

CHAPTER 17

AZIMUTHS AND AMPLITUDES

INTRODUCTION

1700. Compass Checks

At sea, the mariner is constantly concerned about the accuracy of the gyro compass. There are several ways to check the accuracy of the gyro. He can, for example, compare it with an accurate electronic navigator such as an inertial navigation system. Lacking a sophisticated electronic navigation suite, he can use the celestial techniques of comparing the

measured and calculated azimuths and amplitudes of celestial bodies. The difference between the calculated value and the value determined by gyro measurement is gyro error. This chapter discusses these procedures.

Theoretically, these procedures work with any celestial body. However, the sun and Polaris are used most often when measuring azimuths, and the sun when measuring amplitudes.

AZIMUTHS

1701. Compass Error By Azimuth Of The Sun

Mariners use *Pub 229, Sight Reduction Tables for Marine Navigation* to compute the sun's azimuth. They compare the computed azimuth to the azimuth measured with the compass to determine compass error. In computing an azimuth, interpolate the tabular azimuth angle for the difference between the table arguments and the actual values of declination, latitude, and local hour angle. Do this triple interpolation of the azimuth angle as follows:

1. Enter the *Sight Reduction Tables* with the nearest integral values of declination, latitude, and local hour angle. For each of these arguments, extract a base azimuth angle.
2. Reenter the tables with the same latitude and LHA arguments but with the declination argument 1° greater or less than the base declination argument, depending upon whether the actual declination is greater or less than the base argument. Record the difference between the respondent azimuth angle and the base azimuth angle and label it as the azimuth angle difference (Z Diff.).
3. Reenter the tables with the base declination and LHA arguments, but with the latitude argument 1° greater or less than the base latitude argument, depending upon whether the actual (usually DR) latitude is greater or less than the base argument. Record the Z Diff. for the increment of latitude.
4. Reenter the tables with the base declination and latitude arguments, but with the LHA argument 1° greater or less than the base LHA argument, de-

pending upon whether the actual LHA is greater or less than the base argument. Record the Z Diff. for the increment of LHA.

5. Correct the base azimuth angle for each increment.

Example:

In DR latitude $33^\circ 24.0'N$, the azimuth of the sun is 096.5° pgc. At the time of the observation, the declination of the sun is $20^\circ 13.8'N$; the local hour angle of the sun is $316^\circ 41.2'$. Determine compass error.

Solution:

*See Figure 1701 Enter the actual value of declination, DR latitude, and LHA. Round each argument to the nearest whole degree. In this case, round the declination and the latitude down to the nearest whole degree. Round the LHA up to the nearest whole degree. Enter the *Sight Reduction Tables* with these whole degree arguments and extract the base azimuth value for these rounded off arguments. Record the base azimuth value in the table.*

*As the first step in the triple interpolation process, increase the value of declination by 1° to 21° because the actual declination value was greater than the base declination. Enter the *Sight Reduction Tables* with the following arguments: (1) Declination = 21° ; (2) DR Latitude = 33° ; (3) LHA = 317° . Record the tabulated azimuth for these arguments.*

*As the second step in the triple interpolation process, increase the value of latitude by 1° to 34° because the actual DR latitude was greater than the base latitude. Enter the *Sight Reduction Tables* with the following arguments: (1) Declination = 20° ; (2) DR Latitude = 34° ; (3) LHA = 317° .*

	Actual	Base Arguments	Base Z	Tab* Z	Z Diff.	Increments	Correction (Z Diff x Inc.÷ 60)
Dec.	20° 13.8' N	20°	97.8°	96.4°	-1.4°	13.8'	-0.3°
DR Lar.	33° 24.0' N	33° (Same)	97.8°	98.9°	+1.1°	24.0'	+0.4°
LHA	316° 41.2'	317°	97.8°	97.1°	-0.7°	18.8'	-0.2°
						Total Corr.	-0.1°
Base Z	97.8°						
Corr.	(-) 0.1°						
Z	N 97.7° E						
Zn	097.7°						
Zn pgc	096.5°						
Gyro Error	1.2° E						

*Respondent for the two base arguments and 1° change from third base argument, in vertical order of Dec., DR Lat., and LHA.

Figure 1701. Azimuth by *Pub. No. 229*.

Record the tabulated azimuth for these arguments.

As the third and final step in the triple interpolation process, decrease the value of LHA to 316° because the actual LHA value was smaller than the base LHA. Enter the Sight Reduction Tables with the following arguments: (1) Declination = 20°; (2) DR Latitude = 33°; (3) LHA = 316°. Record the tabulated azimuth for these arguments.

Calculate the Z Difference by subtracting the base azimuth from the tabulated azimuth. Be careful to carry the correct sign.

$$Z \text{ Difference} = \text{Tab Z} - \text{Base Z}$$

Next, determine the increment for each argument by taking the difference between the actual values of each argument and the base argument. Calculate the correction for each of the three argument interpolations by multiplying the increment by the Z difference and dividing the resulting product by 60.

The sign of each correction is the same as the sign of the corresponding Z difference used to calculate it. In the above example, the total correction sums to -0.1°. Apply this value to the base azimuth of 97.8° to obtain the true azimuth 97.7°. Compare this to the compass reading of 096.5° pgc. The compass error is 1.2°E.

AZIMUTH OF POLARIS

1702. Compass Error By Azimuth Of Polaris

The Polaris tables in the *Nautical Almanac* list the azimuth of Polaris for latitudes between the equator and 65° N. Figure 2011 in Chapter 20 shows this table. Compare a compass bearing of Polaris to the tabular value of Polaris to determine compass error. The entering arguments for the table are LHA of Aries and observer latitude.

Example:

On March 17, 1994, at L 33° 15.0' N and 045° 00.0' W, at 02-00-00 GMT, Polaris bears 358.6°T by compass. Calculate the compass error.

Date 17 March 1994
 Time (GMT) 02-00-00
 GHA Aries 204° 25.4'

Longitude 045° 00.0' W
 LHA Aries 161° 25.4'

Solution:

Enter the azimuth section of the Polaris table with the calculated LHA of Aries. In this case, go to the column for LHA Aries between 160° and 169°. Follow that column down and extract the value for the given latitude. Since the increment between tabulated values is so small, visual interpolation is sufficient. In this case, the azimuth for Polaris for the given LHA of Aries and the given latitude is 359.3°.

Tabulated Azimuth 359.3°T
 Compass Bearing 358.6°T
 Error 0.7°E

AMPLITUDES

1703. Amplitudes

A celestial body's **amplitude** is the arc between the observed body on the horizon and the point where the

observer's horizon intersects the celestial equator. See Figure 1703.

Calculate an amplitude after observing a body on either the celestial or visual horizon. Compare a body's measured

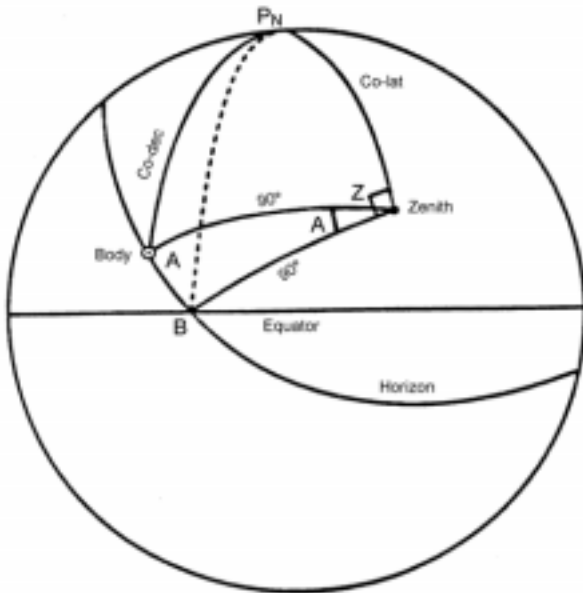


Figure 1703. The amplitude is the arc (A) between the observed body on the horizon and the point where the observer’s horizon intersects the celestial equator.

amplitude with an amplitude extracted from the Amplitude table. The difference between the two values represents compass error.

Give amplitudes the suffix N if the body from which it was determined has a northern declination and S if it has a southern declination. Give the amplitudes the prefix E if the body is rising and W if the body is setting.

The values in the *Amplitude* table assume that the body is on the *celestial* horizon. The sun is on the celestial horizon when its lower limb is about two-thirds of a diameter above the visible horizon. The moon is on the celestial horizon when its upper limb is on the visible horizon. Planets and stars are on the celestial horizon when they are approximately one sun diameter above the visible horizon.

When using a body on the visible, not celestial, horizon, correct the observed amplitude from Table 23 Apply this table’s correction to the *observed* amplitude and *not* to the amplitude extracted from the *Amplitude* table. For the sun, a planet, or a star, apply this correction to the observed amplitude in the direction *away from* the elevated pole. If using the moon, apply one-half of the Table 23 correction in the direction *towards* the elevated pole.

Navigators most often use the sun when determining amplitudes. The rule for applying the Table 23 corrections to a sun’s observed amplitude is summarized as follows. If the DR latitude is north and the sun is rising, or if the DR latitude is south and the sun is setting, add the Table 23 correction to the observed amplitude. Conversely, if the DR latitude is north and the sun is setting, or the DR latitude is

south and the sun is rising, then subtract the Table 23 correction from the observed amplitude.

The following two sections demonstrate the procedure for obtaining the amplitude of the sun on both the celestial and visible horizons.

1704. Amplitude Of The Sun On The Celestial Horizon

Example:

The DR latitude of a ship is 51° 24.6’ N. The navigator observes the setting sun on the celestial horizon. Its declination is N 19° 40.4’. Its observed amplitude is W 32.9° N. (32.9° “north of west,” or 302.9°).

Required:

Compass error.

Solution:

Interpolate in Table 22 for the sun’s calculated amplitude as follows. See Figure 1704. The actual values for latitude and declination are L = 51.4° N and dec. = N 19.67°. Find the tabulated values of latitude and declination closest to these actual values. In this case, these tabulated values are L = 51° and dec. = 19.5°. Record the amplitude corresponding to these base values, 32.0°, as the base amplitude.

Next, holding the base declination value constant at 19.5°, increase the value of latitude to the next tabulated value: N 52°. Note that this value of latitude was increased because the actual latitude value was greater than the base value of latitude. Record the tabulated amplitude for L = 52° and dec. = 19.5°: 32.8°. Then, holding the base latitude value constant at 51°, increase the declination value to the next tabulated value: 20°. Record the tabulated amplitude for L = 51° and dec. = 20°: 32.9°.

The latitude’s actual value (51.4°) is 0.4 of the way between the base value (51°) and the value used to determine the tabulated amplitude (52°). The declination’s actual value (19.67°) is 0.3 of the way between the base value (19.5°) and the value used to determine the tabulated amplitude (20.0°). To determine the total correction to base amplitude, multiply these increments (0.4 and 0.3) by the respective difference between the base and tabulated values (+0.8 and +0.9, respectively) and sum the products. The total correction is +0.6°. Add the total correction (+0.6°) to the base amplitude (32.0°) to determine the final amplitude (32.6°).

Calculate the gyro error as follows:

Amplitude (observed) pgc	=	W 32.9° N
Amplitude (from Table 22)	=	<u>W 32.6° N</u>
Compass Error		0.3° W

1705. Amplitude Of The Sun On The Visible Horizon

Example:

The same problem as section 1704, except that the sun is setting on the visible horizon.

Required:

Compass error.

Solution:

Interpolate in Table 23 to determine the correction for the sun on the visible horizon as follows. See Figure 1705. Choose as base values of latitude and declination the tabular values of latitude and declination closest to the actual values. In this case, these tabulated values are $L = 51^\circ$ and $dec. = 20^\circ$. Record the correction corresponding to these base values, 1.1° , as the base correction.

Completing the interpolation procedure indicates that the base correction (1.1°) is the actual correction.

Apply this correction in accordance with the rules discussed in section 1703. Since the vessel's latitude was north and the sun was setting, subtract the correction from the observed amplitude. The observed amplitude was $W 32.9^\circ N$. Subtracting the 1.1° correction yields a corrected observed amplitude of $W 31.8^\circ N$. From section 1704, the tabular amplitude was $W 32.6^\circ N$.

Calculate the gyro error as follows:

$$\begin{aligned} \text{Amplitude (from Table 22)} &= W 32.6^\circ N \\ \text{Amplitude (observed)} &= W 31.8^\circ N \\ \text{Compass Error} &= \frac{W 31.8^\circ N}{0.8^\circ E} \end{aligned}$$

1706. Amplitude By Calculation

As an alternative to using Table 22 and Table 23, use the following formulas to calculate amplitudes:

a) Body on the celestial horizon:

$$\text{Amplitude} = \sin^{-1} \left[\frac{\sin d}{\cos L} \right]$$

where d = celestial body's declination and L = observer's latitude.

b) Body on the visible horizon:

$$\text{Amplitude} = \sin^{-1} \left[\frac{\sin d - \sin L \sin h}{\cos L \cos h} \right]$$

where d = celestial body's declination, L = observer's latitude, and $h = -0.7^\circ$.

Using the same example as in section 1704, $d = 19.67^\circ N$ and $L = N 51.4^\circ$. If the sun is on the celestial horizon, its amplitude is:

$$\text{Amplitude} = \sin^{-1} \left[\frac{\sin 19.67^\circ}{\cos 51.4^\circ} \right] = W 32.6^\circ N.$$

If the sun is on the visible horizon, its amplitude is:

$$\begin{aligned} \text{Amplitude} &= \sin^{-1} \left[\frac{\sin 19.67^\circ - \sin 51.4^\circ \sin -0.7^\circ}{\cos 51.4^\circ \cos -0.7^\circ} \right] \\ &= W 33.7^\circ N \end{aligned}$$

Actual	Base	Base Amp.	Tab. Amp.	Diff.	Inc.	Correction
$L=51.4^\circ N$	51°	32.0°	32.8°	$+0.8^\circ$	0.4	$+0.3^\circ$
$dec=19.67^\circ N$	19.5°	32.0°	32.9°	$+0.9^\circ$	0.3	$\pm 0.3^\circ$
					Total	$+0.6^\circ$

Figure 1704. Interpolation in Table 22 for Amplitude.

Actual	Base	Base Amp.	Tab. Amp.	Diff.	Inc.	Correction
$L=51.4^\circ N$	51°	1.1°	1.1°	0.0°	0.4	0.0°
$dec=19.67^\circ N$	20°	1.1°	1.0°	-0.1°	0.2	0.0°

Figure 1705. Interpolation in Table 23 for Amplitude Correction.