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AIR FORCE MANUAL 51-40

4/86

air navigation

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1951

DEPARTMENT OF THE AIR FORCE

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zenith; therefore it is the zenith distance of the body. Thus you want to find side ZM of the triangle.

You also want to find the azimuth of the body. Azimuth is the angle measured at the zenith from north clockwise to the vertical circle through the body. The angle PZM of the triangle is measured at the zenith from the elevated pole to the vertical circle through the body. Unlike azimuth, this angle is measured from either north or south (depending on the observer's latitude), and it is measured either clockwise or counterclockwise, never exceeding 180°. To distinguish it from azimuth, the angle PZM is called **azimuth angle.** Although azimuth angle is not necessarily equal to azimuth, one can always be found from the other. If the observer is in north latitude, azimuth equals azimuth angle or 360° minus azimuth angle, depending on whether the body is east or west of the observer's meridian. Likewise, if the observer is in south latitude, azimuth equals 180° minus or plus azimuth angle. Therefore, if you know the azimuth angle, you can find the azimuth. Thus you want to find angle PZM of the triangle.

In a spherical triangle, as in a plane triangle, if you know certain sides and angles, you can find others. Consider which sides and angles of the astronomical triangle you already know. The line EM is the angular distance of the body from the equinoctial; therefore it is the declination of the body, which you know. Since the pole is 90° from the equinoctial, EP is equal to 90°. Therefore MP, the **polar distance** or **co-declination** of the body, is equal to 90° minus the declination. Thus you know side MP of the triangle.

The line E'Z is the angular distance of the zenith from the equinoctial; therefore it is the observer's latitude, which you know. ZP, the **co-latitude,** is equal to 90° minus the observer's latitude. Thus you know side ZP of the triangle.

ZP is part of the observer's meridian, and MP is part of the hour circle through the body. Therefore, angle ZPM is equal to the LHA of the body (or 360°—LHA). You can find the LHA by applying the observer's longitude, which you know, to the GHA of the body, which you also know. Thus you know angle ZPM of the triangle.

In the astronomical triangle PMZ you know the co-declination (MP), the co-latitude (ZP), and the LHA (ZPM). You want to find the zenith distance (ZM) and the azimuth angle (PZM). In a spherical triangle, as in a plane triangle, if you know two sides and the included angle, you can find the other side and the other two angles. The details of the solution need not concern you.

H.O. 218

There are several sets of tables by means of which you can find the altitude and azimuth of a body from a known position. The set of tables most used in the Air Force, is Hydrographic Office Publication No. 218, entitled **Astronomical Navigation Tables.** This work is in 16 volumes, each volume encompassing 5° of latitude in the northern hemisphere and the corresponding 5° in the southern hemisphere. Thus the set covers latitudes 0° to 79°, both north and south.

Each volume of H.O. 218 contains two main parts. The first part is for finding the altitude and azimuth of 22 important navigational stars, which have been selected for their brightness and for their distribution in the sky. It contains a separate section for each of these stars. The second part is used mainly for finding the altitude and azimuth of the sun, moon, and planets. It contains a separate section for each whole degree of declination from 0° to 28°.

ALTITUDE AND AZIMUTH OF NAVIGATION STARS

In each volume of H.O. 218, a section of about 4 pages is devoted to each of the 22 important navigational stars. The section for each star contains 2 tables of altitude and azimuth angle, one for the southern hemisphere latitude band and one for the northern hemisphere latitude band. On each page the five values of latitude appear across the top, and the values of LHA down the sides. In a column for each latitude, the altitude and azimuth angle of the star are listed opposite each LHA. If the LHA of the body and the latitude of the position are each a whole number of degrees, you will find the altitude and azimuth angle listed under the latitude and opposite the LHA. For example, at a latitude of 25° N, if the LHA of Betelgeuse is 45°, the Hc is 43°38′, and the azimuth angle or tabulated azimuth is 104°. You find true azimuth by

8 **NORTH** LATITUDES **BETELGEUSE**

LAT.	25°			26°			27°			28°			29°			LAT.
H.A.	Alt.	t	Az.	Alt.	t	Az.	Alt.	t	Az.	Alt.	t	Az.	Alt.	t	Az.	H.A.
°	° ′		°	° ′		°	° ′		°	° ′		°	° ′		°	°
0	72 24	+1	180	71 24	+1	180	70 24	+1	180	69 24	+1	180	68 24	+1	180	360
1	72 23	1	177	71 23	1	177	70 23	1	177	69 23	1	177	68 23	1	177	359
2	72 18	1	173	71 18	1	174	70 19	1	174	69 19	1	174	68 19	1	175	358
3	72 10	1	170	71 11	1	171	70 12	1	171	69 12	1	172	68 13	1	172	357
4	72 00	1	167	71 01	1	168	70 02	1	168	69 03	1	169	68 05	1	169	356
5	71 46	+1	164	70 48	+1	165	69 50	+1	165	68 52	+1	166	67 54	+1	167	355
6	71 30	1	161	70 33	1	162	69 36	1	163	68 38	1	163	67 41	1	164	354
7	71 10	1	158	70 15	1	159	69 18	1	160	68 22	1	161	67 25	1	162	353
8	70 49	1	155	69 54	1	156	68 59	1	157	68 03	1	158	67 08	1	159	352
9	70 25	1	152	69 31	1	154	68 37	1	155	67 43	1	156	66 48	1	157	351
10	69 59	+1	150	69 06	+1	151	68 14	+1	152	67 20	+1	153	66 26	+1	154	350
11	69 30	0	147	68 39	+1	149	67 48	1	150	66 56	1	151	66 03	1	152	349
12	69 00	0	145	68 10	0	146	67 20	+1	148	66 29	1	149	65 37	1	150	348
13	68 28	0	143	67 40	0	144	66 51	0	145	66 01	+1	147	65 10	+1	148	347
14	67 54	0	140	67 07	0	142	66 20	0	143	65 31	0	145	64 42	0	146	346
15	67 18	0	138	66 33	0	140	65 47	0	141	65 00	0	143	64 12	0	144	345
16	66 42	0	136	65 58	0	138	65 13	0	139	64 27	0	141	63 40	0	142	344
17	66 03	0	134	65 21	0	136	64 37	0	137	63 53	0	139	63 07	0	140	343
18	65 24	0	133	64 43	0	134	64 00	0	136	63 17	0	137	62 33	0	138	342
19	64 43	0	131	64 04	0	132	63 22	0	134	62 40	0	135	61 57	0	137	341
20	64 02	0	129	63 23	0	131	62 43	0	132	62 03	0	134	61 21	0	135	340
21	63 19	0	128	62 42	0	129	62 03	0	131	61 24	0	132	60 43	0	133	339
22	62 36	0	126	62 00	0	128	61 22	0	129	60 44	0	131	60 04	0	132	338
23	61 52	0	125	61 17	0	126	60 41	0	128	60 03	0	129	59 25	0	130	337
24	61 07	0	123	60 33	0	125	59 58	0	126	59 22	0	128	58 45	0	129	336
25	60 21	0	122	59 48	0	124	59 14	0	125	58 40	0	126	58 03	0	128	335
26	59 34	0	121	59 03	0	122	58 30	0	124	57 56	0	125	57 22	0	126	334
27	58 48	0	120	58 17	0	121	57 46	0	122	57 13	0	124	56 39	0	125	333
28	58 00	0	119	57 31	0	120	57 00	0	121	56 28	0	123	55 56	0	124	332
29	57 12	0	117	56 44	0	119	56 14	0	120	55 44	0	121	55 12	0	123	331
30	56 24	0	116	55 56	0	118	55 28	0	119	54 58	0	120	54 27	0	121	330
31	55 35	0	115	55 08	0	117	54 41	0	118	54 12	0	119	53 42	0	120	329
32	54 45	0	114	54 20	0	116	53 53	0	117	53 26	0	118	52 57	0	119	328
33	53 56	0	113	53 31	0	115	53 06	0	116	52 39	0	117	52 11	0	118	327
34	53 06	0	113	52 42	0	114	52 17	0	115	51 51	0	116	51 24	0	117	326
35	52 15	0	112	51 53	0	113	51 29	0	114	51 04	0	115	50 38	0	116	325
36	51 25	0	111	51 03	0	112	50 40	0	113	50 16	0	114	49 50	0	115	324
37	50 34	0	110	50 13	0	111	49 50	0	112	49 27	0	113	49 03	0	114	323
38	49 43	0	109	49 22	0	110	49 01	0	111	48 38	0	113	48 15	0	114	322
39	48 51	0	109	48 32	0	110	48 11	0	111	47 49	0	112	47 27	0	113	321
40	48 00	0	108	47 41	0	109	47 21	0	110	47 00	0	111	46 38	0	112	320
41	47 08	0	107	46 50	0	108	46 30	0	109	46 10	0	110	45 49	0	111	319
42	46 16	0	106	45 58	0	107	45 40	0	108	45 20	0	109	45 00	0	110	318
43	45 23	0	106	45 07	0	107	44 49	0	108	44 30	0	109	44 11	0	109	317
44	44 31	0	105	44 15	0	106	43 58	0	107	43 40	0	108	43 21	0	109	316
45	43 38	0	104	43 23	0	105	43 07	0	106	42 50	0	107	42 32	0	108	315

{For argument H.A. on the left, True Azimuth = 360° − Tabulated Azimuth.} See p. 90.
{For argument H.A. on the right, True Azimuth = Tabulated Azimuth.}
No correction for date is necessary.

applying the rule at the bottom of the page. The azimuth depends on whether the star is east or west of the meridian of the position, that is, whether the LHA is in the right or left column. In the example, the LHA is in the left-hand column, so true azimuth equals 360° minus tabulated azimuth. Therefore the true azimuth is 256°.

The tables give altitude and azimuth angle directly if latitude and LHA are whole numbers of degrees. If either latitude or LHA were not a whole number, you would have to interpolate to find the altitude. Since the azimuth angle is given only to the nearest degree, you would not have to interpolate for azimuth angle. Ordinarily you can avoid interpolation for LHA and latitude by using only whole degrees of LHA and latitude, as you will see presently.

Assumed Position

To construct an LOP by the intercept method, you must find the altitude and azimuth of the body from some assumed position near your actual position. The closer this assumed position is to your actual position, the more accurate will be your LOP. Since your DR position is your best guess as to your actual position, it would seem logical to use your DR position as an assumed position. However, your results will not suffer greatly so long as the assumed position is within about 50 miles of your actual position. Consequently, you are not obliged to use your DR position as an assumed position. Rather, you should select *near* your DR position a point for which it is easy to find altitude and azimuth. The latitude of this point should be a whole number of degrees. And its longitude combined with the GHA of the star should give a whole number of degrees of LHA. Then you will not have to interpolate for latitude and LHA. Thus your assumed position should be the closest point to your DR position for which you can find the altitude without interpolating for LHA and latitude.

For example, suppose that the GHA of the star is 178°26′. If your DR position is 35°27′N, 97°14′W, you use an assumed position of 35°00′N, 97°26′W. Then you enter the tables with a latitude of 35°N and an LHA of 81°. If your DR position is 35°27′N, 97°14′E, you use an assumed position of 35°00′N, 97°34′E. Then you enter the tables with a latitude of 35°N and an LHA of 276°.

"t" Correction

The tables for the navigational stars were calculated by using the 1940 declination of each star. However, the declination of each star slowly changes through the years. Therefore in later years some correction of the tabulated altitude may be necessary.

I.—CORRECTION FOR DATE TO TABULATED ALTITUDE OF STARS

t / Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	t / Year
1941	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1941
1942	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1942
1943	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1943
1944	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1944
1945	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	1945
1946	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	1946
1947	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	1947
1948	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	1948
1949	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	1949
1950	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	1950
1951	0	0	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	4	1951
1952	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	1952
1953	0	0	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	1953
1954	0	0	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	4	5	1954
1955	0	0	1	1	1	2	2	2	2	2	3	3	3	4	4	4	4	4	5	5	1955
1956	0	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	5	5	5	5	1956
1957	0	1	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	5	6	1957
1958	0	1	1	1	2	2	2	2	3	3	3	4	4	4	4	5	5	5	6	6	1958
1959	0	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	1959
1960	0	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	1960
1961	0	1	1	1	2	2	2	3	3	4	4	4	5	5	5	6	6	6	7	7	1961
1962	0	1	1	1	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	1962
1963	0	1	1	2	2	2	3	3	3	4	4	5	5	5	6	6	7	7	7	8	1963
1964	0	1	1	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	1964
1965	0	1	1	2	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8	8	1965
1966	0	1	1	2	2	3	3	3	4	4	5	5	6	6	6	7	7	8	8	9	1966
1967	0	1	1	2	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	1967
1968	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	7	8	8	9	9	1968
1969	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	1969
1970	0	1	2	2	2	3	4	4	4	5	6	6	6	7	8	8	8	9	10	10	1970
1971	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	1971
1972	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	9	9	10	10	11	1972
1973	1	1	2	2	3	3	4	4	5	6	6	7	7	8	8	9	9	10	10	11	1973
1974	1	1	2	2	3	3	4	5	5	6	6	7	7	8	8	9	10	10	11	11	1974
1975	1	1	2	2	3	4	4	5	5	6	6	7	8	8	9	9	10	10	11	12	1975
1976	1	1	2	2	3	4	4	5	5	6	7	7	8	8	9	10	10	11	11	12	1976
1977	1	1	2	2	3	4	4	5	6	6	7	7	8	9	9	10	10	11	12	12	1977
1978	1	1	2	3	3	4	4	5	6	6	7	8	8	9	10	10	11	11	12	13	1978
1979	1	1	2	3	3	4	5	5	6	6	7	8	8	9	10	10	11	12	12	13	1979
1980	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10	11	11	12	13	13	1980
1981	1	1	2	3	3	4	5	5	6	7	8	8	9	10	10	11	12	12	13	14	1981
1982	1	1	2	3	4	4	5	6	6	7	8	8	9	10	10	11	12	13	13	14	1982
1983	1	1	2	3	4	4	5	6	6	7	8	9	9	10	11	11	12	13	14	14	1983
1984	1	1	2	3	4	4	5	6	7	7	8	9	10	10	11	12	12	13	14	15	1984
1985	1	2	2	3	4	4	5	6	7	8	8	9	10	10	11	12	13	14	14	15	1985
1986	1	2	2	3	4	5	5	6	7	8	8	9	10	11	12	12	13	14	15	15	1986
1987	1	2	2	3	4	5	5	6	7	8	9	9	10	11	12	13	13	14	15	16	1987
1988	1	2	2	3	4	5	6	6	7	8	9	10	10	11	12	13	14	14	15	16	1988
1989	1	2	2	3	4	5	6	7	7	8	9	10	11	11	12	13	14	15	16	16	1989
1990	1	2	2	3	4	5	6	7	8	8	9	10	11	12	12	13	14	15	16	17	1990
1991	1	2	3	3	4	5	6	7	8	8	9	10	11	12	13	14	14	15	16	17	1991
1992	1	2	3	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	16	17	1992
1993	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18	1993
1994	1	2	3	4	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	18	1994
1995	1	2	3	4	5	6	6	7	8	9	10	11	12	13	14	15	16	16	17	18	1995
1996	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	15	16	17	18	19	1996
1997	1	2	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	17	18	19	1997
1998	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	18	19	1998
1999	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	1999
2000	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	2000

After each altitude is a value of t, which is variation of altitude with time. Table I, inside the front cover of each volume, gives the correction to be applied to the altitude for each value of t and for each year up to 2000; this correction must be added or subtracted according to the sign of t. For example, in 1946 if t is -12, the correction is -1.

At the bottom of each page in the star section is given a limiting year before which no correction needs to be applied. Thus you may find, "No correction for date is necessary until 1947." Even after the limiting year, the *t* correction is little trouble. You do not need to refer to table I every time you find an altitude. Rather, you can note the correction for each *t* value during the current year. Thus, for 1946 you note that if *t* is 0 to 5, the correction is 0′; if *t* is 6 to 14, the correction is 1′; and if *t* is 15 to 20, the correction is 2′.

Summary of Procedure

Lest you have become lost amid the details, here is a summary of the procedure for finding the altitude and azimuth of a navigational star for an assumed position:

1. From the Almanac ascertain the GHA of the star for the time of observation.
2. Assume a position as close as possible to your DR position, so that (1) the latitude of the position is a whole number of degrees, and (2) its longitude combined with the GHA of the star gives a whole number of degrees of LHA. Find the LHA of the star for this position.
3. Select the volume of H.O. 218 for the latitude band which includes the assumed position. Turn to the section for the star you have observed. Find the page showing the latitude of the assumed position and the LHA of the star from this position. Be careful to use the page for north latitude if the assumed position is in north latitude, or the page for south latitude if it is in south latitude. Opposite the LHA read tabulated altitude and azimuth angle in the column headed by the latitude of the assumed position.
4. If the limiting date has passed, determine the correction for time, if any. Note the sign of *t*, and apply the correction to the tabulated altitude accordingly.
5. Convert azimuth angle to true azimuth by means of the rule at the bottom of the page.

For example, suppose that you observe Acrux on 3 July 1945, at 2013 GCT. Your DR position is 29°07′S, 90°48′E.

1.	GHA ♈ 2010 GCT	223°59′
	GHA correction for 3ᵐ	45′
	SHA Acrux	174°07′
		398°51′
		−360°00′
	GHA Acrux 2013 GCT	38°51′
2.	Longitude of Assumed Position	+91°09′E
	LHA Acrux 2013 GCT	130°00′
	Latitude of Assumed Position	29°00′S
3.	Tabulated Altitude	10°05′
	Azimuth Angle	021°
4.	Correction to Tabulated Altitude (for $t = +15$)	+01′
	Hc	10°06′
5.	Azimuth (= 180° + Azimuth Angle)	201°

2   SOUTH LATITUDES   ACRUX

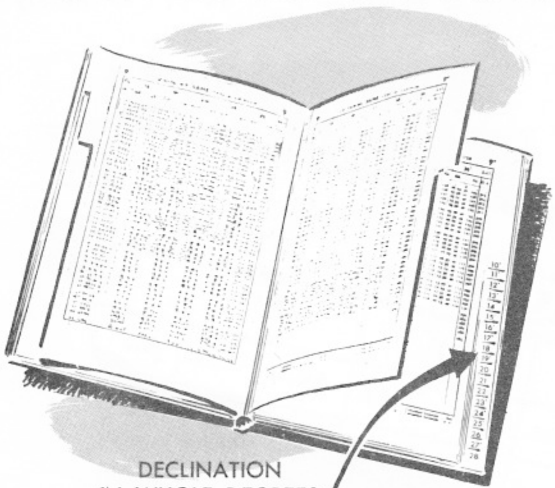
LAT. H.A.	25° Alt. ° ′ t	Az. °	26° Alt. ° ′ t	Az. °	27° Alt. ° ′ t	Az. °	28° Alt. ° ′ t	Az. °	29° Alt. ° ′ t	Az. °	LAT. H.A.
90	22 06 +4	30	22 58 +4	30	23 50 +5	30	24 42 +5	30	25 34 +5	30	270
					...		...		10 43 14	22	232
	...				...		...		10 24 14	21	231
129	...		...		...		...		10 05+15	21	230
130	...		...								

{For argument H.A. on the left, True Azimuth = 180° + Tabulated Azimuth.} See
{For argument H.A. on the right, True Azimuth = 180° − Tabulated Azimuth.} p. 91.
No correction for date is necessary until 1944.
8

ALTITUDE AND AZIMUTH OF THE SUN, MOON, AND PLANETS

The first part of each volume of H.O. 218 consists of tables of altitude and azimuth for each of 22 stars. Since the declination of each star changes but slowly, these tables can be used for many years with only small corrections. The declination of the sun, moon, and planets, on the contrary,. changes rapidly. Therefore, a similar table for one of these bodies would become obsolete in a few days or sometimes in a few hours! A different plan must be used.

In the second part of each volume, a section of 4 pages is devoted to each whole number of degrees of declination from 0° to 28°. The section for each number of degrees contains two tables of altitude and azimuth: one is for declination of the *same* name as latitude (*e.g.* declination north if latitude is north), and the other is for declination of *contrary* name to latitude. With these tables you can find the altitude and azimuth of any body whose declination lies between 29°N and 29°S. This band includes the sun, moon, and planets at all times. And of course it also includes some bright stars. For any of the 22 stars in the first part of the volume, you save time by using the special tables. But any star marked by a dagger (†) in the Almanac star table, is in this declination band. For it you can use the tables in this second part of the volume.



In the second part of the volume the arrangement of each page is much like that in the first part. The five values of latitude appear across the top of the page, and the values of LHA appear down the sides. If the LHA and declination of the body and the latitude of the position are each a whole number of degrees, you will find the altitude and azimuth angle under the latitude and opposite the LHA. For example, at a latitude of 25°N, if the LHA of a body is 45° and its declination is 22°S, the Hc is 25°52′ and the azimuth angle is 133°. Thus when latitude, LHA, and declination are whole numbers of degrees, the tables give altitude and azimuth angle directly. Here again you assume a position such that latitude and LHA are whole numbers.

22° DECLINATION CONTRARY NAME TO LATITUDE 22°

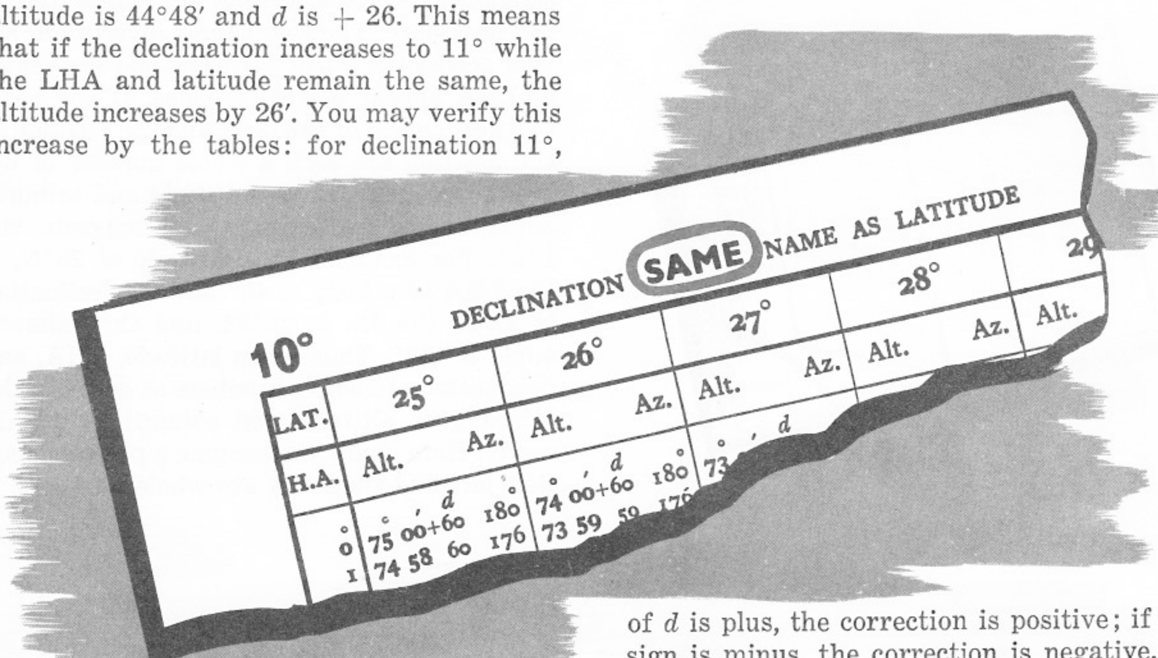
LAT.	25°		26°		27°		28°		29°		LAT.
H.A.	Alt.	Az.	Alt.	Az.	Alt.	Az.	Alt.	Az.	Alt.	Az.	H.A.
°	° ′ d	°	° ′ d	°	° ′ d	°	° ′ d	°	° ′ d	°	°
45	25 52 −42	133	25 11 −43	134	24 30 −44	134	23 48 −44	134	23 06 −45	135	315
46	25 12 41	133	24 32 43	133	23 51 43	133	23 10 44	134	22 28 44	134	314
47	24 32 41	132	23 52 42	132	23 12 43	132	22 31 43	133	21 50 43	133	313
48	23 51 40	131	23 12 41	131	22 32 42	132	21 52 42	132	21 12 43	132	312

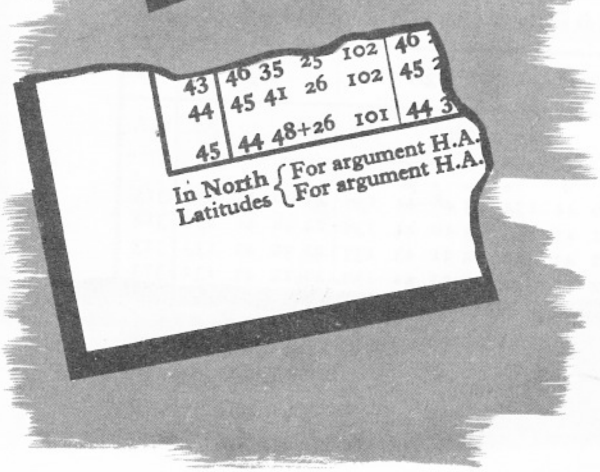
Interpolation for Declination

When the declination of a body is a number of minutes in addition to a whole number of degrees, you extract the altitude for the whole number of degrees and correct this altitude by interpolation for the additional minutes. You need not interpolate for azimuth angle, which is given only to the nearest degree. But you must convert azimuth angle to true azimuth as before.

After each tabulated altitude is a value for *d*, which is the change in altitude with a 1° increase in declination. Thus *d* is the difference between the tabulated altitude and the altitude for the next whole degree of declination. For declination 10°, same name as latitude, LHA 45° and latitude 25°, the tabulated altitude is 44°48′ and *d* is + 26. This means that if the declination increases to 11° while the LHA and latitude remain the same, the altitude increases by 26′. You may verify this increase by the tables: for declination 11°, same name as latitude, LHA 45°, and latitude 25°, the tabulated altitude is 45°14′.

The correction to altitude for additional minutes of declination is proportional to *d* and proportional to the number of additional minutes. Obviously, in the previous example, if the declination increases from 10°00′ to 10°30′, the altitude increases by 13′ (½ x 26′). Thus the correction for 30′ of declination is + 13′ of altitude. Similarly, the correction to the tabulated altitude for any number of minutes of declination is equal to *d* times the number of minutes divided by 60. Thus, in the same example, if the declination is 10°21′, the correction for declination is + 26′ x 21/60 = + 9′. Thus if the declination is 10°21′, the altitude is 44°48′ + 9′ = 44°57′. If the sign





of *d* is plus, the correction is positive; if the sign is minus, the correction is negative.

To obtain the correction for additional minutes of declination, you do not have to multiply by longhand. Instead, you may use table XV inside the back cover of each volume. This is a table of sixtieths. Values of *d* are given across the top of the table, and additional minutes of declination are given down the side of the table. You find the correction at the intersection of (1) the column headed by the value of *d* and (2) the horizontal line headed by the number of additional minutes of declination. Thus if *d* is −18 and the declination is 14°21′, you must apply a correction of −6′ to the altitude tabulated for a declination of 14°.

XV.—CORRECTION TO TABULATED ALTITUDE FOR MINUTES OF DECLINATION

d	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	d
00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00
01	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	01
02	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	02
03	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	03
04	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	04
05	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	05
06	0	0	0	0	0	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	06
07	0	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	07
08	0	0	0	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	4	4	4	4	08
09	0	0	0	1	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	3	3	4	4	4	4	4	4	4	09
10	0	0	0	1	1	1	1	1	2	2	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	4	4	5	5	5	10
11	0	0	1	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	11
12	0	0	1	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	12
13	0	0	1	1	1	1	2	2	2	2	2	3	3	3	3	3	4	4	4	4	5	5	5	5	5	6	6	6	6	6	13
14	0	0	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	4	4	5	5	5	5	6	6	6	6	7	7	7	14
15	0	0	1	1	1	2	2	2	2	2	3	3	3	4	4	4	4	4	5	5	5	6	6	6	6	6	7	7	7	8	15
16	0	1	1	1	1	2	2	2	2	3	3	3	3	4	4	4	5	5	5	5	6	6	6	6	7	7	7	7	8	8	16
17	0	1	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	5	6	6	6	7	7	7	7	8	8	8	8	17
18	0	1	1	1	2	2	2	2	3	3	3	4	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	8	9	9	18
19	0	1	1	1	2	2	2	3	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	19
20	0	1	1	1	2	2	2	3	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	20
21	0	1	1	1	2	2	2	3	3	4	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10	21
22	0	1	1	1	2	2	3	3	3	4	4	4	5	5	6	6	6	7	7	7	8	8	8	9	9	10	10	10	11	11	22
23	0	1	1	2	2	2	3	3	3	4	4	5	5	5	6	6	7	7	7	8	8	8	9	9	10	10	10	11	11	12	23
24	0	1	1	2	2	2	3	3	4	4	4	5	5	6	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12	12	24
25	0	1	1	2	2	2	3	3	4	4	5	5	5	6	6	7	7	8	8	8	9	9	10	10	10	11	11	12	12	12	25
26	0	1	1	2	2	3	3	3	4	4	5	5	6	6	6	7	7	8	8	9	9	10	10	10	11	11	12	12	13	13	26
27	0	1	1	2	2	3	3	4	4	4	5	5	6	6	7	7	8	8	9	9	9	10	10	11	11	12	12	13	13	14	27
28	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	28
29	0	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	14	29
30	0	1	2	2	2	3	4	4	4	5	6	6	6	7	8	8	8	9	10	10	10	11	12	12	12	13	14	14	14	15	30
31	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	16	31
32	1	1	2	2	3	3	4	4	5	5	6	6	7	7	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15	16	32
33	1	1	2	2	3	3	4	4	5	6	6	7	7	8	8	9	9	10	10	11	12	12	13	13	14	14	15	15	16	16	33
34	1	1	2	2	3	3	4	5	5	6	6	7	7	8	8	9	10	10	11	11	12	12	13	14	14	15	15	16	16	17	34
35	1	1	2	2	3	4	4	5	5	6	6	7	8	8	9	9	10	10	11	12	12	13	13	14	15	15	16	16	17	18	35
36	1	1	2	2	3	4	4	5	5	6	7	7	8	8	9	10	10	11	11	12	13	13	14	14	15	16	16	17	17	18	36
37	1	1	2	2	3	4	4	5	6	6	7	7	8	9	9	10	10	11	12	12	13	14	14	15	15	16	17	17	18	18	37
38	1	1	2	3	3	4	4	5	6	6	7	8	8	9	10	10	11	11	12	13	13	14	15	15	16	16	17	18	18	19	38
39	1	1	2	3	3	4	5	5	6	6	7	8	8	9	10	10	11	12	12	13	14	14	15	16	16	17	18	18	19	20	39
40	1	1	2	3	3	4	5	5	6	7	7	8	9	9	10	11	11	12	13	13	14	15	15	16	17	17	18	19	19	20	40
41	1	1	2	3	3	4	5	5	6	7	8	8	9	10	10	11	12	12	13	14	14	15	16	16	17	18	18	19	20	20	41
42	1	1	2	3	4	4	5	6	6	7	8	8	9	10	10	11	12	13	13	14	15	15	16	17	18	18	19	20	20	21	42
43	1	1	2	3	4	4	5	6	6	7	8	9	9	10	11	11	12	13	14	14	15	16	16	17	18	19	19	20	21	22	43
44	1	1	2	3	4	4	5	6	7	7	8	9	10	10	11	12	12	13	14	15	15	16	17	18	18	19	20	21	21	22	44
45	1	2	2	3	4	4	5	6	7	8	8	9	10	10	11	12	13	14	14	15	16	16	17	18	19	20	20	21	22	22	45
46	1	2	2	3	4	5	5	6	7	8	8	9	10	11	12	12	13	14	15	15	16	17	18	18	19	20	21	21	22	23	46
47	1	2	2	3	4	5	5	6	7	8	9	9	10	11	12	13	13	14	15	16	16	17	18	19	20	20	21	22	23	24	47
48	1	2	2	3	4	5	6	6	7	8	9	10	10	11	12	13	14	14	15	16	17	18	18	19	20	21	22	22	23	24	48
49	1	2	2	3	4	5	6	7	7	8	9	10	11	11	12	13	14	15	16	16	17	18	19	20	20	21	22	23	24	24	49
50	1	2	2	3	4	5	6	7	8	8	9	10	11	12	12	13	14	15	16	17	18	18	19	20	21	22	22	23	24	25	50
51	1	2	3	3	4	5	6	7	8	8	9	10	11	12	13	14	14	15	16	17	18	19	20	20	21	22	23	24	25	26	51
52	1	2	3	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	16	17	18	19	20	21	22	23	23	24	25	26	52
53	1	2	3	4	4	5	6	7	8	9	10	11	11	12	13	14	15	16	17	18	19	19	20	21	22	23	24	25	26	26	53
54	1	2	3	4	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	18	19	20	21	22	22	23	24	25	26	27	54
55	1	2	3	4	5	6	6	7	8	9	10	11	12	13	14	15	16	16	17	18	19	20	21	22	23	24	25	26	27	28	55
56	1	2	3	4	5	6	7	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	21	22	23	24	25	26	27	28	56
57	1	2	3	4	5	6	7	8	9	10	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	28	57
58	1	2	3	4	5	6	7	8	9	10	11	12	13	14	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	58
59	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	59

XV.—CORRECTION TO TABULATED ALTITUDE FOR MINUTES OF DECLINATION

d	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	d
00	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	00
01	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	01
02	1	1	1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	02
03	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	03
04	2	2	2	2	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	04
05	3	3	3	3	3	3	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	05
06	3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	06
07	4	4	4	4	4	4	4	4	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	6	7	7	7	7	7	07
08	4	4	4	5	5	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	7	7	8	8	8	8	08
09	5	5	5	5	5	5	6	6	6	6	6	6	6	7	7	7	7	7	7	8	8	8	8	8	8	8	9	9	9	9	09
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11	6	6	6	6	6	7	7	7	7	7	8	8	8	8	8	8	9	9	9	9	9	10	10	10	10	10	10	11	11	11	11
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17	9	9	9	10	10	10	10	11	11	11	12	12	12	12	13	13	13	14	14	14	14	15	15	15	16	16	16	16	17	17	17
18	9	10	10	10	10	11	11	11	12	12	12	13	13	13	14	14	14	14	15	15	15	16	16	16	16	17	17	17	18	18	18
19	10	10	10	11	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	16	17	17	17	18	18	18	19	19	19
20	10	11	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	17	18	18	18	19	19	19	20	20	20
21	11	11	12	12	12	13	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	18	19	19	19	20	20	20	21	21	21
22	11	12	12	12	13	13	14	14	14	15	15	15	16	16	16	17	17	18	18	18	19	19	19	20	20	21	21	21	22	22	22
23	12	12	13	13	13	14	14	15	15	15	16	16	16	17	17	18	18	18	19	19	20	20	20	21	21	21	22	22	23	23	23
24	12	13	13	14	14	14	15	15	16	16	16	17	17	18	18	18	19	19	20	20	20	21	21	22	22	22	23	23	24	24	24
25	13	13	14	14	15	15	15	16	16	17	17	18	18	18	19	19	20	20	20	21	21	22	22	22	23	23	24	24	25	25	25
26	13	14	14	15	15	16	16	16	17	17	18	18	19	19	20	20	20	21	21	22	22	23	23	23	24	24	25	25	26	26	26
27	14	14	15	15	16	16	17	17	18	18	18	19	19	20	20	21	21	22	22	22	23	23	24	24	25	25	26	26	27	27	27
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30	16	16	16	17	18	18	18	19	20	20	20	21	22	22	22	23	24	24	24	25	26	26	26	27	28	28	28	29	30	30	30
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32	17	17	18	18	19	19	20	20	21	21	22	22	23	23	24	25	25	26	26	27	27	28	28	29	29	30	30	31	31	32	32
33	17	18	18	19	19	20	20	21	21	22	23	23	24	24	25	25	26	26	27	28	28	29	29	30	30	31	31	32	32	33	33
34	18	18	19	19	20	20	21	22	22	23	23	24	24	25	26	26	27	27	28	28	29	29	30	31	31	32	32	33	33	34	34
35	18	19	19	20	20	21	22	22	23	23	24	24	25	26	26	27	27	28	29	29	30	30	31	32	32	33	33	34	34	35	35
36	19	19	20	20	21	22	22	23	23	24	25	25	26	26	27	28	28	29	29	30	31	31	32	32	33	34	34	35	35	36	36
37	19	20	20	21	22	22	23	23	24	25	25	26	27	27	28	28	29	30	30	31	31	32	33	33	34	35	35	36	36	37	37
38	20	20	21	22	22	23	23	24	25	25	26	27	27	28	28	29	30	30	31	32	32	33	34	34	35	35	36	37	37	38	38
39	20	21	21	22	23	23	24	25	25	26	27	27	28	29	29	30	31	31	32	32	33	34	34	35	36	36	37	38	38	39	39
40	21	21	22	23	23	24	25	25	26	27	27	28	29	29	30	31	31	32	33	33	34	35	35	36	37	37	38	39	39	40	40
41	21	22	23	23	24	25	25	26	27	27	28	29	29	30	31	31	32	33	33	34	35	36	36	37	38	38	39	40	40	41	41
42	22	22	23	24	24	25	26	27	27	28	29	29	30	31	32	32	33	34	34	35	36	36	37	38	38	39	40	41	41	42	42
43	22	23	24	24	25	26	27	27	28	29	29	30	31	32	32	33	34	34	35	36	37	37	38	39	39	40	41	42	42	43	43
44	23	23	24	25	26	26	27	28	29	29	30	31	32	32	33	34	34	35	36	37	37	38	39	40	40	41	42	43	43	44	44
45	23	24	25	26	26	27	28	28	29	30	31	32	32	33	34	34	35	36	37	38	38	39	40	40	41	42	43	44	44	45	45
46	24	25	25	26	27	28	28	29	30	31	31	32	33	34	34	35	36	37	38	38	39	40	41	41	42	43	44	44	45	46	46
47	24	25	26	27	27	28	29	30	31	31	32	33	34	34	35	36	37	38	38	39	40	41	42	42	43	44	45	45	46	47	47
48	25	26	26	27	28	29	30	30	31	32	33	34	34	35	36	37	38	38	39	40	41	42	42	43	44	45	46	46	47	48	48
49	25	26	27	28	29	29	30	31	32	33	33	34	35	36	37	38	38	39	40	41	42	42	43	44	45	46	47	47	48	49	49
50	26	27	28	28	29	30	31	32	32	33	34	35	36	37	38	38	39	40	41	42	42	43	44	45	46	47	48	48	49	50	50
51	26	27	28	29	30	31	31	32	33	34	35	36	37	37	38	39	40	41	42	42	43	44	45	46	47	48	48	49	50	51	51
52	27	28	29	29	30	31	32	33	34	35	36	36	37	38	39	40	41	42	42	43	44	45	46	47	48	49	49	50	51	52	52
53	27	28	29	30	31	32	33	34	34	35	36	37	38	39	40	41	42	42	43	44	45	46	47	48	49	49	50	51	52	53	53
54	28	29	30	31	32	32	33	34	35	36	37	38	39	40	40	41	42	43	44	45	46	47	48	49	50	50	51	52	53	54	54
55	28	29	30	31	32	33	34	35	36	37	38	38	39	40	41	42	43	44	45	46	47	48	49	50	50	51	52	53	54	55	55
56	29	30	31	32	33	34	35	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	49	50	51	52	53	54	55	56	56
57	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	48	49	50	51	52	53	54	55	56	57	57
58	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	58
59	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	59

Summary of Procedure

Here is a summary of the procedure for finding the altitude and azimuth of a body whose declination lies between 29°N and 29°S.

1. From the Almanac ascertain the declination and GHA of the body for the time of the observation.

2. Assume a position as close as possible to your DR position, so that (1) the latitude of the position is a whole number of degrees and (2) its longitude combined with the GHA of the body gives a whole number of degrees of LHA. Find the LHA of the body for this position.

3. Select the volume of H.O. 218 for the latitude band which includes the latitude of the assumed position. Disregarding minutes of declination, turn to the section for the whole number of degrees of declination. Thus if the declination is 19°54′, turn to the section for 19°. Find the page showing the latitude of the assumed position and the LHA of the body from this position. Be careful to use the page for *same name* if declination and latitude are both north or both south, and the page for *contrary name* if one is north and the other south. Opposite the LHA read the tabulated altitude and azimuth angle in the column headed by the latitude of the assumed position.

4. If the declination is not a whole number of degrees, determine the altitude correction for the additional minutes of declination: enter table XV with the value *d* and the number of additional minutes. Apply the correction to the tabulated altitude according to the sign of *d*.

5. Convert azimuth angle to true azimuth by means of the rule at the bottom of the page.

For example, suppose that you observe the sun on 5 August 1945, at 1713 GCT. Your DR position is 27°21′S, 118°19′W.

1.	Declination ⊙ 1713 GCT	N16°57′
	GHA ⊙ 1710 GCT	76°02′
	GHA Correction for 3^m	45′
	GHA ⊙ 1713 GCT	76°47′
2.	Longitude of Assumed Position	118°47′W
	LHA ⊙ 1713 GCT	318°00′
	Latitude of Assumed Position	27°00′S
3.	Tabulated Altitude	30°47′
	Azimuth Angle	132°
4.	*d*	−44
	Correction to Tabulated Altitude (for 57′ of Declination)	−42′
	Hc	30°05′
5.	Azimuth (= 180° − Azimuth Angle)	048°

TRIPLE INTERPOLATION

Ordinarily when you use H. O. 218, you assume a position such that interpolation for LHA and latitude is unnecessary. Sometimes, however, you may need to find the altitude and azimuth of a body for some definite position. Then you must interpolate for latitude and LHA as well as for declination. This process is called **triple interpolation.**

In triple interpolation you first find the tabulated altitude for a whole number of degrees of latitude and LHA. You correct this tabulated altitude not only for declination (*t* or *d*) but also for additional minutes of LHA and latitude. You find these three corrections, add them algebraically, and apply the sum to the tabulated altitude.

You find the correction for *t* or *d* just as before. And you find the corrections for additional minutes of latitude and LHA in a somewhat similar manner.

Correction for Latitude

Usually the latitude of the position is not a whole number of degrees. Then, to the altitude tabulated for the whole degree of latitude, you must apply a correction for the additional minutes of latitude. With the tabulated altitude which you extract from the table, compare the tabulated altitude for the same LHA and declination but for the next higher degree of latitude. This is the corresponding altitude in the adjacent column to the right. The difference between these two altitudes is the change in altitude with a 1° change in latitude. The correction for additional minutes of latitude is the part of this change proportional to the number of additional minutes. Thus, if the change in altitude is 24′ per 1° of latitude, the correction for 20 additional minutes of latitude is 8′ of altitude. Therefore, you find the correction in table XV, entering with (1) the change in altitude per 1° of latitude, and (2) the number of additional minutes of latitude. If the altitude increases with latitude, the sign of the correction is plus; if it decreases, the sign is minus. Note that if you extract the tabulated altitude from the right-hand column, you find the change of altitude with latitude either by reference to the next volume of H. O. 218 or by extrapolation.

Correction for LHA

Usually, the LHA of the body is not a whole number of degrees. Then, to the altitude tabulated for the whole degree of LHA, you must apply a correction for the additional minutes of LHA. With the tabulated altitude which you extract from the table, compare the tabulated altitude for the same latitude and declination but for the next higher degree of LHA. The difference between these two altitudes is the change in altitude with a 1° increase in LHA. The correction for additional minutes of LHA is proportional to the number of minutes. You find this correction in table XV, entering with (1) the change of altitude per 1° of LHA, and (2) the number of additional minutes of LHA. If the altitude increases with LHA, the sign of the correction is plus; if it decreases, the sign is minus.

Example of Triple Interpolation

Suppose that you are at 36°21′N, 114°52′W. The sun's declination is 3°14′S and its GHA is 87°39′. What are its altitude and azimuth? The LHA of the sun is 332°47′.

You find the altitude and azimuth tabulated for declination 3°00′ contrary name, latitude 36°, LHA 332°. The tabulated altitude is 43°04′, and the azimuth angle is 140°.

Next you find the three corrections for the altitude.

1. DECLINATION CORRECTION. Since *d* is — 52, the altitude decreases 52′, for a 1° increase in declination. There are 14 additional minutes of declination. From table XV you find the *d* correction = −12′.

2. LATITUDE CORRECTION. The tabulated altitude which you have extracted for latitude 36° is 43°04′. The tabulated altitude for the same declination and LHA but for latitude 37° is 42°17′. The difference is 47′. Thus the altitude decreases 47′ with a 1° increase in latitude. There are 21 additional minutes of latitude. From table XV you find the latitude correction = −16′.

3. LHA CORRECTION. The tabulated altitude which you have extracted for LHA 332° is 43°04′. The tabulated altitude for the same declination and latitude but for LHA 333° is 43°34′. The difference is 30′. Thus the altitude increases 30′ with a 1° increase in LHA. There are 47 additional minutes of LHA. From table XV you find the LHA correction = +24′.

Now you add the corrections for declination, latitude, and LHA. (−12′) + (−16′) + 24′ = −4′. You apply the total correction to the tabulated altitude to find Hc. 43°04′ −4′ = 43°00′.

The tabulated azimuth angle is 140°. According to the rule at the bottom of the page, azimuth angle here equals azimuth. Therefore the azimuth is 140°.