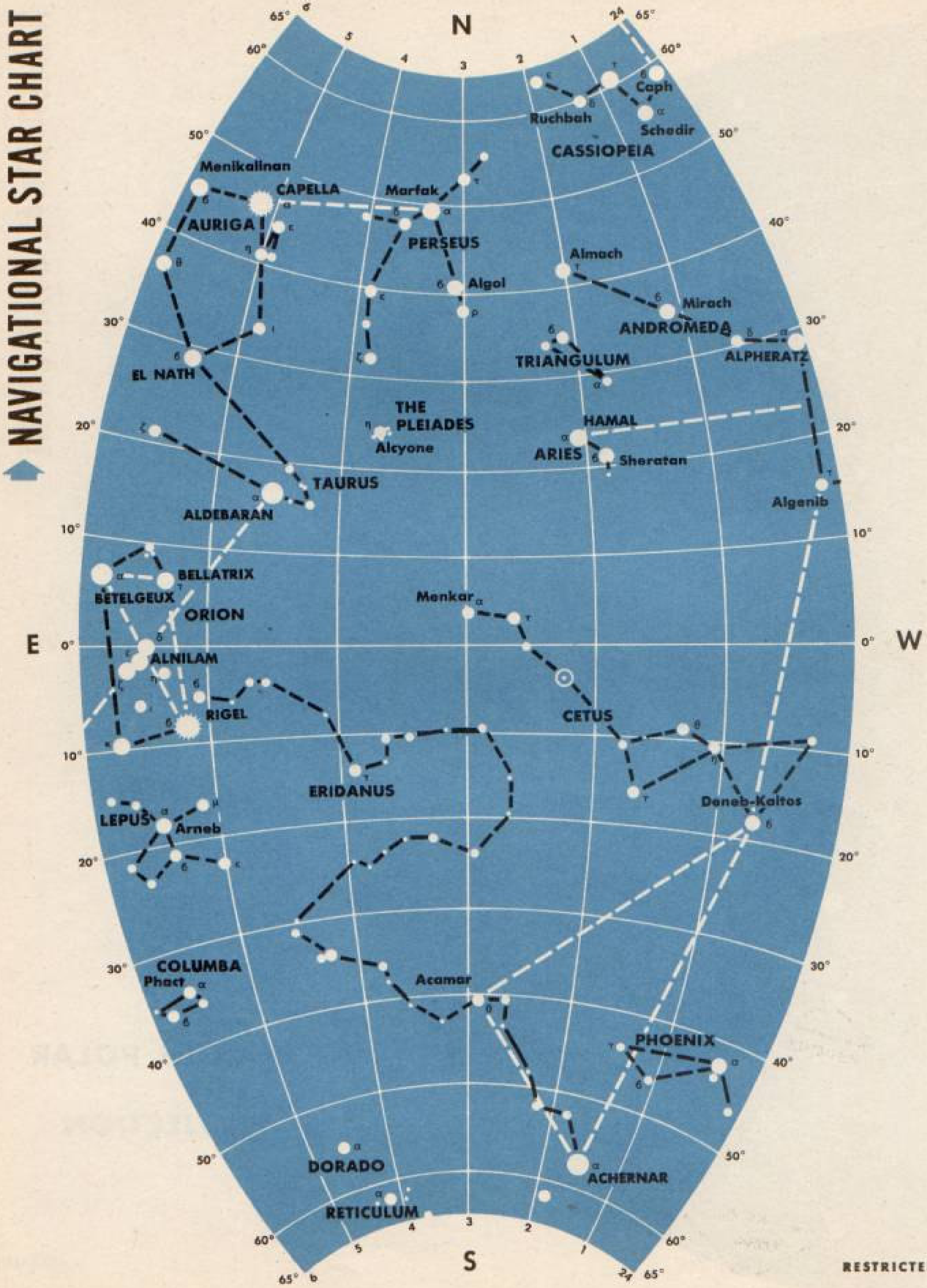




SOUTH POLAR

PROJECTION

NAVIGATIONAL STAR CHART



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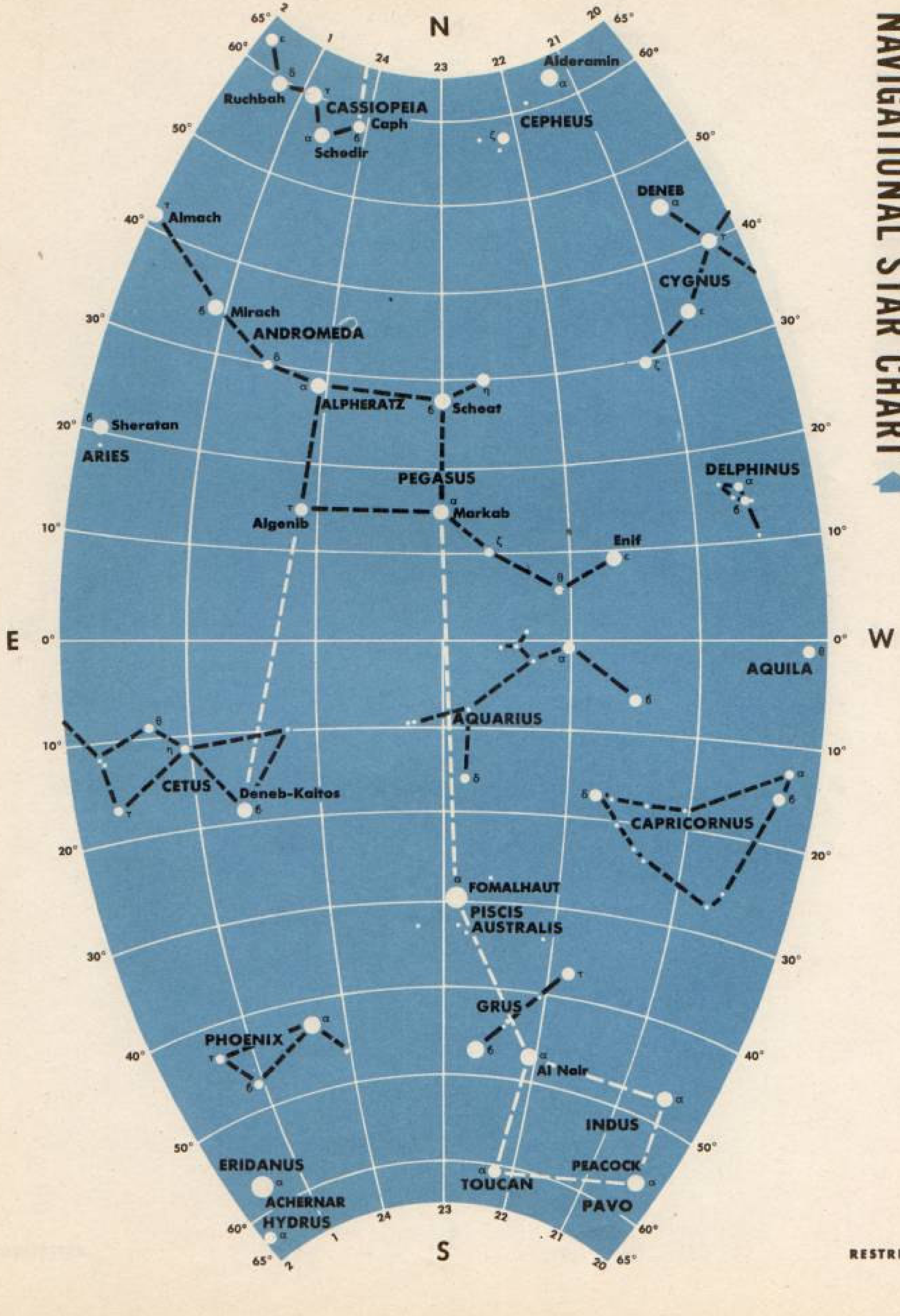

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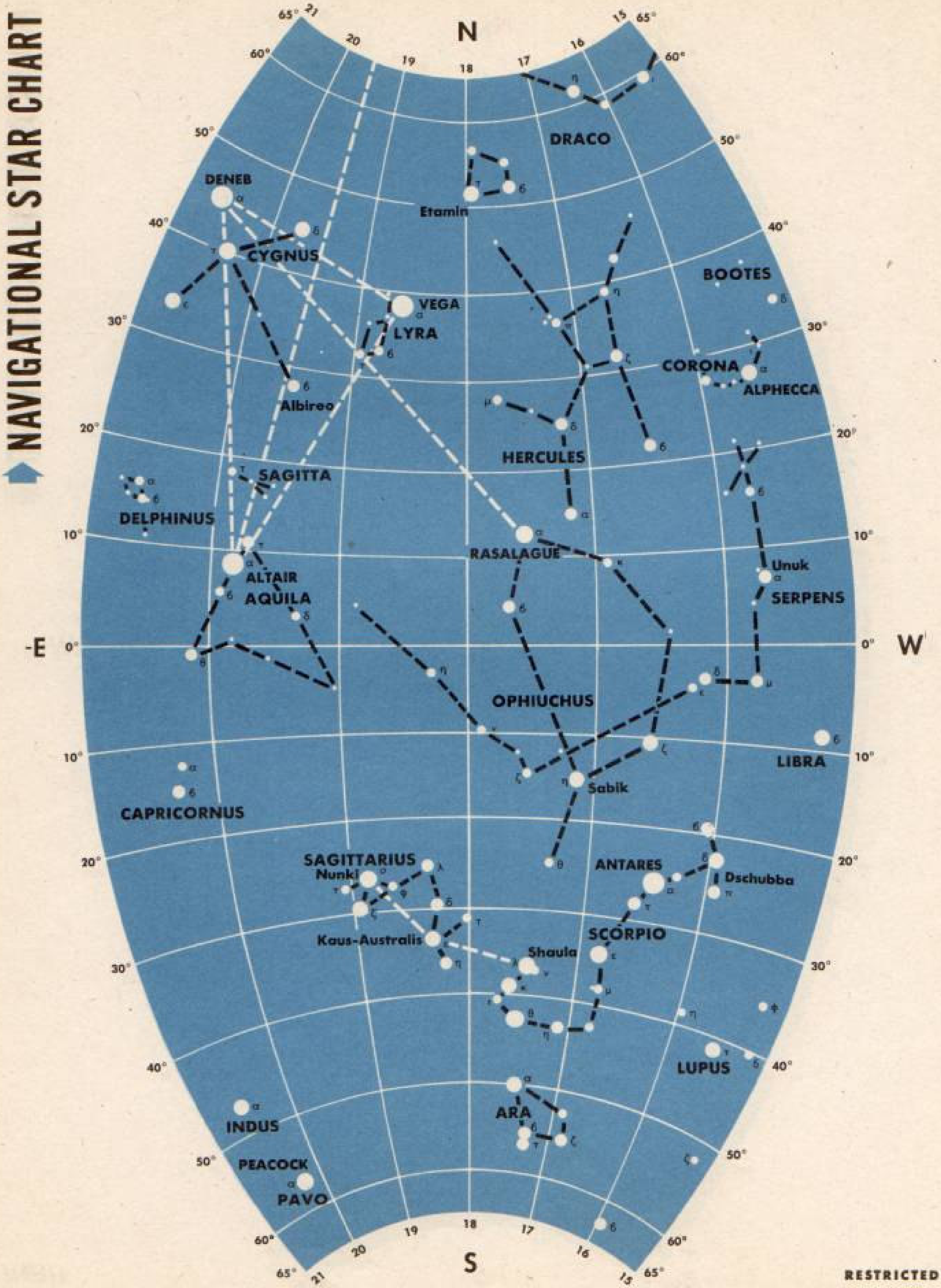

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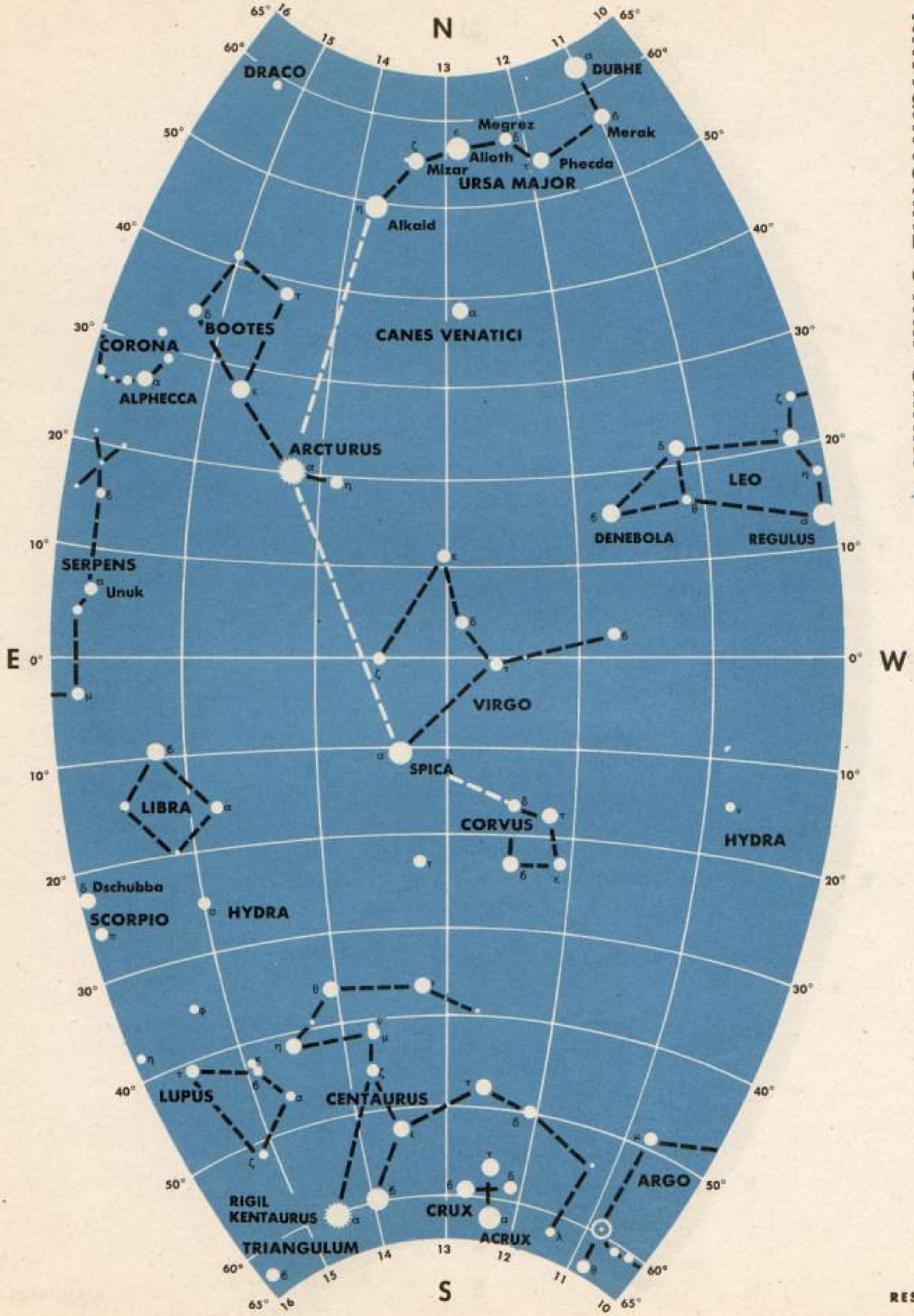

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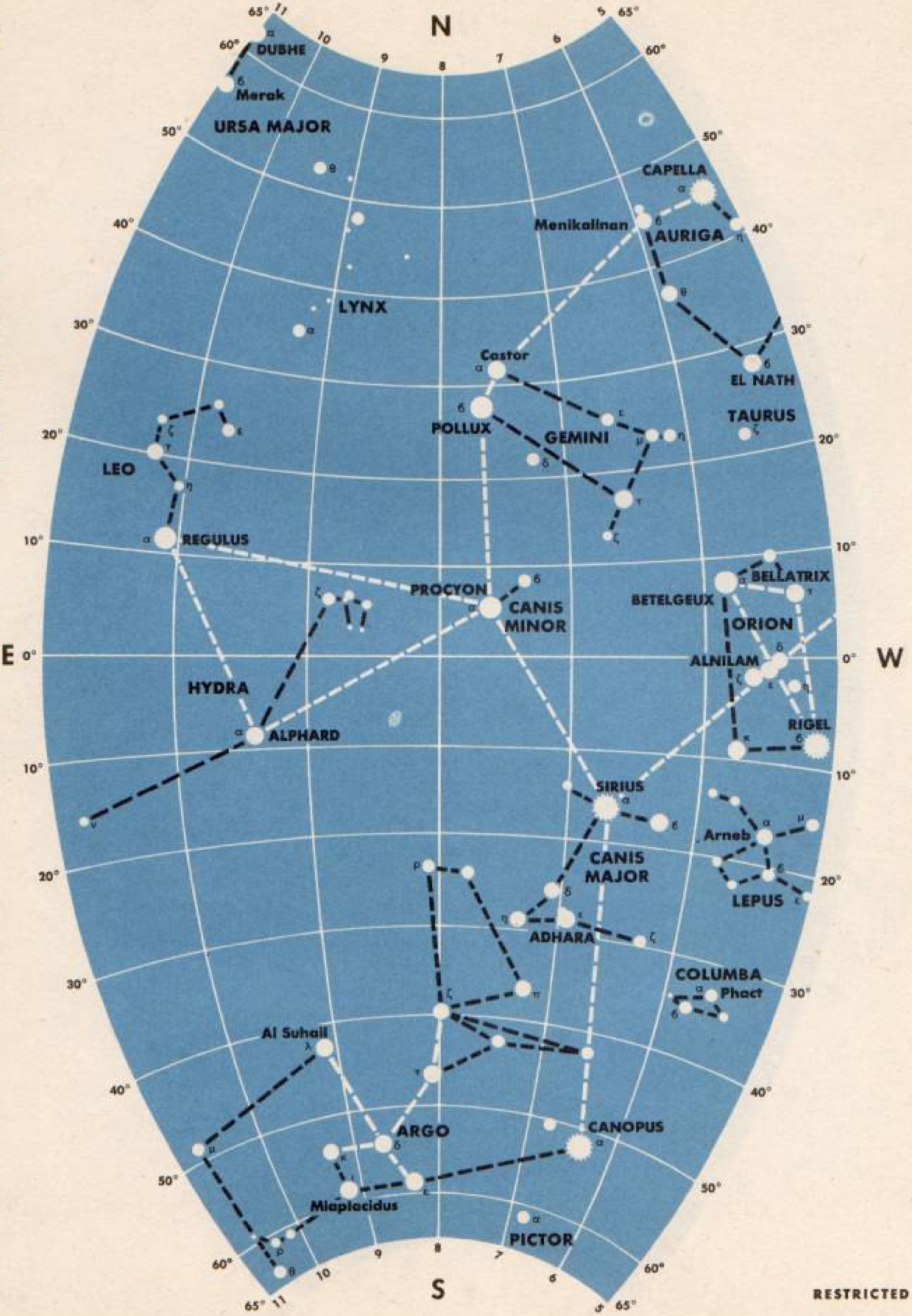
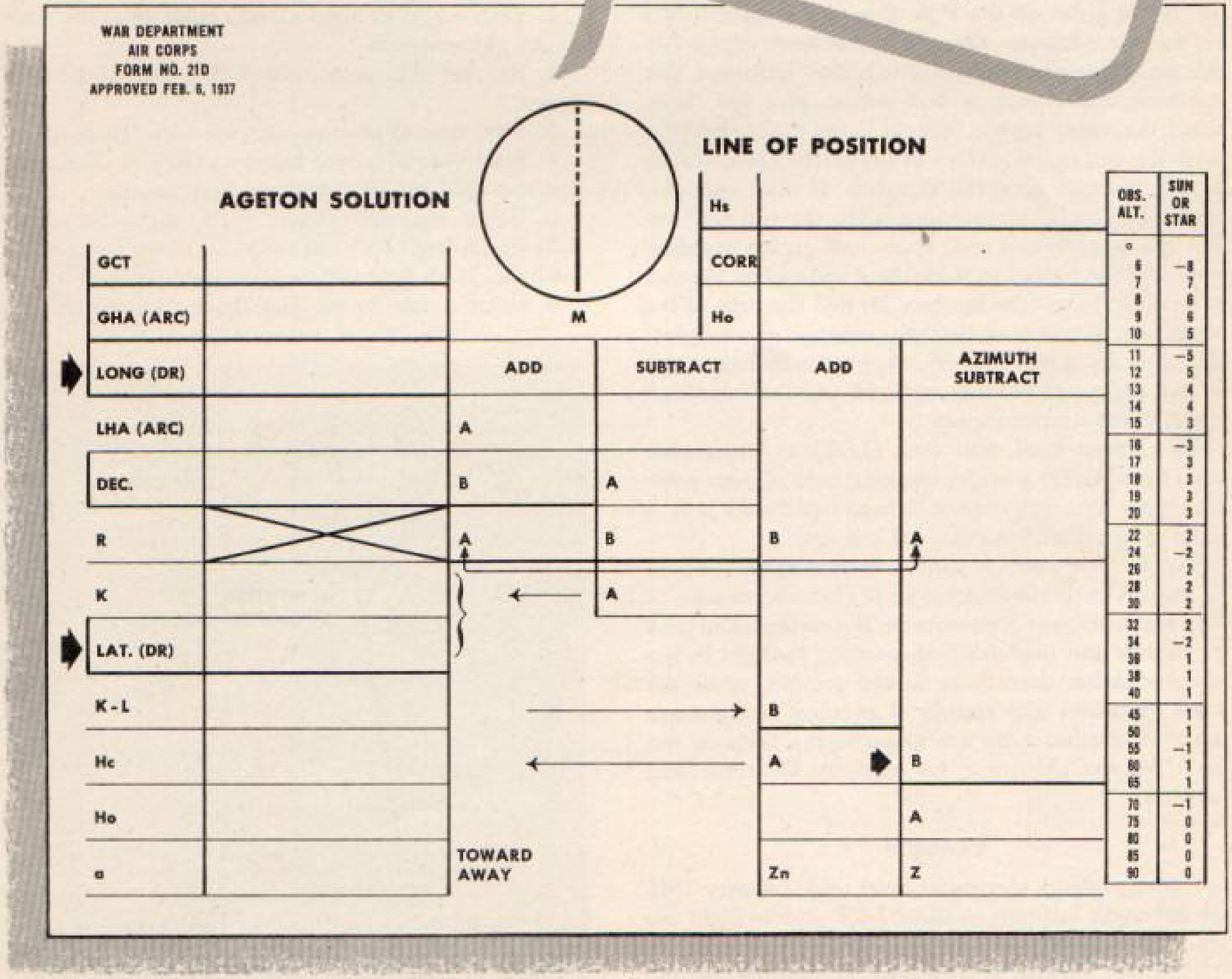


AGETON SOLUTION

Ageton solves the astronomical triangle. Be sure you know how to use the forms properly, then follow the signposts. All rules governing use of this form are found in Ageton H. O. 211, Dead Reckoning Altitude and Azimuth table.

KNOW HOW TO WORK THIS SOLUTION IN YOUR SLEEP....



WAR DEPARTMENT
AIR CORPS
FORM NO. 21D
APPROVED FEB. 6, 1937

AGETON SOLUTION

M

LINE OF POSITION

Hs	
CORR	
Ho	

		ADD	SUBTRACT	ADD	AZIMUTH SUBTRACT
GCT					
GHA (ARC)					
➧ LONG (DR)					
LHA (ARC)		A			
DEC.		B	A		
R		A	B	B	A
K		←	A		
➧ LAT. (DR)					
K - L		→		B	
Hc		←		A ➧	B
Ho					A
a		TOWARD AWAY		Zn	Z

OBS. ALT.	SUN OR STAR
°	
6	−8
7	7
8	6
9	6
10	5
11	−5
12	5
13	4
14	4
15	3
16	−3
17	3
18	3
19	3
20	3
22	2
24	−2
26	2
28	2
30	2
32	2
34	−2
36	1
38	1
40	1
45	1
50	1
55	−1
60	1
65	1
70	−1
75	0
80	0
85	0
90	0

Almanac Tables

Digest all information contained in the Air Almanac. Check each new issue. Additions are being made, so study the changes until you understand their meanings and application thoroughly.

Sunrise and Sunset Tables

Tables for finding the local civil time of sunrise, sunset, beginning and ending of civil twilight, moonrise and moonset for latitudes between 60° S and 70° N are given on the P.M. side of the daily sheets in the Air Almanac. Graphs in the back of the Air Almanac extend these tables to higher latitudes. The columns under sunrise and sunset give the times when the **upper limb** is tangent to the visible horizon with the eye at the surface of the earth. The columns under twilight give the duration of civil twilight, which begins in the morning when the sun is 6° below the horizon and ends at sunrise. In the evening, civil twilight begins at sunset and ends when the sun is again 6° below the horizon. To find the time of the beginning of morning twilight, subtract the tabulated value from the time of sunrise. To find the time of the ending of evening twilight add the tabulated value to the time of sunset.

To convert local civil time (LCT) to Greenwich civil time (GCT) convert the longitude of your position into time (15° equals 1 hour) and add if it is west of Greenwich, subtract if it is east.

The times of sunrise, sunset, beginning and ending of twilight are affected by your altitude because of Dip and increased Atmospheric Refraction. The time of sunrise and beginning of morning twilight in the air are earlier than those on the ground, while the time of sunset and ending of evening twilight are later. The differences are given in the table in the back of the Almanac for various latitudes and heights.

Example

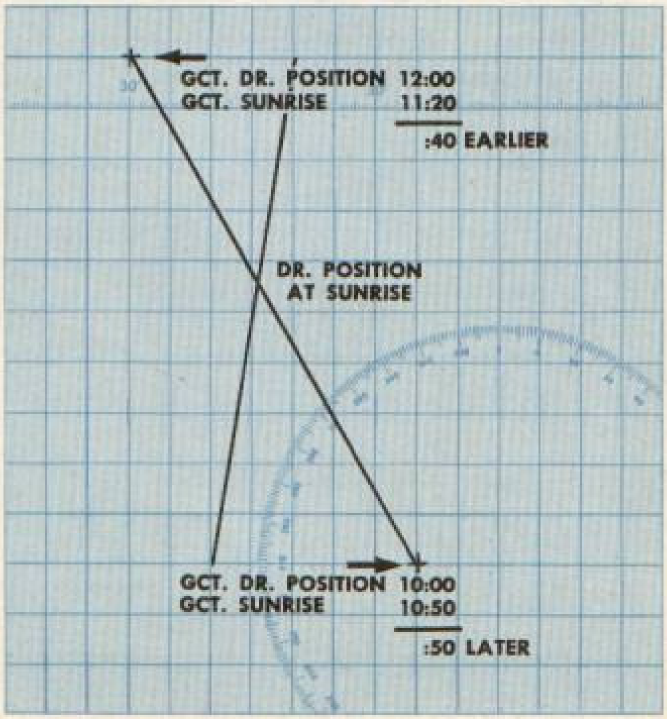
Sunrise occurs at ground level on 1 January 1944 at 40° north latitude at 07:22 LCT and twilight occurs 31 minutes earlier or at 06:51. However, at 10,000 feet sunrise is observed 12 minutes earlier or at 07:10 and twilight is observed 2 minutes earlier or at 06:49.

If DR longitude is 72° 30′ W you have to add 4 hours and 50 minutes to each of the above times to convert them to GCT.

Sunrise and Sunset in Flight

To find the time and position of sunrise or sunset on your flight path:

1. Estimate your approximate position at the time of the phenomenon.
2. Bracket this point with DR positions 2 hours apart.
3. Find time of phenomenon for each DR position.
4. Find the difference between GCT of phenomenon and GCT of DR position at both points.
5. Using any convenient scale, mark off these differences from both DR positions along parallels of latitude. Mark them off in opposite directions.
6. Draw a line to connect these two points. The



DR position of the phenomenon is where this line crosses your course line.

Solve this mathematically as follows:

GCT of 1st DR position	10:00
GCT of sunrise	10:50
	:50 Later
GCT of 2nd DR position	12:00
GCT of sunrise	11:20
	:40 Earlier

The sun rises five ninths of the time difference (02:00) after the time of the first DR position.

$\frac{5}{9} \times 120 = 66.6$ minutes.

Sunrise occurs at 11:07.

LOPs by Sunrise or Sunset

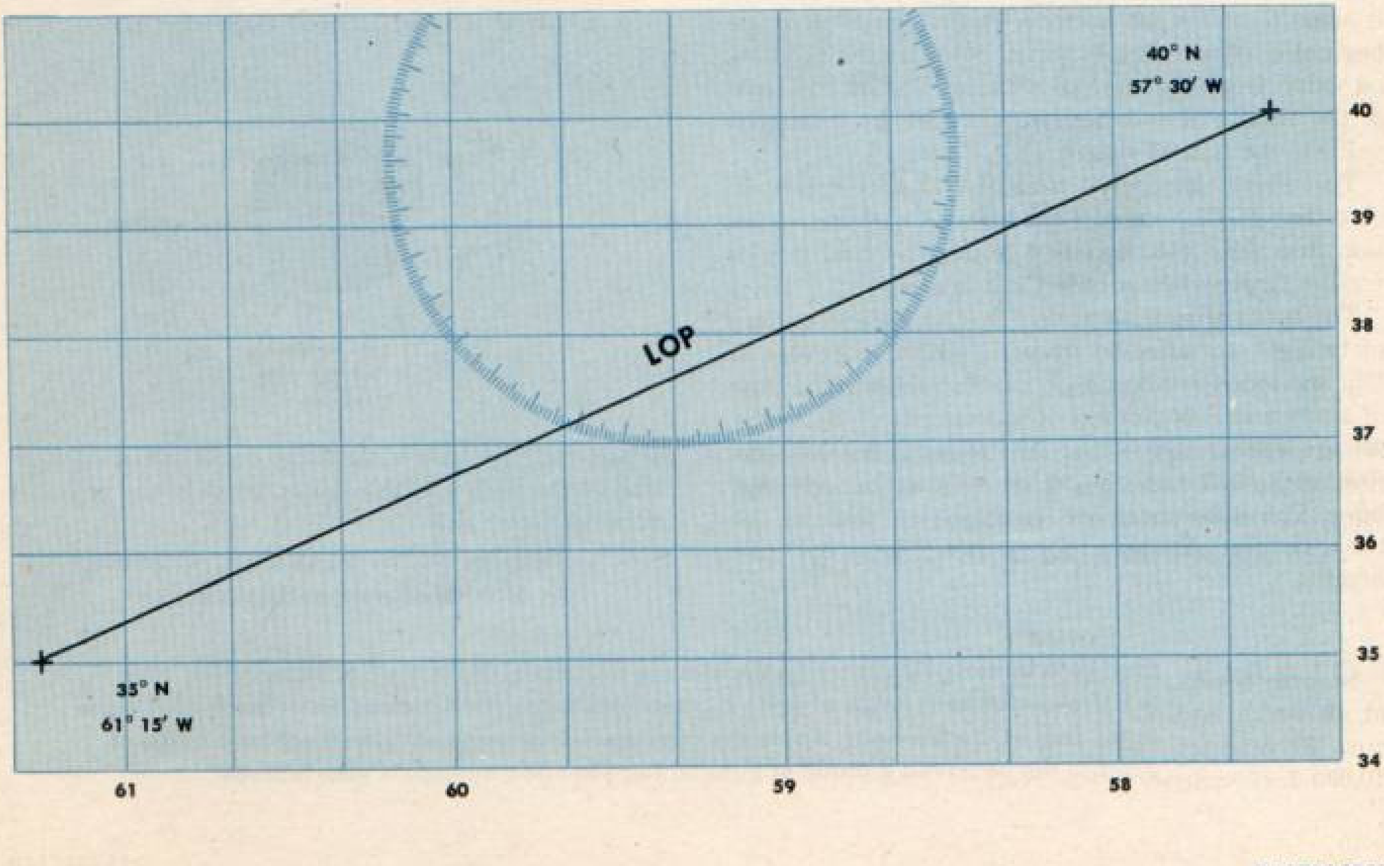
In an emergency you can use the observed time of sunrise or sunset to determine a LOP with a moderate degree of accuracy. Note the GCT when the sun's upper limb becomes tangent to the visible horizon. Use the Air Almanac to determine the LCT of the phenomenon, being sure to make the additional correction for altitude of the airplane. Extract values of LCT for latitudes on either side of your position. The difference between the GCT and the LCT is the longitude in units of time which is then converted into degrees and minutes (use the table in the back of the Almanac). Knowing the longitude for positions on either side of your DR position, plot these points and connect them with a straight line. This is your LOP.

Example

Flying at approximately 38° N, you observe the GCT of sunrise on 1 January 1944 to be 11:01. Your altitude is 10,000 feet. The P.M. page gives the LCT of sunrise at 35° N and 40° N as 07:08 and 07:22 respectively. The correction for altitude is minus 12 minutes and minus 11 minutes, giving values of 06:56. and 07:11. Subtract these from the GCT of 11:01 to get longitudes of 4 hours and 05 minutes and 3 hours and 50 minutes or 61° 15′ W and 57° 30′ W.

Corrections for Semi-diameter and Dip

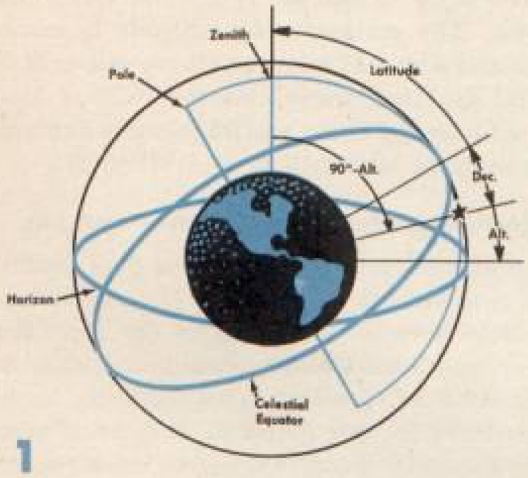
Many navigators have found that they obtain excellent results by using the sea horizon instead of the bubble horizon. When using the sea horizon, however, you must make a correction for Dip to all sextant altitudes. The Dip correction table is on the back cover of the Air Almanac. It is usual practice to make the lower limb of the sun or moon tangent to the sea horizon. Add the correction for semi-diameter to the sextant altitude. This correction is given on the A.M. side of the daily sheets. Occasionally it is necessary to observe the upper limb of the moon. When observing the upper limb, be sure to subtract semi-diameter from your sextant altitude.



OBSERVATIONS FOR LATITUDE

If the azimuth of a body is 0° or 180° from your position, it is on your meridian.

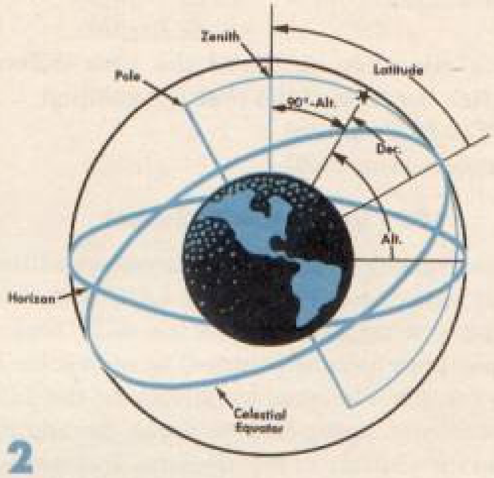
Use one of the following formulas to find your latitude.



1

When your latitude is opposite in name from the declination of the body,

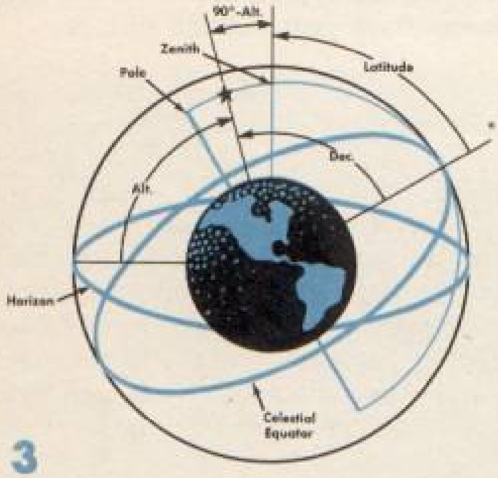
Latitude = (90° — Altitude) — Declination



2

When your latitude is the same name as the declination of the body, and the body is between you and the equator, (declination less than latitude)

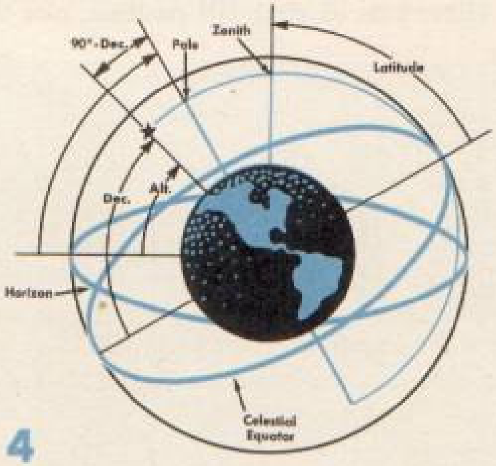
Latitude = (90° — Altitude) + Declination



3

When your latitude is the same name as the declination of the body and the body is between you and the pole, (declination greater than latitude)

Latitude = Declination — (90° — Altitude)



4

When your latitude is the same name as the declination of the body and the star is between the pole and your horizon,

Latitude = (90° — Declination) + Altitude

Altitude of pole equals latitude.

POLARIS **Find your latitude by observing the altitude of Polaris. At the time of observation, find the Greenwich hour angle of Aries by reference to the Air Almanac. Enter the Polaris table in the rear of the Almanac. Apply the correction shown opposite the local hour angle of Aries to the observed altitude of Polaris. The corrected altitude is your latitude.**

DAYTIME FIXES

Daylight Over-Water Flights

If you have to dead reckon over water for hours, under adverse conditions, during the daytime, celestial observations and good common sense will help you find your way. Here are some combinations that you can use:

Cross a sun line with a radio bearing. Remember, bearings and stations more than 200 miles away, or closer than 50 miles, are seldom accurate enough to give more than a general indication of position. Use radio bearings with caution. (See NIF 2-23.)

Cross a sun line with a moon line of position.

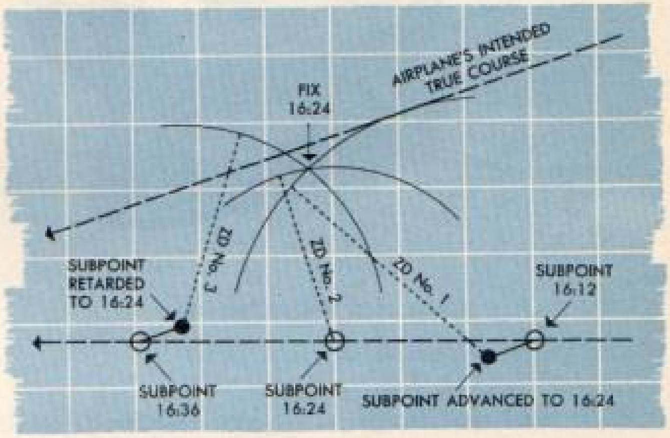
Cross a sun line with a coastline. If you are crossing a coastline, island chain, or some other terrestrial line on which you cannot fix your position definitely, obtain a fix by shooting the sun at the same time that you cross the terrestrial line.

Cross a sun line with another sun line. At local noon the azimuth of the sun changes rapidly, especially in low latitudes. The time interval varies with the latitude of the observer and the declination of the body.

For example, at 30° north latitude on June 1, the azimuth of the sun changes 57° in one hour. Take a sun line a half hour before noon, take one at noon, and take one a half hour after noon. Move them all up to the same time, to obtain a fix.

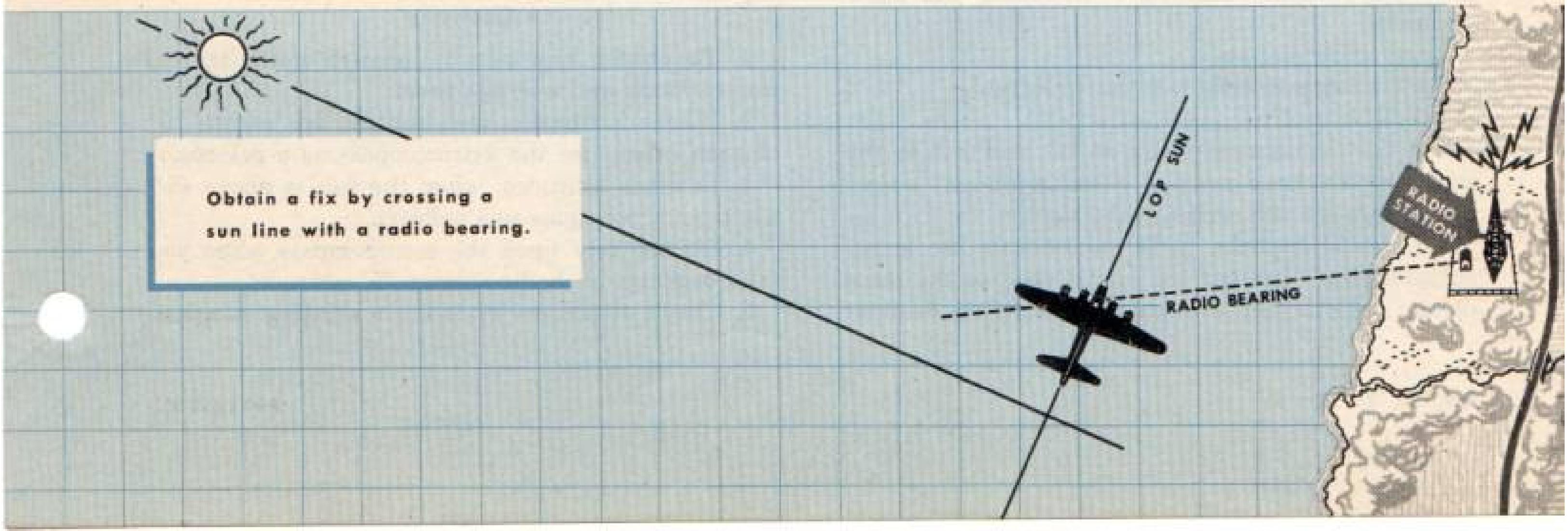
Meridian altitudes. Apply the rules involving combinations of observed altitude and declination.

Advance one sun line to another over a period of time. While this method is not too accurate, it does give you a general picture of the trend of your flight. A little common sense helps a great deal in the interpretation of these lines. Move all sun lines with true airspeed or the best known groundspeed. The best known groundspeed may be the one found between two LOP's. Use this information when a more accurate groundspeed check is not possible.

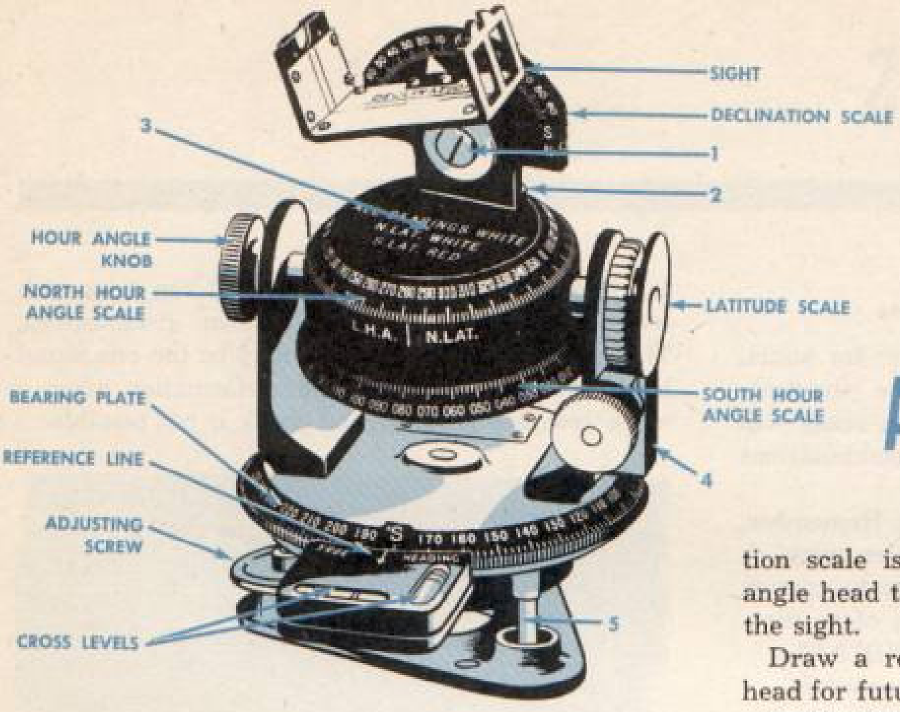


High-Altitude Shots

If the altitude of the body is 85° or more, plot the usable arc of the circle of equal altitude. Plot the subpoint of the body by using Greenwich hour angle and declination as longitude and latitude. Swing a circle using 90° minus altitude (zenith distance) as the radius. You can do this with a piece of string. The line of position will be curved. To move up such a position arc for time, move up the sub-point of the body for groundspeed parallel to course and swing off a new arc from the new center. Two such circles intersect at two points. It usually is possible to select the reasonable intersection of the two circles and find the fix.


Obtain a fix by crossing a sun line with a radio bearing.

ASTROCOMPASS



Care and Adjustment

1. To tighten motion of sight gear:

Loosen locknut.

Turn shoulder screw until you obtain desired friction.

Tighten locknut.

2. Entire sight assembly must be mounted firmly. Tighten the two screws behind the declination scale to insure correct mounting. At certain times during the day, 1° error in LHA causes up to 10° error in azimuth.

To check:

Unloosen two rear screws.

Set true bearing at 180°.

Sight down declination scale (0° south latitude) to the true bearing index.

Move sight assembly until it is aligned.

Tighten screws.

Draw a reference line on the north hour-angle head for future alignment.

Here is another method of checking the sight assembly:

Level astrocompass.

Set the latitude scale to 0° north latitude.

Set LHA to 270°.

Set the declination index to 0° and rotate the astrocompass head until a suitable distant object passes through the center of the sight.

Set the LHA drum to 90° and rotate the astrocompass head through 180° until you see the same distant object again through the sight. If the declination scale is correctly aligned on the north hour-angle head the object will still pass exactly through the sight.

Draw a reference line on the north hour-angle head for future alignment.

3. Check the three screws above and below the hour-angle head to see that they are snug. They mount the LHA scales on enclosed drive assembly.

4. To obtain correct latitude settings, tighten the two screws which fasten the micrometer knob and worm to the upright. Keep tension between worm and worm gear by checking to see that the two screws holding the springs are secure. Increase spring tension by bending the spring slightly.

5. Vibration of the airplane causes errors if the azimuth circle does not have a sufficient amount of friction to stay on set readings.

Increase tension in this manner:

Clamp spring leg in depressed position.

Remove two opposite screws from yoke to separate upper section from base.

Remove locknut.

Adjust tension until desired drag results.

Replace locknut and mount in reverse order.

You can adjust these nuts without removing the base if you have a special socket wrench that reaches through the base.

Cautions

1. To obtain best results, always make several observations and average them.

2. When declination and latitude are within 20° of each other, use the astrocompass as a pelorus.

3. In other latitudes, when the sun is above 45°, use the astrocompass as a pelorus.

4. Do not rely upon the astrocompass when you take bearings on bodies above 75° altitude.

5. Check alignment by using a sighting compass.

2. Place astrocompass in the standard and level.

3. Set the latitude and declination and LHA of the sun on the proper scales.

4. Rotate the astrocompass until the shadow of the bar falls between the parallel lines on the shadow screen.

5. Compare the true heading of the airplane with the astrocompass reading.

6. The difference between the two headings is the correction which must be applied to the astrocompass readings to obtain the true heading.

7. The error may be removed at one position of the astrocompass in the dome by loosening the base mounting screws and turning the standard until the two headings are the same. Tighten the base mounting screws and recheck alignment.

Another Method

1. Place a base standard on a saw-horse. Align it with a line drawn down the center of the horse.

2. Cut a notch at both ends of the line.

3. Align the saw-horse with the fore and aft axis of the airplane by dropping the plumb-bobs from the notches over a line parallel to the longitudinal axis.

4. Place the astrocompass on the saw-horse and find true heading. This is the correct true heading of the airplane.

5. Place the astrocompass in the base standard in the airplane to find the correction for that position.

Alignment Check

You can check the alignment by using the astrocompass as a pelorus. Set local hour angle at 0° or 180° and latitude at 90°. Obtain the bearing of some part of the airplane. Write this bearing down and keep it in your compartment so you can check alignment in flight on future missions.

Uses of the Astrocompass

1. **Check the true heading of the airplane.**

a. Place the instrument in the mount and level it. An error of 1° in level may cause an error of 1° or more in observation.

b. Set the latitude to the nearest degree.

c. Calculate and set the local hour angle of the body to be observed on the proper hour angle scale.

d. Set the declination of the body.

e. Rotate the bearing plate until the sights are aligned on the body. In observing the sun or moon, rotate the bearing plate until the shadow cast by the shadow bar falls between the proper marks on the translucent screen.

f. When the sights are aligned, read the true heading of the airplane against the lubber line.

2. **Steer a true heading.**

a. Set the true heading you want to fly against the bearing plate lubber line.

b. Set the instrument for latitude, declination and local hour angle and level it.

c. Have the pilot turn the airplane until the selected body comes into your sights.

d. Maintain heading by directional gyro.

e. Check the true heading with the astrocompass at least every 15 minutes, altering the true heading steered on the directional gyro if necessary.

3. **Identify a star.**

a. Place the compass in its mount and level it.

b. Rotate the bearing plate until the true heading registers against the lubber line.

c. Set the correct latitude.

d. Turn the hour angle scale and adjust the declination scale until the star is on the sights.

e. Read off the local hour angle of the star and its declination.

f. Use the Air Almanac to calculate the sidereal hour angle of the star.

g. From the table on the inside back cover of the Air Almanac, find the star by its declination and sidereal hour angle.

4. **Use as a pelorus.**

a. Place the compass in its mount and level it.

b. Set the true heading on the bearing plate, against the lubber line.

c. Set the latitude scale to 90°. This makes the hour angle scales parallel to the bearing plate.

d. Turn the hour angle knob until you sight the object, just as you would sight a star.

e. Read the true bearing on the hour angle scale against the true bearing lubber line.

f. Note that if the bearing plate were set to "N", you would read relative bearing.

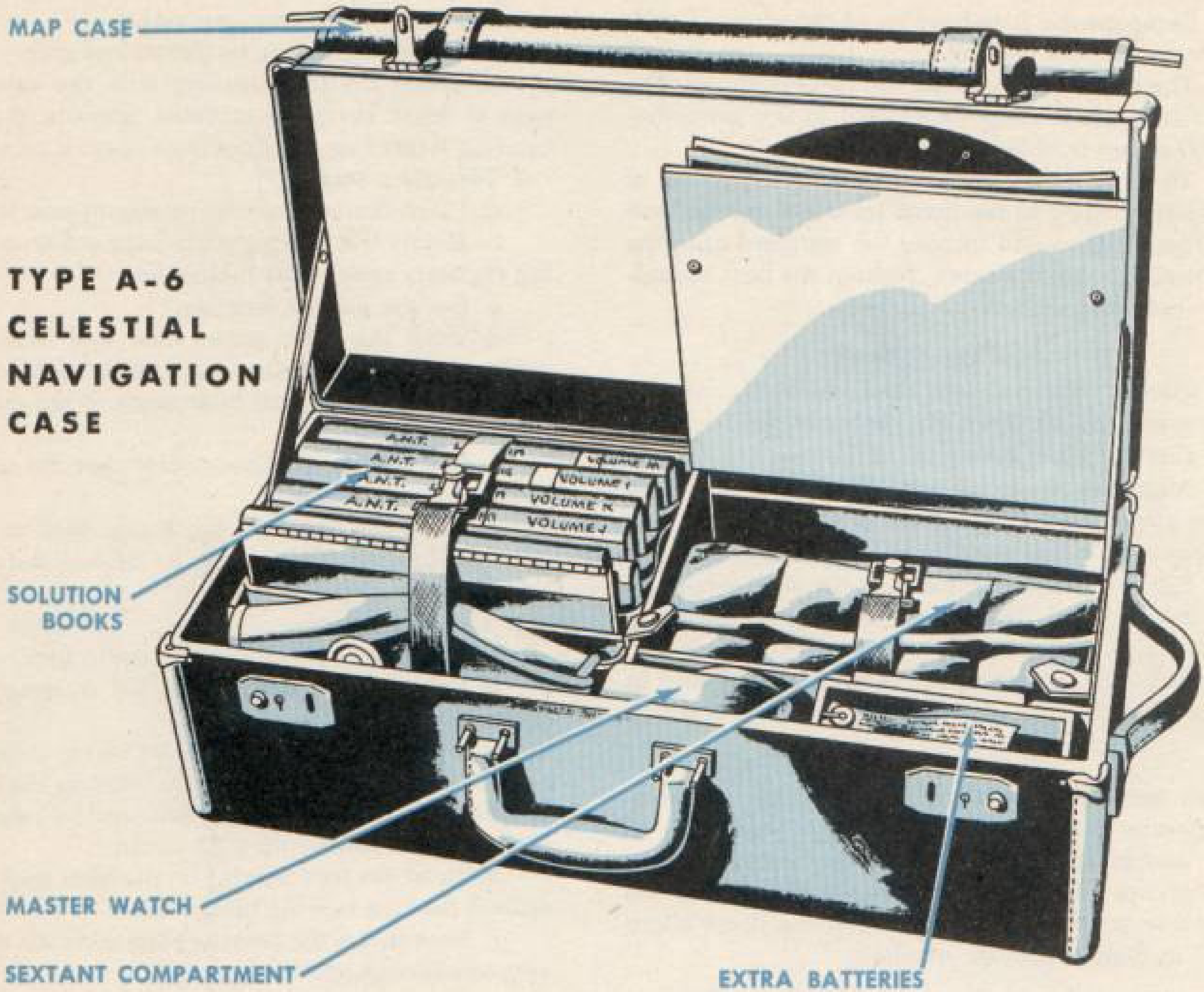
Caution

When turning the local hour angle scale, be sure to push in the knob. Don't force it.

When observing the sun or moon, be sure that the shadow of the bar on the front sight falls between the parallel lines on the shadow screen.

When observing any other body, place your eye behind the small magnifying glass and sight the star through the intersection of the white lines of the foresight. If you do not sight the star through the intersection of the white lines, you can still get a correct reading when it is vertically above the point of intersection of the white lines. Do not change the declination setting to put the star at the intersection.

CELESTIAL NAVIGATION CASE



TYPE A-6 CELESTIAL NAVIGATION CASE

Take Care of Your Equipment

Type A-6 celestial navigation case is designed to carry all of your equipment, compactly and comfortably. Use it on every flight. Carry solution books and forms in the compartment constructed to fill this requirement. You can carry any type of sextant in the padded compartment equipped with the two tie-down straps. Always tighten the straps securely before closing the case.

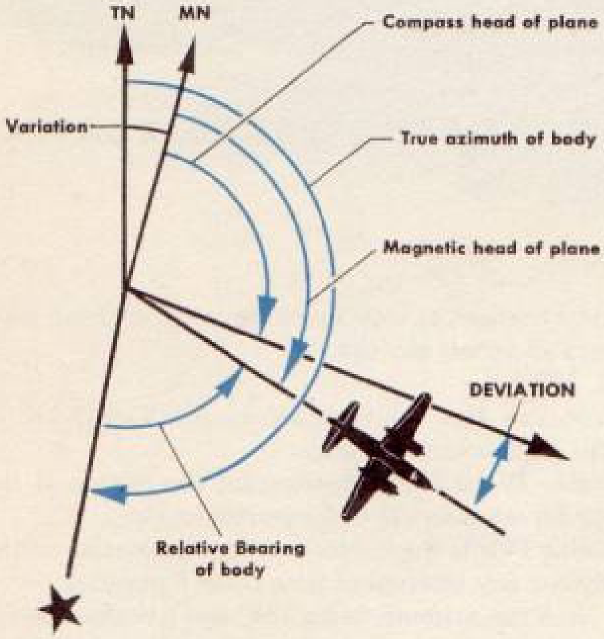
Carry your maps in the outside pocket. They can either be folded or rolled.

Hang the insert containing your plotting equipment above your desk in the airplane.

Procure Type A-6 celestial navigation case through regular supply channels.

CELESTIAL COMPASS SWING

Record the azimuth of the body observed and the relative bearing of that body from the heading of your plane, at a given instant of time. You can then find the magnetic heading of the airplane by using the following diagram:



Obtain the relative bearing of the body with your driftmeter, pelorus, astrocompass or gun turret.

Local Hour Angle Tables

Use the following local hour angle tables to make your air swinging easier.

This is an alternative to the more usual local hour angle graph employed when air swinging the compass by astrocompass. This critical table is both easier to prepare, and much handier to refer to while in the air.

1. Look up the Greenwich hour angle of the sun for the time at which you expect to begin the swing.

2. Convert this to local hour angle of the sun by applying your longitude in the usual way.

3. Add to the local hour angle the number of minutes necessary to increase it to the half degree; e.g., to 300° 11′ add 19′ = 300½°.

4. Correct time for this addition to the hour angle, by multiplying the number of minutes of arc added to the local hour angle by 4. The answer is **seconds of time** you must add to the original time.

Local hour angle of the sun alters at a rate of 1° in 4 minutes of time. Add 4 minutes to the time finally obtained above. This is the time at which the local hour angle reaches the next degree-and-a-half. Anywhere between these two times, you can set the whole degree on the astrocompass.

As an example:

You expect the swing to begin at 08:00 GCT and the Greenwich hour angle of the sun is 299° 53′. Local longitude is 5° 09′ West.

		GCT
299° 53′	= GHA sun	08:00:00
−5° 09′	West longitude	
294° 44′	= LHA sun	
+ 46′	4 × 46 = 184 sec.	03:04
295½°	= Local hour angle sun	08:03:04
and 296½°	= Local hour angle sun	08:07:04

Therefore between 08:03:04 and 08:07:04, you can set 296° on your astrocompass. Then write the critical table as follows:

GCT	LHA Sun
08:03:04	296°
08:07:04	297°
08:11:04	298°
08:15:04	299°
08:19:04	300°
08:23:04	

Just keep adding 4 minutes and 1 degree each time. Then at any time between 08:15:04 and 08:19:04 the correct figure to set on your astrocompass is 299°.

If the swing doesn't start as soon as you expected it to, you can carry the table on for as long as necessary. If you carry it on for more than about 5 hours, an error of about 4 seconds of time is introduced.

ADJUSTMENT FOR TIME

PRECOMPUTED SOLUTIONS ARE GREAT TIME SAVERS

Two Methods of Adjusting for Time

1. The table that follows is self-explanatory with the possible exception that "Z" is the azimuth angle to the nearest pole. This can never be over 90°

Example

Make a precomputed solution for 0500 GCT on the body Dubhe. You find the azimuth to be 160°. The local hour angle is east.

a. At 04:55 you take an observation on Dubhe, at a dead reckoning latitude of 32° north, "Z", the azimuth angle to the nearest pole, is 20°.

b. Entering "Z," at 20° and latitude at 32° north, 4.4 is the change of altitude in one minute of time.

c. Since the observation was 5 minutes before the time of the solution, 4.4 is multiplied by 5. The correction you must apply to the observed altitude is 22 minutes of arc.

d. The rules directly below the table tell you whether to add the correction to the observed altitude or to subtract it from the observed altitude.

e. In this example the observation is early, and the local hour angle of the body is east. Local hour angle east means the body is rising. Add the correction to the observed altitude.

f. Be sure to move the line of position either up or back on the chart for distance run. For you must make a correction for your movement over the earth's surface, as well as for the motion of the body observed across the sky.

2. HO 218.

You can also use table IV in A.N.T. HO 218 to make adjustment for time.

Table IVa is the correction for the motion of the body for an interval of 3 minutes of time.

Table IVb is the correction for the motion of the body for any interval of time up to 3 minutes.

a. True azimuth being 160° and a correction for 5 minutes of time required at 32° north, enter Table IVa to find the correction for the motion of the body.

b. You find the figure plus 13 minutes. This is the correction for 3 minutes of time.

c. Enter Table IVb with 13 minutes at the required number of minutes of time, (2 in this case).

d. By interpolating between 12 and 15, you find the correction to be 9 minutes.

e. Add 13 and 9 to find the correction due to motion of body for 5 minutes. The correction is 22.

You can also use these tables to make the correction for your movement over the earth's surface.

Use the second part of Table IVa to find this correction for the motion of the observer.

Combine this correction with the correction for the motion of the body before entering Table IVb.

If you use this HO 218 solution you won't have to move the line of position once you have plotted it.

CHANGE OF ALTITUDE IN ONE MINUTE OF TIME (TABULATIONS IN MINUTES OF ARC)

LAT. \ Z	0°	2½°	5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°	32½°	35°	37½°	40°	42½°	45°	47½°	50°	52½°	55°	57½°	60°	62½°	65°	67½°	70°	75°	80°	90°	LAT.
0°	0	0.7	1.3	1.9	2.6	3.2	3.9	4.5	5.1	5.7	6.3	6.9	7.5	8.0	8.6	9.1	9.6	10.1	10.6	11.0	11.5	11.9	12.3	12.7	13.0	13.3	13.6	13.8	14.1	14.5	14.8	15.0	0°
4°	0	0.7	1.3	1.9	2.6	3.2	3.9	4.5	5.1	5.7	6.3	6.9	7.5	8.0	8.6	9.1	9.6	10.1	10.6	11.0	11.5	11.9	12.3	12.6	13.0	13.3	13.6	13.8	14.1	14.5	14.7	15.0	4°
8°	0	0.7	1.3	1.9	2.6	3.2	3.8	4.4	5.1	5.7	6.3	6.8	7.4	7.9	8.5	9.0	9.5	10.0	10.5	11.0	11.4	11.8	12.2	12.5	12.9	13.2	13.5	13.7	14.0	14.4	14.6	14.9	8°
12°	0	0.7	1.3	1.9	2.5	3.1	3.8	4.4	5.0	5.6	6.2	6.7	7.3	7.8	8.4	8.9	9.4	9.9	10.4	10.8	11.2	11.6	12.0	12.3	12.7	13.0	13.3	13.5	13.8	14.2	14.4	14.7	12°
16°	0	0.7	1.3	1.9	2.5	3.1	3.7	4.3	4.9	5.5	6.1	6.6	7.2	7.7	8.3	8.8	9.3	9.8	10.2	10.6	11.0	11.4	11.8	12.1	12.5	12.8	13.1	13.3	13.5	13.9	14.2	14.4	16°
20°	0	0.6	1.2	1.8	2.4	3.0	3.6	4.2	4.8	5.4	6.0	6.5	7.0	7.5	8.1	8.6	9.1	9.5	10.0	10.4	10.8	11.1	11.5	11.8	12.2	12.5	12.8	13.0	13.2	13.6	13.9	14.1	20°
24°	0	0.6	1.2	1.8	2.4	3.0	3.5	4.1	4.7	5.3	5.8	6.3	6.9	7.4	7.9	8.4	8.8	9.2	9.7	10.2	10.5	10.8	11.2	11.5	11.9	12.2	12.4	12.6	12.9	13.2	13.5	13.7	24°
26°	0	0.6	1.2	1.7	2.3	2.9	3.5	4.0	4.6	5.1	5.7	6.2	6.7	7.2	7.7	8.2	8.7	9.1	9.5	9.9	10.3	10.6	11.0	11.3	11.7	12.0	12.2	12.5	12.7	13.0	13.3	13.5	26°
28°	0	0.6	1.2	1.7	2.3	2.8	3.4	4.0	4.5	5.0	5.6	6.1	6.6	7.1	7.6	8.0	8.5	9.0	9.4	9.7	10.1	10.4	10.8	11.1	11.5	11.7	12.0	12.2	12.4	12.8	13.1	13.2	28°
30°	0	0.6	1.1	1.7	2.3	2.8	3.4	3.9	4.4	5.0	5.5	6.0	6.5	7.0	7.4	7.8	8.3	8.8	9.2	9.6	9.9	10.2	10.6	10.9	11.2	11.5	11.8	12.0	12.2	12.5	12.8	13.0	30°
32°	0	0.5	1.1	1.6	2.2	2.7	3.3	3.8	4.4	4.9	5.4	5.9	6.4	6.9	7.3	7.7	8.2	8.6	9.0	9.4	9.7	10.0	10.4	10.7	11.0	11.3	11.5	11.8	12.0	12.3	12.5	12.7	32°
34°	0	0.5	1.1	1.6	2.2	2.7	3.2	3.7	4.3	4.8	5.3	5.8	6.2	6.6	7.1	7.5	8.0	8.4	8.8	9.2	9.5	9.8	10.2	10.5	10.8	11.0	11.3	11.5	11.7	12.0	12.3	12.4	34°
36°	0	0.5	1.1	1.6	2.1	2.6	3.1	3.6	4.2	4.6	5.1	5.6	6.1	6.5	7.0	7.4	7.8	8.2	8.6	9.0	9.3	9.6	9.9	10.2	10.5	10.7	11.0	11.2	11.4	11.7	12.0	12.1	36°
38°	0	0.5	1.0	1.5	2.1	2.6	3.1	3.5	4.0	4.5	5.0	5.4	5.9	6.3	6.8	7.2	7.6	8.0	8.4	8.7	9.1	9.4	9.7	10.0	10.2	10.5	10.7	10.9	11.1	11.4	11.6	11.8	38°
40°	0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	3.9	4.4	4.9	5.3	5.7	6.1	6.6	7.0	7.4	7.7	8.1	8.5	8.8	9.1	9.4	9.7	10.0	10.2	10.4	10.6	10.8	11.1	11.3	11.5	40°
42°	0	0.5	1.0	1.4	1.9	2.4	2.9	3.4	3.8	4.3	4.7	5.1	5.6	6.0	6.4	6.8	7.2	7.5	7.9	8.2	8.5	8.8	9.1	9.4	9.7	9.9	10.1	10.3	10.5	10.8	11.0	11.1	42°
44°	0	0.4	0.9	1.4	1.9	2.4	2.8	3.3	3.7	4.2	4.6	5.0	5.4	5.8	6.2	6.5	6.9	7.2	7.6	8.0	8.3	8.6	8.8	9.0	9.3	9.6	9.8	10.0	10.1	10.4	10.6	10.8	44°
46°	0	0.4	0.9	1.3	1.8	2.3	2.7	3.2	3.6	4.0	4.4	4.8	5.2	5.6	6.0	6.3	6.7	7.0	7.4	7.7	8.0	8.3	8.5	8.7	9.0	9.2	9.4	9.6	9.8	10.1	10.3	10.4	46°
48°	0	0.4	0.9	1.3	1.7	2.2	2.6	3.0	3.4	3.8	4.3	4.6	5.0	5.4	5.8	6.1	6.5	6.8	7.1	7.4	7.7	8.0	8.2	8.5	8.7	8.9	9.1	9.3	9.4	9.7	9.9	10.0	48°
49°	0	0.4	0.8	1.3	1.7	2.2	2.5	2.9	3.4	3.8	4.2	4.5	4.9	5.3	5.7	6.0	6.3	6.6	6.9	7.2	7.6	7.8	8.0	8.3	8.5	8.7	8.9	9.1	9.2	9.5	9.7	9.8	49°
50°	0	0.4	0.8	1.2	1.7	2.1	2.5	2.9	3.3	3.7	4.1	4.4	4.8	5.1	5.5	5.8	6.2	6.5	6.8	7.1	7.4	7.6	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.5	9.6	50°
51°	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.6	4.0	4.3	4.7	5.0	5.4	5.7	6.0	6.3	6.6	6.8	7.2	7.5	7.7	7.9	8.1	8.3	8.5	8.7	8.9	9.1	9.3	9.4	51°
52°	0	0.4	0.8	1.2	1.6	2.0	2.4	2.8	3.2	3.5	3.9	4.2	4.6	5.0	5.3	5.6	5.9	6.2	6.5	6.8	7.1	7.4	7.6	7.8	8.0	8.2	8.4	8.6	8.7	8.9	9.1	9.2	52°
53°	0	0.4	0.8	1.2	1.6	2.0	2.3	2.7	3.1	3.4	3.8	4.1	4.5	4.9	5.2	5.5	5.8	6.1	6.4	6.7	7.0	7.3	7.5	7.7	7.9	8.1	8.3	8.4	8.5	8.7	8.9	9.0	53°
54°	0	0.4	0.8	1.2	1.5	1.9	2.3	2.6	3.0	3.4	3.7	4.0	4.4	4.8	5.1	5.4	5.7	6.0	6.2	6.5	6.8	7.0	7.2	7.4	7.6	7.8	8.0	8.2	8.3	8.5	8.7	8.8	54°
55°	0	0.4	0.7	1.1	1.5	1.8	2.2	2.5	2.9	3.2	3.5	3.9	4.3	4.6	4.9	5.2	5.5	5.8	6.1	6.3	6.6	6.8	7.0	7.2	7.5	7.6	7.8	8.0	8.1	8.3	8.5	8.6	55°
56°	0	0.4	0.7	1.1	1.5	1.8	2.2	2.5	2.9	3.2	3.5	3.8	4.2	4.5	4.8	5.1	5.4	5.7	5.9	6.2	6.4	6.7	6.9	7.1	7.3	7.4	7.6	7.8	7.9	8.1	8.3	8.4	56°
57°	0	0.3	0.7	1.1	1.4	1.7	2.1	2.5	2.8	3.1	3.5	3.8	4.1	4.4	4.7	5.0	5.2	5.5	5.8	6.0	6.3	6.5	6.7	6.9	7.1	7.2	7.4	7.6	7.7	7.9	8.0	8.2	57°
58°	0	0.3	0.7	1.0	1.4	1.7	2.0	2.4	2.7	3.0	3.4	3.7	4.0	4.3	4.6	4.8	5.1	5.3	5.6	5.8	6.1	6.3	6.5	6.7	6.9	7.0	7.2	7.4	7.5	7.7	7.8	8.0	58°
59°	0	0.3	0.7	1.0	1.3	1.6	2.0	2.3	2.6	3.0	3.3	3.6	3.9	4.2	4.4	4.7	5.0	5.2	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.9	7.0	7.2	7.3	7.5	7.6	7.7	59°
60°	0	0.3	0.7	1.0	1.3	1.6	1.9	2.3	2.6	2.9	3.2	3.6	3.8	4.1	4.3	4.6	4.8	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.7	6.8	6.9	7.0	7.2	7.4	7.5	60°
61°	0	0.3	0.7	1.0	1.3	1.6	1.9	2.3	2.6	2.9	3.2	3.6	3.8	4.1	4.3	4.6	4.8	5.1	5.3	5.5	5.7	5.9	6.1	6.3	6.5	6.6	6.7	6.8	6.9	7.0	7.2	7.3	61°
62°	0	0.3	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.7	3.0	3.3	3.5	3.8	4.0	4.2	4.5	4.7	5.0	5.2	5.4	5.6	5.8	5.9	6.1	6.2	6.4	6.5	6.6	6.7	6.9	7.0	62°
63°	0	0.3	0.6	0.9	1.2	1.5	1.7	2.0	2.3	2.6	2.9	3.1	3.4	3.5	3.8	4.0	4.3	4.5	4.8	5.0	5.2	5.4	5.6	5.7	5.9	6.0	6.2	6.3	6.4	6.5	6.7	6.8	63°
64°	0	0.3	0.6	0.9	1.2	1.4	1.7	2.0	2.3	2.6	2.8	3.0	3.3	3.5	3.7	3.9	4.2	4.4	4.7	4.9	5.1	5.2	5.4	5.5	5.7	5.8	6.0	6.1	6.2	6.3	6.4	6.5	64°
65°	0	0.3	0.6	0.9	1.1	1.4	1.6	1.9	2.2	2.5	2.7	2.9	3.2	3.4	3.6	3.8	4.1	4.3	4.5	4.7	4.9	5.0	5.2	5.3	5.5	5.6	5.8	5.9	6.0	6.1	6.2	6.3	65°
66°	0	0.3	0.5	0.8	1.0	1.3	1.5	1.8	2.1	2.4	2.6	2.8	3.0	3.3	3.5	3.7	4.0	4.1	4.3	4.5	4.7	4.9	5.0	5.1	5.3	5.4	5.5	5.6	5.7	5.9	6.0	6.1	66°
67°	0	0.2	0.5	0.8	1.0	1.2	1.5	1.7	2.0	2.3	2.5	2.7	2.9	3.2	3.4	3.6	3.8	4.0	4.1	4.3	4.5	4.7	4.8	5.0	5.1	5.2	5.3	5.4	5.5	5.7	5.8	5.9	67°
68°	0	0.2	0.5	0.8	1.0	1.2	1.5	1.7	1.9	2.1	2.4	2.6	2.8	3.0	3.2	3.4	3.6	3.8	4.0	4.1	4.3	4.5	4.6	4.8	4.9	5.0	5.1	5.1	5.2	5.4	5.5	5.6	68°
69°	0	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0	2.3	2.5	2.7	2.9	3.1	3.3	3.5	3.6	3.8	4.0	4.1	4.3	4.4	4.6	4.7	4.8	4.9	5.0	5.0	5.1	5.3	5.4	69°
70°	0	0.2	0.5	0.7	0.9	1.1	1.4	1.6	1.8	2.0	2.2	2.4	2.6	2.8	3.0	3.1	3.3	3.5	3.6	3.7	3.9	4.1	4.2	4.3	4.5	4.6	4.7	4.7	4.8	4.9	5.0	5.1	70°
71°	0	0.2	0.4	0.6	0.9	1.1	1.3	1.5	1.7	1.9	2.1	2.3	2.4	2.6	2.8	2.9	3.1	3.3	3.5	3.6	3.7	3.9	4.0	4.1	4.2	4.3	4.4	4.5	4.6	4.7	4.8	4.9	71°
72°	0	0.2	0.4	0.6	0.8	1.0	1.2	1.4	1.6	1.8	2.0	2.1	2.3	2.5	2.6	2.8	2.9	3.1	3.3	3.4	3.5	3.7	3.8	3.9	4.0	4.1	4.2	4.2	4.3	4.4	4.5	4.6	72°
73°	0	0.2	0.4	0.6	0.8	0.9	1.1	1.3	1.5	1.7	1.9	2.0	2.2	2.4	2.5	2.7	2.8	3.0	3.1	3.3	3.4	3.5	3.6	3.7	3.8	3.9	4.0	4.1	4.1	4.2	4.3	4.4	73°
74°	0	0.2	0.4	0.6	0.8	0.9	1.1	1.2	1.4	1.6	1.8	1.9	2.0	2.2	2.4	2.5	2.6	2.8	2.9	3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.9	3.9	4.0	4.1	74°
75°	0	0.1	0.3	0.5	0.7	0.8	1.0	1.1	1.3	1.5	1.6	1.8	1.9	2.0	2.2	2.3	2.5	2.6	2.7	2.9	3.0	3.1	3.2	3.3	3.4	3.4	3.5	3.5	3.6	3.7	3.8	3.9	75°
LAT. \ Z	0°	2½°	5°	7½°	10°	12½°	15°	17½°	20°	22½°	25°	27½°	30°	32½°	35°	37½°	40°	42½°	45°	47½°	50°	52½°	55°	57½°	60°	62½°	65°	67½°	70°	75°	80°	90°	LAT.

RULES

IF OBSERVATION IS EARLY AND BODY $\frac{\text{RISING}}{\text{SETTING}}$ CORRECTION IS $\frac{\text{ADDED TO}}{\text{SUBTRACTED FROM}}$ OBSERVED ALTITUDE

IF OBSERVATION IS LATE AND BODY $\frac{\text{RISING}}{\text{SETTING}}$ CORRECTION IS $\frac{\text{SUBTRACTED FROM}}{\text{ADDED TO}}$ OBSERVED ALTITUDE

RUDE STAR FINDER

KEEP YOUR STAR IDENTIFIER WITH YOU ALL THE TIME

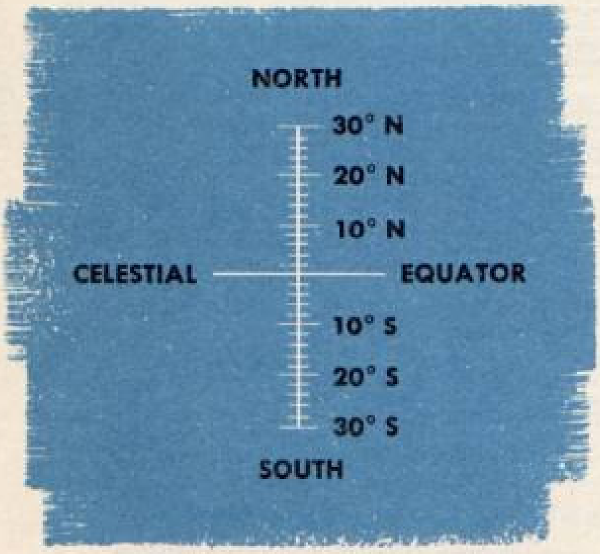
Use the template nearest your latitude and place the zero degree line over the local hour angle of Aries. This shows you the relative position of all the stars in the sky at the time of observation.

Remember, the local hour angle of Aries and the right ascension of your meridian are the same.

To plot a planet or moon on your star identifier:

1. Subtract the Greenwich hour angle of the planet or moon from the Greenwich hour angle of Aries (plus 360° if necessary).
2. Take these values from the same horizontal line in the Air Almanac.
3. Mark the resulting value on the outer edge of the star base and draw a pencil line to the pole.
4. Plot the planet or moon at a distance along this line equal to the body's declination. You can measure distance on the scale shown on the identifier instruction sheet, and transfer it to the base.

The scale is reproduced below.



Be sure to have the North Pole of the star finder up when you are in the Northern Hemisphere, and the South Pole up when you are in the Southern Hemisphere. This is important.

Example: Your dead reckoning position is 42° 25′ N 83° W on Saturday 22 April 1944 at GCT 23:20. Your true heading is 50°.

GHA Aries 200° 53′
Longitude 83° W
LHA Aries 117° 53′ This is the same as the right ascension of your meridian.

Place the 45° N template over the northern sky base. Rotate the template to bring the arrow of the 0°-180° line to 118° on the outer edge of the base.

The stars that will give you good course lines are:

1. Regulus	approximate altitude 47°
2. Alphard	approximate altitude 33°
3. Caph	approximate altitude 26°
4. Ruchbah	approximate altitude 35°

These are good course line stars because they bear approximately 90° from your heading of 50°.

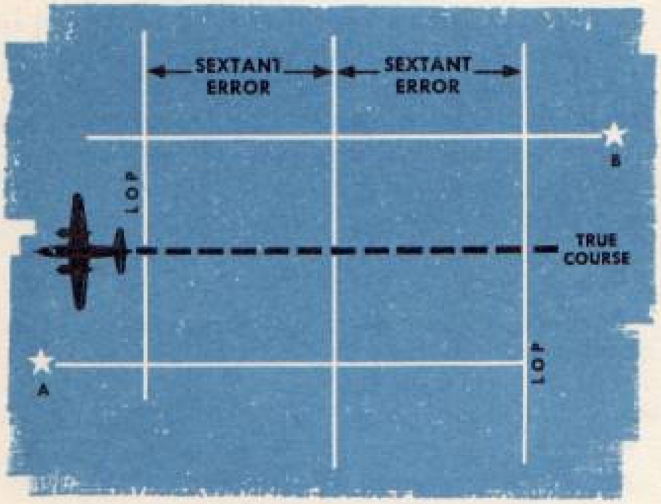
The stars that will give you good speed lines are:

1. Dubhe	approximate altitude 58°
2. Alioth	approximate altitude 43°
3. Mizar	approximate altitude 39°
4. Rigel	approximate altitude 27°
5. Bellatrix	approximate altitude 40°
6. Betelgeux	approximate altitude 45°
7. Alnilam	approximate altitude 35°

These are good speed line stars because they lie nearly directly ahead or behind your airplane.

Whenever you are in doubt as to the identity of any star, use your star finder to give you the approximate altitude and bearing of the star from your position and heading.

Checking the Sextant in the Air



At Night

1. Observe a body on one side of the airplane that will give you a good course line.

2. Observe a body on the other side of the airplane that will give you a good course line.

Take 3 lines of position on each body, and reduce each set of 3 to a single line of position by moving them up or averaging them visually.

If it is possible to shoot forward and to the rear from the airplane you are flying, observe speed line stars and use them in the same manner.

If your observations are accurate and your sextant error is zero, all lines of position on bodies with the same or reciprocal azimuth will fall on top of each other after being reduced to the same time.

3. Measure the distance between the two lines of position and divide by 2. This is your sextant error.

4. The sign of the error is determined by the lines of position falling away from, or toward the bodies observed. If the lines of position fall away from the bodies observed, the correction is plus, if they fall toward the bodies observed, the correction is minus.

Pilotage Fix

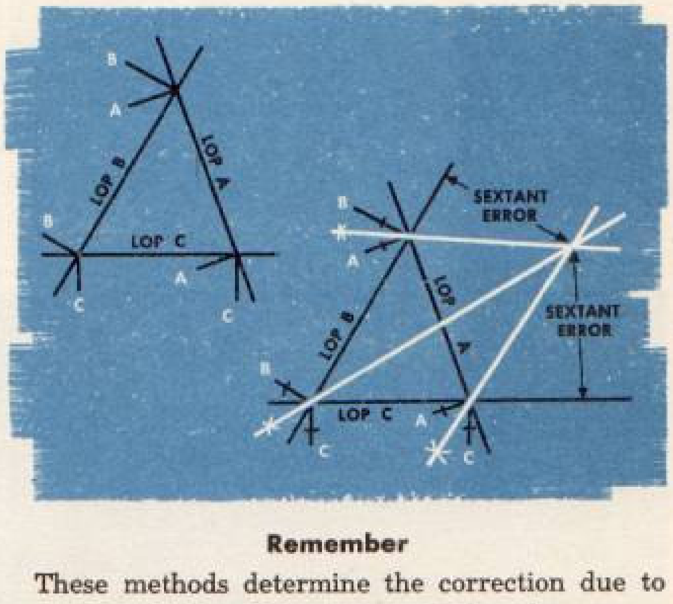
Take a set of observations while passing over a definite pilotage fix. Check your observations for sextant error against the pilotage fix.

Another Method

1. Shoot a 3 star fix and plot the lines of position.

2. If you get a large triangle, draw lines perpendicular to each line of position at the corners of the triangle. These lines represent the true azimuth of each of the bodies.

3. Bisect the angle formed by these lines at the corners of the triangle. The intersection of the bisectors is your most probable position. The difference between this point and the lines of position gives the sextant correction.



Remember

These methods determine the correction due to the sextant consistently shooting high or low on any body. It does not tell you your personal error which may vary on each shot from plus to minus.

CHECKING TIME

Precomputed Curve

Use a precomputed curve and a correct sextant to find the correct time. Measure a series of altitudes, recording each altitude and corresponding watch time. Plot each measured altitude exactly on the curve, and note the corresponding curve time. Then compare watch and curve times for watch error. The average of time discrepancies of a number of observations is the watch error.

Time Check by Equal Altitudes

Checking your time within a few seconds depends upon your ability to shoot accurately and to record your time accurately. You can use this method during the daytime by shooting the sun, and at night by shooting one of the stars or planets.

If a body has a constant declination, it passes evenly across the sky at a constant rate. When it is 15° east of your meridian, you will observe the same altitude as when it is 15° west of your meridian. The altitude of the body, therefore, depends upon the magnitude of the local hour angle. It takes the same length of time for the body to travel from a certain altitude east of your meridian to the meridian as it takes the body to pass from your meridian to the same altitude west of your meridian.

Use this fact to correct your watch as follows:

1. Observe the body an hour or so before crossing your meridian and record the Hs and the chronometer time. Take at least three sets of observations.

2. Observe the body after it has crossed your meridian, when its altitude is slightly higher than the last observation. Take several sets of observations until the Hs becomes less than that of the first observation.

3. Construct a small graph, plotting Hs against chronometer time, and draw a smooth curve through the plotted shots. Choose the times so that the two curves intersect on the graph.

4. Average the two times where the Hs curves intersect. This is the chronometer time of meridian transit. Compare this with the computed time of meridian transit to obtain the chronometer error.

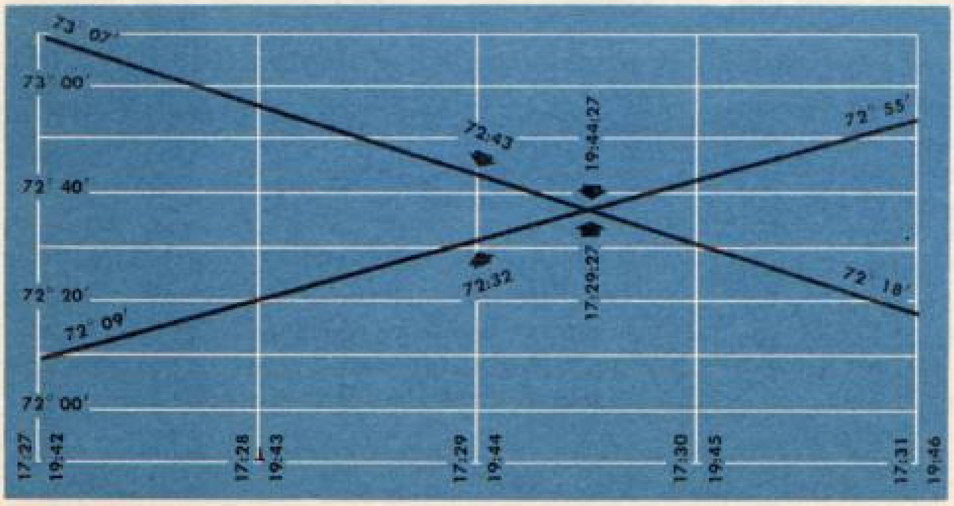
You can use this method on any star or planet as well as the sun. The fact that the sun's declination changes slightly during the interval between observations causes an error which is negligible. The advantage of this method is that you need not apply corrections for refraction or sextant error, and you don't need to know your latitude accurately.

Problem

As an example of this procedure, on 16 July 1943 the sun was observed at 97° 52′ W as follows:

Observations Sun Rising	Chronometer Time GCT	Observations Sun Setting	Chronometer Time GCT
72° 09′	17:27:00	73° 07′	19:42:00
72° 32′	17:29:00	72° 43′	19:44:00
72° 55′	17:31:00	72° 18′	19:46:00

Plot these observations on a graph. The time of intersection of the two curves is 17:29:27 and 19:44:27 GCT. The mean time is, 18:36:57 GCT, which is the chronometer time of meridian transit. The computed time of the meridian transit is 18:37:20 GCT, giving a chronometer error of −23 seconds.



TIME CHECK
BY EQUAL
ALTITUDES

DATE, 16 JULY 1943
LONG. 97° 52′ W
M.T. ⊙ = 18:37:20
M.T. CHRON. = 18:36:57
CHRON. ERROR = −23 SECONDS

LANDFALLS

Landfalls are of two types: course line landfalls and speed line landfalls.

Course Line Landfall

The easiest landfall to fly and things being equal, the most accurate, is the course line landfall.

1. Observe a celestial body that gives a course line, line of position. Plot it on your Mercator chart.
2. Advance the line of position through destination parallel to the one you just plotted.
3. Fly directly to the line of position through destination and turn toward destination.
4. Stay on this line of position until another line of position shows you to be off course.
5. Then repeat the process. But stay on a line of position through destination. There is no ETA in a landfall other than your best known groundspeed.

Speed Line Landfall

Because a course line is at times the more difficult type of line of position to observe, and because sometimes only speed lines are available, you will also fly a speed line landfall.

In this type of landfall fly definitely to one side of destination. When you reach the speed line through destination, turn and fly into destination.

Precomputed landfalls, intersection of Ho-Hc curves, and double Ho-Hc curves are variations of the simple landfall. Use these for speed line landfalls ordinarily. The double Ho-Hc curve is really a series of precomputed fixes. But it is used as a landfall.

In actual combat the use of landfalls is limited, for you must make most base approaches from certain bearings and at certain altitudes. To keep from arousing the interceptors on particular bases each time you approach them, you must give definite ETA's. This is impossible when flying a landfall.

In the interest of precomputed work, the following HO 218 precomputed landfall is a definite time saver.

HO 218 Precomputed Landfall

No curves to be drawn. No long hours of precomputed work. All work accomplished during the flight in your spare time. It is easy and accurate.

Here's How

1. Figure an approximate ETA for destination.
2. Pick a body that will give a good speed line.
3. Find the Greenwich hour angle of that body at 20 minute intervals. Each Greenwich hour angle will end in approximately the same number of minutes.
4. Use an assumed longitude to give you a local

hour angle of even degrees.

5. Enter HO 218 by an assumed position as close to destination as possible, and extract an Hc and an azimuth for each 20 minute interval.

6. Plot at least one line of position on your Mercator at your assumed position.

7. Measure the distance necessary to move this line of position through destination, and apply this correction to each Hc.

8. When approaching the line of position through destination, establish track by observation of course line stars if possible.

9. Observe the body for which you made the precomputation.

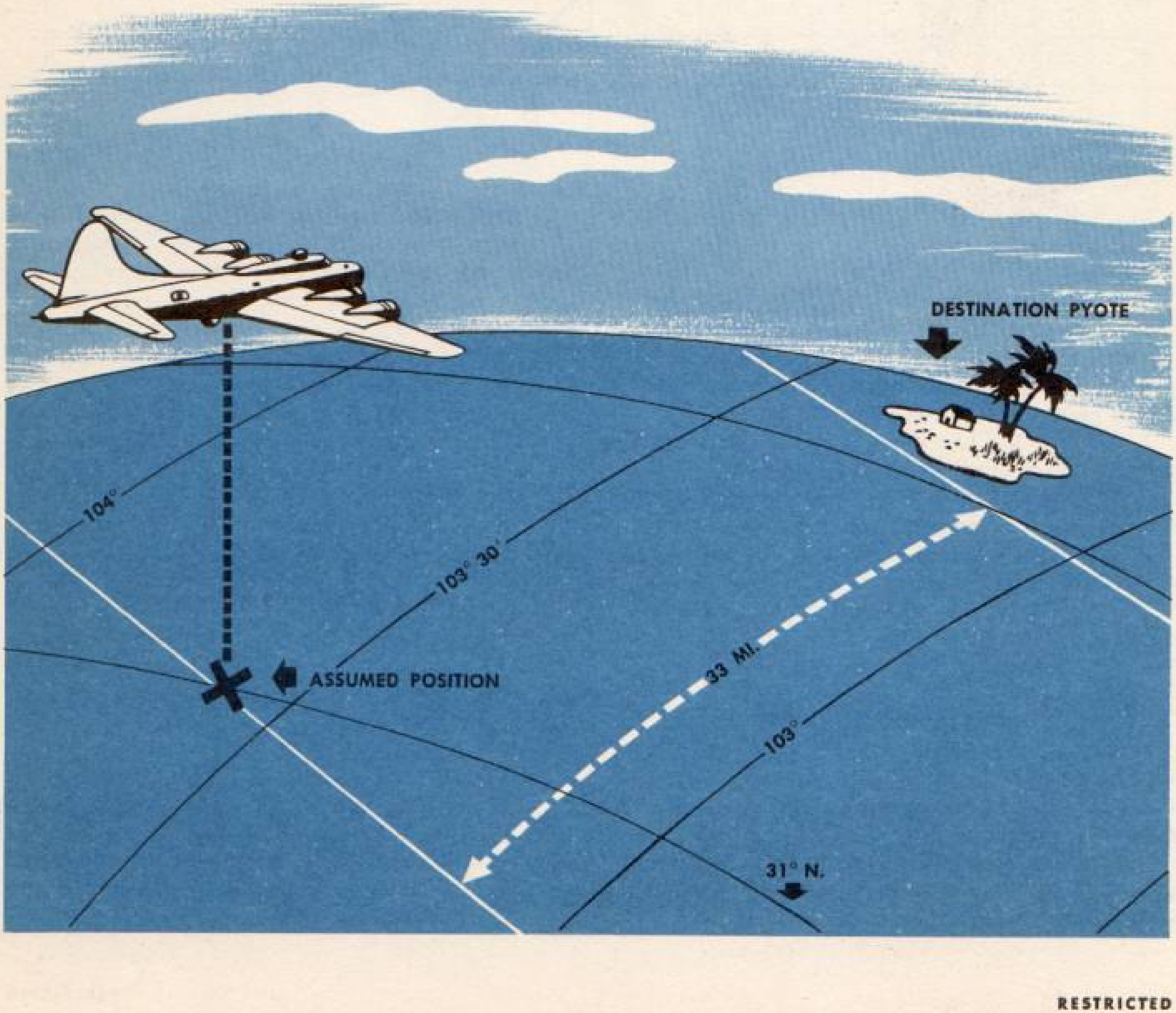
10. Visually compare Ho's with Hc's.

11. When Ho is equal to Hc, turn on the azimuth plus or minus 90°.

Problem

Depart from 34° 30′ N, 99° 30′ W, at flight altitude of 10,000 feet, flying a true course of 233°. This will place you about 35 miles right of destination, Pyote, 31° 31′ N, 103° 09′ W. Departure time is 18:50 GCT, with a dead reckoning groundspeed of 170 knots, which will make your arrival on the line of position through destination approximately 20:17 GCT, as the distance is approximately 248 nautical miles.

Precompute a table for 20:00 GCT to 21:20 GCT. Enter the Almanac as of the date April 26, 1943, at 20:00 GCT and find the Greenwich hour angle of the sun to be 120° 33′; 20:20 GCT is 125° 33′, 20:40 GCT is 130° 33′, 21:00 GCT is 135° 33′, and 21:20 GCT is 140° 33′. Note that at 20 minute intervals the number of minutes of Greenwich hour angle of the sun al-



ways agrees within a mile or two, which presents no great difficulties.

Then, assume a position of 31° N, 103° 33′ W, in order to work the solutions by HO 218.

Applying your assumed longitude to the Greenwich hour angle of the sun, you have local hour angles of 17° W for 20:00 GCT, 22° W for 20:20 GCT, 27° W for 20:40 GCT, 32° W for 21:00 GCT, and 37° W for 21:20 GCT.

Then enter the HO 218 solution book, under declination N13° 26′, and extract the Hc's and azimuth for the body.

	Hc	Azimuth
20:00 GCT	66°29′	225°
20:20 GCT	63°13′	233°
20:40 GCT5	59°36′	240°
21:00 GCT	55°45′	246°
21:20 GCT	51°46′	250°

Extract them all by opening the book but once.

You now have the change of altitude and azimuth of the body at the position of 31° N, 103° 33′ W. You want the altitude of the body at destination, Pyote, 31° 31′ N, 103° 09′ W.

To obtain this, draw the line of position through the assumed position for each of the time intervals, and measure the distance required to move each line of position through destination, Pyote. Apply the proper sign to the correction by noting whether this action is increasing or decreasing the altitude of the body. This is done as follows:

	Hc	Correction	Corrected Hc
20:00 GCT	66°29′	−36′	65°53′
20:20 GCT	63°13′	−35′	62°38′
20:40 GCT	59°36′	−33′	59°03′
21:00 GCT	55°46′	−32′	55°14′
21:20 GCT	51°46′	−30′	51°16′

You now have the altitude of the sun for 1 hour and 20 minutes at destination. When you approach the line of position through destination, start shooting.

As you shoot, visually interpolate between the Hc's you have computed, in order to compare your observations with your precomputed solutions. You can break down your Hc's to 5 minute intervals to make your interpolation easier, as below.

20:00 GCT	65°53′ (difference 49′)
20:05 GCT	65°04′ (difference 49′)
20:10 GCT	64°15′ (difference 49′)
20:15 GCT	63°26′ (difference 48′)
20:20 GCT	62°38′ (difference 54′)
20:25 GCT	61°44′ (difference 54′)
20:30 GCT	60°50′ (difference 54′)
20:35 GCT	59°56′ (difference 53′)
20:40 GCT	59°56′ (difference etc.)

Then start shooting. Your shots fall as follows:

	Ho	Hc
20:03 GCT	63°53′	65°23′
20:12 GCT	62°45′	63°55′
20:19 GCT	62°01′	62°45′
20:27 GCT	61°00′	61°22′
20:31 GCT	60°28′	60°39′
20:33 GCT	60°12′	60°17′

At 20:33 GCT you see that you are within 5 miles of the line of position through destination, so at 20:35 you turn on the line of position and continue to observe the body to make sure that you stay on it.

Remember

Find an assumed position as close to your destination as possible that will give you latitude and local hour angle of an integral degree.

Then solve for azimuth and altitude from this position for a time period in which you are sure you will reach the line of position through destination.

Draw the line of position through your assumed position, and measure the distances necessary to move them through destination. Bearing in mind whether you are correcting away from or toward the body, apply the proper sign to the correction. Apply these corrections to the computed altitudes.

As you approach the line of position through destination, take repeated observations on the body, visually interpolating to check the difference between Ho and Hc. When the Ho coincides with the Hc, turn on the azimuth plus or minus 90°.