Contents

Introduction

The late Rear Admiral Arthur A. Ageton, USN (1900-1971), described "The Secant-Cosecant Method for Determining the Altitude and Azimuth of a Heavenly Body" in the U.S. Naval Institute *Proceedings* for October 1931 while a Lieutenant and a member of the Line Class of the Postgraduate School, U.S. Naval Academy. His table was published by the then U.S. Navy Hydrographic Office as "H.O. 211, Dead Reckoning Altitude and Azimuth Table" in several editions until discontinued in 1971. It reappeared in 1975 in Volume II of the Defense Mapping Agency Hydrographic Center's "Pub. No.9, American Practical Navigator (Bowditch)," as "Table 35, The Ageton Method." Other applications of the table were discussed in the Naval Institute *Proceedings* for July 1932.

Since Ageton's Table *(a)* requires but two columns of figures, *(b)* may be used with the coordinates of the DR position, and *(c)* requires only simple addition and subtraction, it has been the most durable and probably the most popular of all the "short methods" of sight reduction. It has been reprinted in full in many popular textbooks of navigation.

The present version introduces two significant simplifications:

(1) Entries for half-minutes of arc have been deleted resulting in precision to the nearest minute of arc (one nautical mile) when used without interpolation. This is in keeping with the variability of the apparent position of the sea horizon and is about the limit of accuracy of the hand-held sextant.

(2) The numerical duplication of the second half of Ageton's Table has been eliminated, a procedure common to most trigonometric tables. This has required a change in the column headings and a restatement of the rules for the use of the table; namely, the substitution of "less than 90°" or "more than 90°" for Ageton's "top of the table" or "bottom of the table."

The much shorter table (9 pages instead of 36 in the original), improved format, and absence of numerical duplication should result in fewer page openings, less table searching, and less chance for copy error. In addition, precision is consistent with the practical accuracy of celestial observations at sea.

This table is the simplest of all methods for pencil-and-paper calculation, barring multi-volume "inspection tables" such as DMAHC Pub's. 229 and 249, and is the ideal backup method for always fallible electronic instruments and calculators. It is small enough to be slipped between the pages of the *Nautical Almanac* for storage or folded and stuffed into the sextant box.

Though of no practical importance, the table has been recalculated to correct the numerous end-figure errors of the original table due to its calculation by six-place logarithms.

The author would be remiss if he did not acknowledge his indebtedness to O. B. Ellis for his indefatigable efforts without which this project would have been well nigh impossible. Also, he wishes to thank the distinguished Captain Alton B. Moody for his valuable suggestions.

Finally, it should be noted this little booklet is in no sense intended to be a textbook, as it is as compact as possible. Whereas the use of the table is presented as completely and clearly as possible, the theory has been omitted, except for the Appendix.

The Second Edition

This edition includes an important addition devised by the late D. H. Sadler, former Superintendent of H.M. Nautical Almanac Office and renowned British authority on navigation and navigational tables, an alternative sight reduction technique which makes it possible to salvage otherwise entirely satisfactory sights formerly discarded because they fell in the *forbidden zone* where K is between 82° and 98°, a little less than 9 per cent of sights. This edition also includes a graph devised by Elliot Laidlaw of USPS by means of which these sights can be identified and the appropriate reduction technique selected before the table is opened.

The long-familiar term *GMT* (Greenwich Mean Time) has been replaced by *UT* (Universal Time) in the *Nautical Almanac*, so the new term has been used in this edition of the *Compact Table* as well. There is no change in the meaning or significance of the new term in navigation: UT = GMT.

The only known error has been corrected (rule 2c for great circle distance).

Format of the Table

The table is composed oflog secants and log cosecants of angles from 0° to 180° multiplied by 100,000 to avoid the need for a decimal point preceding the mantissa. The column headings are arranged as follows:

Top of each page:

Bottom of each page:

Minutes of arc for angles at the top of the page are read from top to bottom on the left side of the page; minutes for angles at the bottom of the page are read from bottom to top on the right side of the page.

There are paired columns of numbers for each degree of arc, either A and B or B and A. The location of the letter adjacent to the degree heading determines to which column the letter applies.

As it is often necessary to enter the table with an A or B to find the corresponding B or A in the paired columns, note that the numbers decrease from infinitely large at the beginning of the table (left column, 0°/90°) to 15051 at the end (45°/135°), then decrease (right column) to 0 at the beginning. As a consequence, there is no duplication of numbers (except for 45°00') so the corresponding number is easily found.

Sight Reduction

Before entering the table, the four angles listed below must be known. As it is intended that the table be used without interpolation, each should be expressed only to the nearest minute of the arc.

1. The corrected sextant altitude of the body, Ho. This is the sextant angle after the necessary corrections have been applied and is the angle relative to the celestial horizon.

2. The declination of the body, dec. This is found in the Almanac for the UT of the sight.

3. The latitude of the observer, L. This is usually the dead reckoning (DR) latitude from the plot.

4. The meridian angle of the body, t. This is the hour angle of the body measured 0° to 180° east or west of the navigator's meridian and is computed from the navigator's assumed longitude (usually the DR longitude) and the GHA of the body from the Almanac for the time of the sight:

	Body west of navigator:	t W = GHA - Lo
Lo W	Body east of navigator, west of Greenwich:	t E = Lo - GHA
(	Body east of navigator, east of Greenwich:	t E = 360° - (GHA - Lo)
	Body east of navigator:	t E = 360° - (GHA + Lo)
Lo E	Body west of navigator, east of Greenwich	t W = Lo - (360° - GHA)
(	Body west of navigator, west of Greenwich:	tW= GHA+ Lo

Were local hour angle, LHA, used instead oft, the table would require twice as many column headings: t W *=LHA, but t E =360° - LHA.*

The Standard Technique

The standard technique for using the table described below is applicable for more than 90 per cent of sights with accuracy ofapproximately one mile. However, when K approaches 90°, the area where K is between 82° *and* 98°, *large and unpredictable errors may occur. Reduction by Sadler's technique results in no loss ofaccuracy in this area. These sights may be identified by Laidlaw's graph before the table is used. The technique and graph appear on pages 12-14.*

The following detailed description of the standard technique refers to the numbered sequence shown in the box. This is the simplest way to layout the calculation as the mechanics of the operation are more apparent and less duplication is required.

	(1)	E/W	A	(2)						
dee	(3)	N/S	+8	(4)	A	(5)				
			A	(6)	-8	(7)	8	(8)	A	(9)
K	(11)	N/S	← ←	← ← ←	A	(10)				
L	(12)	N/S								
K ~ L	(1 3)	....	..... →	→ →	→ →	....	+8	(14)		
He	(17)	← ←	← ←	← ←	← ←	← ←	A	(I 5)	-8	(1 6)
Ho	(18)				Z N/S	(21)	E/W ← ← ← ← ←		A	(20)
a	(19)	mi T/A			Zn	(22)				

1. Enter the meridian angle, t (1), to the nearest minute of are, label it East or West, and find A (2) for this angle from the table.

2. Enter the declination of the body, dec (3), to the nearest minute of arc, label it North or South, and find B (4) and the corresponding A (5) for this angle from the table.

3. Add (2) and (4) to find A (6) and enter this same value as A (9).

4. From the table, find B (7) for the tabulated value closest to A (6) and enter this same value as B (8).

5. Subtract (7) from (5) to find A (10).

6. From the table, find the angle K (11) corresponding to A (10); if t is greater than *90°*, K is greater as well; if t is less than 90°, K is also less than 90°. Give K the same name as the declination, North or South.

7. Enter the latitude of the observer, L (12), to the nearest minute of arc and label it North or South. Calculate (K ~ L) (13), the sum of (11) and (12) if they are of contrary name, the difference if the same name. [K = L and (K ~ L) = a if the body is on the prime vertical, that is, where Z = 90°.]

   L is usually the DR latitude; however, any other position may be used: AP, *Ep, or wild guess-with less accuracy the farther the chosen position is from the actual position of the observer. However, the advantages of using the DR coordinates have contributed to the popularity and longevity of the table. If the DR position is reasonably accurate and the sight taken accurately, the intercept will be quite short. This is not only a check on the reliability of the DR and the sight, but plotting is simplified as a result. Also, in the case of a multi-body fix, the same L and La may be used in calculating all the sights. By contrast, "inspection tables" require the use of an AP based on integral degrees of latitude and hour angle; long and unwieldy intercepts often result. Calculator users will be familiar with plotting from the DR position as there is no advantage in doing it any other way.*

8. From the table, find B (14) for the angl.e (K ~ L) (13).

9. Add (8) and (14) to find A (15).

10. From the table, find B (16) corresponding to A (15) and, at the same time, angle Hc (17), the calculated altitude.

11. Enter the observed sextant altitude (corrected sextant altitude), Ho (18), to the nearest minute of arc and calculate the intercept, a (19). The intercept is the difference between (17) and (18) in minutes of arc = nautical miles. If the computed altitude, He, is greater than the observed altitude, Ho, the intercept is measured Away from the direction of the body (the reciprocal of Zn), and if Ho is greater, it is measured Toward the body (in the direction of Zn). A useful mnemonic: *"Coast Guard Academy:: CGA = Computed Greater Away."* Label the intercept T or A accordingly.

Where the body is very near the horizon, its altitude may be negative due to the effect of refraction and/or dip. Under these circumstances, it is useful to remember the above rule may also be stated: The intercept is the algebraic difference between Ho and Hc and is determined by subtracting Hc from Ho. If the difference is positive (+J, the intercept is Toward; if it is negative (-J, the intercept is Away. The calculated altitude, Hc, will be negative if K and L have the same name and (K ~ L) is greater than 90° or if K and L have contrary names and K is greater than (90° - L). In the latter case, Zis less than 90°.

Example of the Complete Reduction of a Sight

The navigator takes a sight on the lower limb of the sun at 14-57-09 on 1 October 1980. At that time, his DR position is L 25°37' N, Lo 87°06'W. The sextant altitude, hs, is 33°31', the index correction +I', the height of eye is 6 metres, and watch time is 5 seconds fast.

Time				*Altitude*	
WT	14-57-09	1 Oct		hs	33°31'
WE	- 05			IC	+ 01'
ZT	14-57-04			Dip	- 04'
ZD	+ 6			ha	*33°28'*
UT	20–57–04	1 0 ct		Alt corr	+ IS'
				Ho	33°43'

Almanac

GHA sun 20h	122°38'			dec sun	*3°29'*	S
57m 04s	14°16'			d carr	+ 01'	S
GHA sun	136°54'			dec sun	3°30'	S
La	87°06'	W				
t	49°48'	W				

Intercept and Azimuth from the Table

t	49°48'	W	A 11702					
dec	3°30'	S	+B _8_1	A121432				
			A 11783	-B 18894		B18894		A 11783
K	5°25'	S ←	← ← ←	← A102538				
L	25°37'	N						
K ∿ L	31°02'	→	→ → → → → → →			+8 6709		
Hc	33°41'	←	← ← ← ← ← ← ←			A 25603	-B	7982
Ho	33°43'			Z N 114° W	← ← ← ← ←		A	3801
a	2 mi T			Zn 246°				

12. Subtract (16) from (9) to fmd A (20). Occasionally this will be a small negative number, manifestly impossible for a log secant or log cosecant, and is due to the fact that (9) is not a tabulated number. This is most easily corrected by substituting zero for A (20) as it occurs only when the body is on the prime vertical and Z = *90°*.

13. From the table, find the azimuth angle, Z (21), corresponding to A (20). *When K has the same name and is greater than L, Z is less than 90°;* otherwise it is greater than 90°. Ordinarily it will suffice to take Z as the nearest whole degree; however, minutes can be converted to tenths of a degree if desired. The prefix for Z is the name of the elevated pole and the same as the name of the latitude, L (12); label it North or South. The suffix is the same as the name of the meridian angle, t (1), and is labeled East or West.

14. Z (21) is converted to Zn (22), azimuth, the direction relative to north, as follows:

Z NE, Zn = Z	Z SE, Zn = 180° - Z
Z NW, Zn = 360° - Z	Z SW, Zn = 180° + Z

The Sadler Technique

This technique is to be applied to sights where K is between *82°* and *98°*, the formerly *forbidden zone.* These sights can be identified by Laidlaw's graph before the Compact Table is used.

This technique, illustrated by the example, requires a different arrangement of terms and two new quantities, hI and h_Z. Although hI is modified by Ho, the value for Hc is insensitive to quite large errors in Ho. The calculation of Zn is the same as in the standard technique except R is represented by its two components in the rightmost column.

The error in the standard technique fluctuates in a saw-toothed fashion, plus and minus relative to the correct value, so at many points the error is zero, even in the *forbidden zone.* However, the magnitude of the swing increases geometrically as K approaches 90°. Sadler's technique is at least as accurate in this area as the standard technique for sights in other areas, about 1 mile. In the example, K is 90°, but direct trigonometric calculation confirms the value ofHc precisely; by the standard technique, Hc is 30' in error!

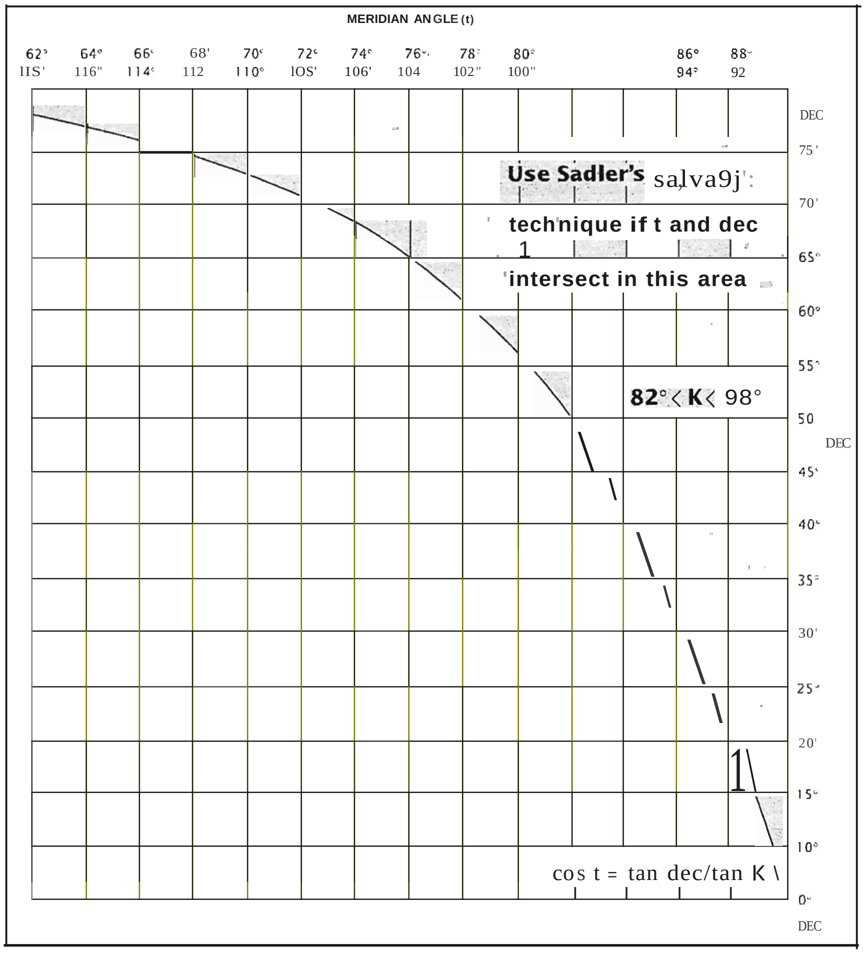
Example of Sadler's Technique

A sight was taken and the following quantities found:
t 89°06'W, Dec 53°16'S, L 33°19'S, Ho 26°35'.

t	89°06'W	---..----▶	B 180390	A 5.4
dec	53°16'S	A 9614	+B 22323	+B 22323
L	33°19'S	+A 26022	+B 7798	
hI	26°07'	◀- A 35636		
Ho	26°35'			
hI + Ho	52°42'			
(h1 + Ho)/2	26°21'	-------------▶	-B 4764	
h2	0°30'	◀------------	A 205747	
He (h1 + h2)	26°37'	-----------------	----------▶	-B 4865
Ho	26°35'		Z S 41°59'W ◀---	A 17463.4
a	--2mi A		Zn 222°	

Signs: *hJ is negative if L and dec have contrary names.*
h2 is positive if is *less than 90°; negative if*
t *is more than 90°, 0°00' ift equals 90°.*

The graph below will determine whether the standard or the Sadler technique is required before the table is entered.



If the values for t and dec intersect to the right and above the curve in the shaded area, reduce the sight by Sadler's technique. As the 82°/98° boundary is somewhat arbitrary, the standard technique may be used for sights where the intersection is on or very close to the curve though in the shaded area.

Plotting

In the case of a single sight, the intercept is drawn from the observer's assumed position (usually the DR) in the direction of the body, if Toward, or in the reciprocal direction, if Away. The length of the intercept will be the number of miles calculated (19). (The actual line representing the intercept is often omitted from the plot.) The line of position (LOP) is a line drawn perpendicular to the intercept at its terminus.

In the case for a multi-body fix, all the LOP's are calculated for the same position, the DR at the time of the fix. The advancement or retirement of any given sight is measured along the course line before or after the position used for the calculation and the intercept drawn from that point. Alternatively, each sight may be calculated from its own DR and all intercepts plotted from the DR for the time of the fix; this automatically advances or retires the other sights.

BRIEF SUMMARY OF THE STANDARD TECHNIQUE

Rules:

1. Observe the rules at the top of the table pages.
2. Interpolation is unnecessary for practical navigation.
3. If K is between 82° and 98°, use Sadler's Technique.
4. Give K the same name as declination.
S. The prefix for Z is the same as the name for L; the suffix is the same as the name for t.

Format of the calculation:

t	(7)	EjW	A	(2)						
dec	(3)	N/S	+B	(4)	A	(5)				
			A	(6)	-B	(7)	B	(8)	A	(9)
K	(71)	N/S ←	← ←	←	A	(70)				
L	(72)	N/S								
K∿L	(73)	→ →	→ →	→ →	→ →	→	+B	(74)		
Hc	(77)	← ←	← ←	← ←	← ←	←	A	(75)	-8	(76)
Ho	(78)			Z N/S	(2/)	E/W ←	← ←		A	(20)
a	(79)			Zn	(22)					

Procedure:

1. Enter meridian angle (7) and find (2) from the table.
2. Enter declination (3) and find (4) and (5) from the table.
3. Add (2) and (4) to find (6) and enter (6) as (9) as well.
4. Find (7) and (8) corresponding to (6).
S. Subtract (7)from (5) to find (70).
6. Find angle K (1 1) from the table corresponding to (70).
7. Enter L (72) and calculate (K∿L) (13).
8. From the table, find (74) corresponding to (13).
9. Add (8) and (/ 4) to find (75).
10. From the table, find Hc (77) and (16) corresponding to (75).
11. Enter Ho (18) and calculate the intercept (79).
12. Subtract (76) from (9) to find (20).
13. From the table, find Z (21) corresponding to (20).
14. Convert Z (21) to Zn (22):

Z NE,	Zn = Z	Z SE,	Zn := 180° - Z
Z NW,	Zn = 360° - Z	Z SW,	Zn:= 180° + Z

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°.
Z IS LESS THAN 90° ONLY WHEN K HAS THE SAME NAME AND IS GREATER THAN L.

	A 0°	B	A 1°	B	A 2°	B	A 3°	B	A 4°	B	
	B 90°	A	B 91°	A	8 92°	A	B 93°	A	B 94°	A	
00	------	0.0	175814	6.6	145718	26.5	128120	59.6	115642	105.9	60
01	353627	0.0	5097	6.8	5358	26.9	7880	60.2	5461	106.8	59
02	323524	0.0	4391	7.1	5001	27.4	7641	60.9	5282	107.7	58
03	305915	0.0	3696	7.3	4646	27.8	7403	61.6	5103	108.6	57
04	293421	0.0	3012	7.5	4295	28.3	7166	62.2	4925	109.5	56
05	283730	0.0	172339	7.8	143946	28.7	126931	62.9	114748	110.4	55
06	275812	0.1	1676	8.0	3600	29.2	6697	63.6	4571	111.3	54
07	269118	0.1	1023	8.2	3257	29.6	6465	64.3	4395	112.2	53
08	3318	0.1	0379	8.5	2916	30.1	6233	65.0	4220	113.1	52
09	258203	0.1	169745	8.7	2579	30.6	6003	65.7	4045	114.0	51
10	253627	0.2	169121	9.0	142243	31.1	125774	66.4	113872	114.9	50
11	249488	0.2	8505	9.3	1911	31.5	5546	67.1	3699	115.9	49
12	5709	0.3	7897	9.5	1581	32.0	5320	67.8	3526	116.8	48
13	2233	0.3	7298	9.8	1253	32.5	5094	68.5	3355	117.7	47
14	239015	0.4	6708	10.1	0928	33.0	4870	69.2	3184	118.7	46
15	236018	0.4	166125	10.3	140605	33.5	124647	69.9	113013	119.6	45
16	3216	0.5	5550	10.6	0285	34.0	4425	70.6	2844	120.5	44
17	0583	0.5	4982	10.9	139967	34.5	4205	71.3	2675	121.5	43
18	228100	0.6	4422	11 .2	9651	35.0	3985	72.1	2506	122.4	42
19	5752	0.7	3869	11.5	9338	35.5	3766	72.8	2339	123.4	41
20	223525	0.7	163322	11.8	139027	36.0	123549	73.5	112171	124.3	40
21	1406	0.8	2783	12.1	8718	36.5	3333	74.3	2005	125.3	39
22	219385	0.9	2250	12.4	8411	37.1	3117	75.0	1839	126.2	38
23	7455	1.0	1724	12.7	8106	37.6	2903	75.8	1674	127.2	37
24	5607	1.1	1204	13.0	7804	38.1	2690	76.5	1510	128.2	36
25	213834	1.1	160690	13.3	137503	38.6	122478	77.3	111346	129.2	35
26	2130	1.2	0182	13.6	7205	39.2	2267	78.0	1183	130.1	34
27	0491	1.3	159680	13.9	6909	39.7	2057	78.8	1020	131.1	33
28	208912	1.4	9184	14.2	6615	40.3	1848	79.5	0858	132.1	32
29	7388	1.5	8693	14.6	6322	40.8	1640	80.3	0696	133.1	31
30	205916	1.7	158208	14.9	136032	41.4	121432	81.1	11 0536	134.1	30
31	4492	1.8	7728	15.2	5744	41.9	1226	81.9	0375	135.1	29
32	3113	1.9	7254	15.6	5457	42.5	1021	82.6	0216	136.1	28
33	1777	2.0	6784	15.9	5173	43.0	0817	83.4	0057	137.1	27
34	0480	2.1	6320	16.2	4890	43.6	0614	84.2	109898	138.1	26
35	199221	2.3	155861	16.6	134609	44.2	120412	85.0	109740	139.1	25
36	7998	2.4	5406	16.9	4330	44.7	0211	85.8	9583	140.1	24
37	6808	2.5	4956	17.3	4053	45.3	0010	86.6	9426	141.1	23
38	5650	2.7	4511	17.6	3777	45.9	119811	87.4	9270	142.2	22
39	4522	2.8	4070	18.0	3503	46.5	9612	88.2	9115	143.2	21
40	193422	2.9	153634	18.4	133231	47.1	119415	89.0	108960	144.2	20
41	2350	3.1	3201	18.7	2961	47.6	9218	89.8	8805	145.2	19
42	1304	3.2	2774	19.1	2692	48.2	9022	90.6	8651	146.3	18
43	0282	3.4	2350	19.5	2425	48.8	8827	91,4	8498	147.3	17
44	189283	3.6	1931	19.9	2159	49.4	8633	92.3	8345	148.4	16
45	188307	3.7	151515	20.3	131896	50.0	118440	93.1	108193	149.4	15
46	7353	3.9	1104	20.6	1633	50.7	8248	93.9	8041	150.5	14
47	6419	4.1	0696	21,0	1373	51,3	8056	94.7	7890	151.5	13
48	5505	4.2	0292	21.4	1114	51.9	7866	95.6	7739	152.6	12
49	4609	4.4	149892	21.8	0856	52.5	7676	96.4	7589	153.6	11
50	183732	4.6	149496	22.2	130600	53.1	117487	97.3	107439	154.7	10
51	2872	4.8	9103	22.6	0346	53.7	7299	98.1	7290	155.8	09
52	2029	5.0	8713	23.1	0093	54.4	7112	99.0	7141	156.9	08
53	1202	5.2	8327	23.5	129841	55.0	6925	99.8	6993	157.9	07
54	0390	5.4	7945	23.9	9591	55.7	6739	100.7	6846	159.0	06
55	179593	5.6	147566	24.3	129342	56.3	116554	101.6	106699	160.1	05
56	8811	5.8	7190	24.7	9095	56.9	6370	102.4	6552	161.2	04
57	8042	6.0	6817	25.2	8849	57.6	6187	103.3	6406	162.3	03
58	7287	6.2	6448	25.6	8605	58.2	6004	104.2	6260	163.4	02
59	6544	6.4	6081	26.0	8362	58.9	5823	105.0	6115	164.5	01
60	175814	6.6	145718	26.5	128120	59.6	115642	105.9	105970	165.6	00
	B 89°	A	B 88°	A	B 87°	A	B 86°	A	B 85°	A	
	A 179°	B	A 178°	B	A 177°	B	A 176°	B	A 175°	B	

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	A 5° B B 95° A		6° B 96° A		A 7° B B 97° A		A 8° B B 98° A		A 9° B B 99° A		
00	105970	166	-0 7	239	91411	325	85644	425	80567	538	60
01	5826	167	97 57	240	308	326	555	426	487	540	59
02	5683	168	837	241	205	328	465	428	408	542	58
03	5539	169	--7	243	103	330	376	430	328	544	57
04	5397	17	598	244	001	331	286	432	249	546	56
05	105254	171	97 80	245	90899	333	85197	434	80170	548	55
06	5113	172	361	247	798	334	109	435	091	550	54
07	4971	173	3	248	696	336	020	437	012	552	53
08	4830	175	-26	249	595	337	84931	439	79933	554	52
09	4690	176	08	251	494	339	843	441	855	556	51
10	104550	17	91	252	90394	341	84755	443	79777	558	50
11	4411	178	-74	253	293	342	667	444	698	560	49
12	4272	179	658	255	193	344	579	446	620	562	48
13	4133	18	542	256	093	345	1\92	448	542	564	47
14	3995	181	26	258	89994	347	404	450	465	566	46
15	103857	18	96310	259	89894	349	84317	452	79387	568	45
16	3720	184	-95	260	795	350	230	454	309	571	44
17	3583	185		262	696	352	143	455	232	573	43
18	3447	18	95 66	263	598	353	056	457	155	575	42
19	3311	18	851	264	499	355	83970	459	078	577	41
20	103175	188	95738	266	89401	357	83884	461	79001	579	40
21	3040	19	624	267	303	358	797	463	78924	581	39
22	2905	191	- 0	269	205	360	711	465	847	583	38
23	2771	19	97	270	107	362	626	467	771	585	37
24	2637	193	285	272	010	363	540	468	694	587	36
25	102504	194	961 2	273	88913	365	83455	470	78618	589	35
26	2371	196	O	274	816	367	369	472	542	591	34
27	2238	197	- 948	276	719	368	284	474	466	593	33
28	2106	19	36	277	623	370	199	476	390	596	32
29	1974	19	25	279	526	371	114	478	315	598	31
30	101843		946 4	280	88430	373	83030	480	78239	600	30
31	1712		- 3	282	334	375	82945	482	164	602	29
32	1581		393	283	239	376	861	483	088	604	28
33	1451		283	284	143	378	777	485	013	606	27
34	1321		73	286	048	380	693	487	77938	608	26
35	101192		94 63	287	87953	382	82609	489	77863	610	25
36	1063		93954	289	858	383	526	491	789	612	24
37	0934		5	290	764	385	442	493	714	615	23
38	0806		36	292	669	387	359	495	639	617	22
39	0678		28	293	575	388	276	497	565	619	21
40	100550	213	93519	295	87481	390	82193	499	77491	621	20
41	0423	21-	411	296	388	392	110	501	417	623	19
42	0296	215	304	298	294	393	027	503	343	625	18
43	0170	217	96	299	201	395	81945	505	269	628	17
44	0044	218	89	301	108	397	863	506	195	630	16
45	99918	219	2982	302	87015	399	81780	508	77122	632	15
46	793	220	876	304	86922	400	698	510	048	634	14
47	668	222	69	305	829	402	617	512	76975	636	13
48	544	223	663	307	737	404	535	514	902	638	12
49	419	224	558	308	645	405	453	516	829	641	11
50	99296	225	92452	310	86553	407	81372	518	76756	643	10
51	172	227	347	311	461	409	291	520	683	645	09
52	049	2	242	313	370	411	210	522	610	64-7	08
53	98926	229	37	314	278	412	129	524	538	649,	07
54	804	231	032	316	187	414	048	526	465	652	06
55	98682	232	- 928	317	86096	416	80967	528	76393	654	05
56	560	233	824	319	006	418	887	530	321	656	04
57	439	235	720	320	85915	419	807	532	248	658	03
58	318	236	617	322	825	421	727	534	177	660	02
59	197	237	514	323	734	423	647	536	105	663	01
60	98077		1411	325	85644	425	567	538	76033	665	00
	B 84° A 174°		83° A 173° B		B 82° A A 172° B		B 81° A 171° B		B 80° A A 170° B		

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°.
Z IS LESS THAN 90° ONLY WHEN K HAS THE SAME NAME AND IS GREATER THAN L.

′	A 10° B 100°	B A	A 11° B 101°	B A	A 12° B 102°	B A	A 13° B 103°	B A	A 14° B 104°	B A	′
00	76033	565	71940	805	68212	960	64791	1128	61632	1310	60
01	75961	667	875	808	153	962	737	131	582	313	59
02	890	669	810	810	093	965	682	133	531	316	58
03	819	672	746	813	034	968	627	136	481	319	57
04	747	674	681	815	67975	970	573	139	430	322	56
05	75676	676	71616	818	67916	973	64519	1142	61380	1325	55
06	605	678	552	820	857	976	464	145	330	329	54
07	534	681	488	823	798	978	410	148	279	332	53
08	464	683	423	825	739	981	356	151	229	335	52
09	393	685	359	828	681	984	302	154	179	338	51
10	75323	687	71295	830	67622	987	64248	1157	61129	1341	50
11	252	690	231	833	563	989	194	160	079	344	49
12	182	692	167	835	505	992	140	163	029	348	48
13	112	694	104	838	447	995	086	166	60979	351	47
14	042	696	040	840	388	998	032	169	929	354	46
15	74972	699	70976	843	67330	1000	63978	1172	60879	1357	45
16	902	701	913	845	272	003	925	175	830	360	44
17	832	703	850	848	214	006	871	178	780	364	43
18	763	706	786	850	156	009	818	181	730	367	42
19	693	708	723	853	098	011	764	184	681	370	41
20	74624	710	70660	855	67040	1014	63711	1187	60631	1373	40
21	555	712	597	858	66982	017	658	190	582	377	39
22	486	715	534	860	925	020	605	193	533	380	38
23	417	717	471	863	867	022	551	196	483	383	37
24	348	719	409	865	810	025	498	199	434	386	36
25	74279	722	70346	868	66752	1028	63445	1202	60385	1390	35
26	210	724	284	870	695	031	392	205	336	393	34
27	142	726	221	873	638	033	340	208	287	396	33
28	073	729	159	876	580	036	287	211	238	399	32
29	005	731	097	878	523	039	234	214	189	403	31
30	73937	733	70034	881	66466	1042	63181	1217	60140	1406	30
31	869	736	69972	883	409	045	129	220	091	409	29
32	801	738	910	886	353	047	076	223	042	412	28
33	733	740	849	888	296	050	024	226	59994	416	27
34	665	743	787	891	239	053	62972	229	945	419	26
35	73597	745	69725	894	66182	1056	62919	1232	59897	1422	25
36	530	748	664	896	126	059	867	235	848	426	24
37	462	750	602	899	069	062	815	238	800	429	23
38	395	752	541	901	013	064	763	241	751	432	22
39	328	755	479	904	65957	067	711	244	703	435	21
40	73261	757	69418	907	65900	1070	62659	1247	59654	1439	20
41	194	759	357	909	844	073	607	250	606	442	19
42	127	762	296	912	788	076	555	254	558	445	18
43	060	764	235	914	732	079	503	257	510	449	17
44	72993	767	174	917	676	081	451	260	462	452	16
45	72927	769	69113	920	65620	1084	62400	1263	59414	1455	15
46	860	771	053	922	564	087	348	266	366	459	14
47	794	774	68992	925	509	090	297	269	318	462	13
48	727	776	932	928	453	093	245	272	270	465	12
49	661	779	871	930	398	096	194	275	222	469	11
50	72595	781	68811	933	65342	1099	62142	1278	59175	1472	10
51	529	783	750	936	287	102	091	281	127	475	09
52	463	786	690	938	231	104	040	285	079	479	08
53	398	788	630	941	176	107	61989	288	032	482	07
54	332	791	570	944	121	110	938	291	58984	485	06
55	72266	793	68510	946	65066	1113	61887	1294	58937	1489	05
56	201	796	451	949	011	116	836	297	889	492	04
57	136	798	391	952	64956	119	785	300	842	495	03
58	070	800	331	954	901	122	734	303	795	499	02
59	005	803	272	957	846	125	683	306	748	502	01
60	71940	805	68212	960	64791	1128	61632	1310	58700	1506	00
′	B 79° A 169°	A B	B 78° A 168°	A B	B 77° A 167°	A B	B 76° A 166°	A B	B 75° A 165°	A B	′

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°.
Z IS LESS THAN 90° ONLY WHEN K HAS THE SA'1E NAME AND IS GREATER THAN L.

	A 15°	B	A 16°	B	A 17°	B	A 18°	B	A 19°	B	
	8 105°	A	B 106°	A	B 107°	A	B 108°	A	B 109°	A	
00	58700	1506	55966	1716	53406	1940	51002	2179	48736	2433	60
01	653	509	922	719	365	944	50963	183	699	437	59
02	606	512	878	723	324	948	924	188	662	442	58
03	559	516	834	727	283	952	885	192	626	446	57
04	512	519	90	730	242	956	847	196	589	450	56
05	58465	1523	55 ·7	1734	53200	1960	50803	2200	48553	2455	55
06	418	526	1 3	738	159	964	769	204	516	459	54
07	372	529	659	741	118	968	731	208	480	464	53
08	325	533	61	745	077	971	692	212	443	468	52
09	278	536	572	749	036	975	653	216	407	472	51
10	58232	1540	5552 -	1752	52995	1979	50615	2221	48371	2477	50
11	185	543	484	756	955	983	576	225	334	481	49
12	139	547	[illegible]	760	914	987	538	229	298	485	48
13	092	550	3	763	873	991	500	233	262	490	47
14	046	553	35	767	832	995	461	237	226	494	46
15	57999	1557	5531	1771	52791	1999	50423	2241	48189	2499	45
16	953	560	267	774	751	2003	385	246	153	503	44
17	907	564	224	78	710	007	346	250	117	508	43
18	860	567	[illegible]	782	670	011	308	254	081	512	42
19	814	571	38	785	629	014	270	258	045	516	41
20	57768	1574	55095	89	52589	2018	50232	2262	48009	2521	40
21	722	578	[illegible]	793	548	022	194	266	47973	525	39
22	676	581	0	96	508	026	156	271	937	530	38
23	630	58:i	54 65	[illegible]	467	030	118	275	901	534	37
24	584	588	923	8 4	427	034	080	279	865	539	36
25	57539	1591	54880	1808	52387	2038	50042	2283	47829	2543	35
26	493	595	837	811	346	042	004	287	793	547	34
27	447	598	794	[illegible] 5	306	046	49966	292	758	552	33
28	401	602	75	[illegible]	266	050	928	296	722	556	32
29	356	605	7	823	226	054	890	300	686	561	31
30	57310	1609	54666	826	52186	2058	49852	2304	47650	2565	30
31	265	612	623	830	146	062	815	309	615	570	29
32	219	616	581	834	106	066	777	313	579	574	28
33	174	619	53	[illegible]	066	070	739	317	544	579	27
34	128	623	496	[illegible]	026	074	702	321	SOB	583	26
35	57083	1627	54453	[illegible]	51986	2078	49664	2326	47473	2588	25
36	038	630	41	[illegible]	946	082	626	330	437	592	24
37	56992	634	368	[illegible]	906	086	589	334	402	597	23
38	947	637	326	[illegible]	867	090	551	338	366	601	22
39	902	641	284	[illegible]	827	094	514	343	331	606	21
40	56857	1644	54242	[illegible]	51787	2098	49477	23 7	47295	2610	20
41	812	648	199	[illegible]	748	102	439	351	260	615	19
42	767	651	15i	[illegible]	708	106	402	355	225	619	18
43	722	655	11 -	[illegible]	668	110	365	36	139	624	17
44	677	658	073	[illegible]	629	114	327	364	154	628	16
45	56633	1662	54031	[illegible]	51589	2118	49290	2368	47119	2633	15
46	588	666	53989	[illegible]	550	122	253	372	084	637	14
47	543	669	947	[illegible]	510	126	216	377	049	642	13
48	498	673	905	[illegible]	471	130	179	381	014	647	12
49	454	676	864	[illegible]	432	134	142	385	46979	651	11
50	56409	1680	53822	[illegible]	51393	2139	49104	239	46944	2656	10
51	365	683	780	[illegible]	353	143	067	[illegible]	908	660	09
52	320	687	738	[illegible]	314	147	030	98	874	.665	08
53	276	691	697	[illegible]	275	151	48993	3	839	669	07
54	231	694	655	[illegible]	236	155	957		804	674	06
55	56187	1698	53614	[illegible]	51197	2159	48920	2411	46769	2678	05
56	143	701	572	[illegible]	158	163	883	4 6	734	683	04
57	099	705	531	[illegible]	119	167	846	20	699	688	03
58	054	709	489	[illegible]	080	171	809	424	664	692	02
59	010	712	448	[illegible]	041	175	773	29	630	697	01
60	55966	1716	53406	[illegible]	51002	2179	48736	2433	46595	2701	00
	B 74°	A	B 73°	[illegible]	B 72°	A	B 71°	[illegible]	B 70°	A	
	A 164°	B	A 163°	[illegible]	A 162°	B	A 16[illegible]	[illegible]	A 160°	B	

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°.
Z IS LESS THAN 90° ONLY WHEN K HAS THE SAME NAME AND IS GREATER THAN L.

'	A 20°	B	A 21°	B	A 22°	B	A 23°	B	A 24°	B	'
	B 110°	A	B 111°	A	B 112°	A	B 113°	A	B 114°	A	
00	46595	2701	44567	2985	42642	3283	40812	3597	39069	3927	60
01	560	706	534	990	611	289	782	603	040	933	59
02	525	711	501	995	580	294	753	608	012	938	58
03	491	715	463	999	549	299	723	613	38984	944	57
04	456	720	436	3004	518	304	693	619	955	950	56
05	46422	2724	44403	3009	42486	3309	40664	3624	38927	3955	55
06	387	729	370	014	455	314	634	630	899	961	54
07	353	734	337	019	424	319	604	635	871	966	53
08	318	738	305	024	393	324	575	640	842	972	52
09	284	743	272	029	362	330	545	646	814	978	51
10	46249	2748	44239	3034	42331	3335	40516	3651	38786	3983	50
11	215	752	207	038	300	340	486	657	758	989	49
12	181	757	174	043	269	345	457	662	730	995	43
13	146	762	142	048	238	350	427	667	702	4000	47
14	112	766	109	053	207	355	398	673	674	006	46
15	46078	2771	44077	3058	42176	3360	40368	3678	38646	4012	45
16	043	776	044	063	145	366	339	684	618	018	44
17	009	780	012	068	115	371	310	689	589	023	43
18	45975	785	43979	073	084	376	280	695	562	029	42
19	941	790	947	078	053	381	251	700	534	035	41
20	45907	2794	43915	3083	42022	3386	40222	3706	38506	4040	40
21	873	799	882	088	41992	392	192	711	478	046	39
22	839	804	850	093	961	397	163	716	450	052	38
23	805	808	818	097	930	402	134	722	422	058	37
24	771	813	785	102	899	407	105	727	394	063	36
25	45737	2818	43753	3107	41869	3412	40076	3733	38366	4069	35
26	703	822	721	112	838	418	046	738	338	075	34
27	669	827	689	117	808	423	017	744	311	080	33
28	635	832	657	122	777	428	39988	749	283	086	32
29	601	837	625	127	747	433	959	755	255	092	31
30	45567	2841	43592	3132	41716	3438	39930	3760	38227	4098	30
31	534	846	560	137	686	444	901	766	200	103	29
32	500	851	528	142	655	449	872	771	172	109	28
33	466	855	496	147	625	454	843	777	144	115	27
34	433	860	464	152	594	459	814	782	117	121	26
35	45399	2865	43432	3157	41564	3465	39785	3788	38089	4127	25
36	365	870	401	162	533	470	756	793	061	132	24
37	332	874	369	167	503	475	727	799	034	138	23
38	298	879	337	172	473	480	698	804	006	144	22
39	265	884	305	177	443	486	669	810	37979	150	21
40	45231	2889	43273	3182	41412	3491	39641	3815	37951	4156	20
41	198	893	241	187	382	496	612	821	924	161	19
42	164	898	210	192	352	502	583	826	896	167	18
43	131	903	178	197	322	507	554	832	869	173	17
44	097	908	146	202	291	512	526	838	841	179	16
45	45064	2913	43114	3207	41261	3517	39497	3843	37814	4185	15
46	031	917	083	212	231	523	468	849	786	190	14
47	44997	922	051	217	201	528	439	854	759	196	13
48	964	927	020	222	171	533	411	860	732	202	12
49	931	932	42988	228	141	539	382	865	704	208	11
50	44898	2937	42956	3233	41111	3544	39354	3811	37677	4214	10
51	864	941	925	238	081	549	325	877	650	220	09
52	831	946	893	243	051	555	296	882	623	225	08
53	798	951	862	248	021	560	268	888	595	231	07
54	765	956	831	253	40991	565	239	893	568	237	06
55	44732	2961	42799	3258	40961	3571	39211	3899	37541	4243	05
56	699	965	768	263	931	576	182	905	514	249	04
57	666	970	736	268	902	581	154	910	487	255	03
58	633	975	705	273	872	587	125	916	459	261	02
59	600	980	674	278	842	592	097	921	432	267	01
60	44567	2985	42642	3283	40812	3597	39069	3927	37405	4272	00
'	B 69°	A	B 68°	A	B 67°	A	B 66°	A	B 65°	A	'
	A 159°	B	A 158°	B	A 157°	B	A 156°	B	A 155°	B	

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°,
Z IS LESS THAN 90° ONLY WHEN K HAS THE SAME NAME AND IS GREATER THAN L.

	A 25°	B	A 26°	B	A 27°	B	A 28°	B	A 29°	B	
	B 115°	A	B 116°	A	B 117°	A	B 118°	A	B 119°	A	
00	37405	4272	35816	4634	34295	5012	32839	5407	31443	5818	60
01	378	278	790	640	271	018	815	413	420	825	59
02	351	284	764	646	246	025	792	420	397	832	58
03	324	290	738	652	221	031	768	427	375	839	57
04	297	296	712	659	196	038	744	433	352	846	56
05	37270	4302	35687	4665	34172	5044	32720	5440	31329	5853	55
06	243	308	661	671	147	051	697	447	306	860	54
07	216	314	635	677	122	057	673	454	284	867	53
08	189	320	609	683	098	064	650	460	261	874	52
09	162	326	583	690	073	070	626	467	238	881	51
10	37135	4332	35558	4696	34048	5077	32602	5474	31216	5888	50
11	108	337	532	702	024	083	579	481	193	895	49
12	082	343	506	708	33999	089	555	487	171	902	48
13	055	349	481	714	975	096	532	494	148	910	47
14	028	355	455	721	950	102	508	501	125	917	46
15	37001	4361	35429	4727	33925	5109	32485	5508	31103	5924	45
16	36974	367	404	733	901	115	461	515	080	931	44
17	948	373	378	739	876	122	438	521	058	938	43
18	921	379	353	746	852	129	414	528	035	945	42
19	894	385	327	752	827	135	391	535	013	952	41
20	36867	4391	35302	4758	33803	5142	32367	5542	30990	5959	40
21	841	397	276	764	779	148	344	549	968	966	39
22	814	403	251	771	754	155	320	555	945	973	38
23	787	409	225	777	730	161	297	562	923	980	37
24	761	415	200	783	705	168	274	569	900	988	36
25	36734	4421	35174	4789	33681	5174	32250	5576	30878	5995	35
26	708	427	149	796	657	181	227	583	856	6002	34
27	681	433	123	802	632	187	204	590	833	009	33
28	655	439	098	808	608	194	180	596	811	016	32
29	628	445	073	815	584	201	157	603	788	023	31
30	36602	4451	35047	4821	33559	5207	32134	5610	30766	6030	30
31	575	457	022	827	535	214	110	617	744	037	29
32	549	463	34997	833	511	220	087	624	721	045	28
33	522	469	971	840	487	227	064	631	699	052	27
34	496	475	946	846	463	233	041	638	677	059	26
35	36469	4481	34921	4852	33438	5240	32018	5645	30655	6066	25
36	443	487	896	859	414	247	31994	651	632	073	24
37	417	493	870	865	390	253	971	658	610	080	23
38	390	500	845	871	366	260	948	665	588	088	22
39	364	506	820	878	342	266	925	672	566	095	21
40	36338	4512	34795	4884	33318	5273	31902	5679	30544	6102	20
41	311	518	770	890	294	280	879	686	521	109	19
42	285	524	745	897	269	286	856	693	499	116	18
43	259	530	719	903	245	293	833	700	477	124	17
44	233	536	694	910	221	300	810	707	455	131	16
45	36206	4542	34669	4916	33197	5306	31787	5714	30433	6138	15
46	180	548	644	922	173	313	763	721	411	145	14
47	154	554	619	929	149	320	740	727	389	153	13
48	128	560	594	935	125	326	717	734	367	160	12
49	102	566	569	941	101	333	695	741	345	167	11
50	36076	4573	34544	4948	33078	5340	31672	5748	30323	6174	10
51	050	579	519	954	054	346	649	755	301	181	09
52	024	585	494	961	030	353	626	762	279	189	08
53	35998	591	469	967	006	360	603	769	257	196	07
54	972	597	444	973	32982	366	580	776	235	203	06
55	35946	4603	34420	4980	32958	5373	31557	5783	30213	6211	05
56	920	609	395	986	934	380	534	790	191	218	04
57	894	616	370	993	910	386	511	797	169	225	03
58	868	622	345	999	887	393	488	804	147	232	02
59	842	628	320	5005	863	400	466	811	125	240	01
60	35816	4634	34295	5012	32839	5407	31443	5818	30103	6247	00
	B 64°	A	B 63°	A	B 62°	A	B 61°	A	B 60°	A	
	A 154°	B	A 153°	B	A 152°	B	A 151°	B	A 150°	B	

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°.
l IS LESS THAN 90° ONLY WHEN K HAS THE SAME NAME AND IS GREATER THAN L.

	A 30°	B	A 31°	B	A 32°	B	A 33°	B	A 34°	B	
	B 120°	A	B 121°	A	B 122°	A	B 123°	A	B 124°	A	
00	30103	6247	28816	6693	27579	7158	26389	7641	25244	8143	60
01	081	254	795	701	559	166	370	649	225	151	59
02	059	262	774	709	539	174	350	657	206	160	58
03	037	269	753	716	518	182	331	665	188	168	57
04	016	276	732	724	498	190	311	674	169	177	56
05	29994	6283	28711	6731	27478	7197	26292	7682	25150	8185	55
06	972	291	690	739	458	205	273	690	132	194	54
07	950	298	669	747	438	213	253	698	113	202	53
08	928	305	648	754	418	221	234	707	094	211	52
09	907	313	627	762	398	229	215	715	076	219	51
10	29885	6320	28607	6770	27378	7237	26195	7723	25057	8228	50
11	863	327	586	777	357	245	176	731	039	237	49
12	841	335	565	785	337	253	157	740	020	245	48
13	820	342	544	793	317	261	137	748	001	254	47
14	798	350	523	800	297	269	118	756	24983	262	46
15	29776	6357	28502	6808	27277	7277	26099	7765	24964	8271	45
16	755	364	481	816	257	285	079	773	946	280	44
17	733	372	461	823	237	293	060	781	927	288	43
18	712	379	440	831	217	301	041	789	909	297	42
19	690	386	419	839	197	309	022	798	890	305	41
20	29668	6394	28398	6846	27177	7317	26003	7806	24872	8314	40
21	647	401	378	854	157	325	25983	814	853	323	39
22	625	409	357	862	137	333	964	823	835	331	38
23	604	416	336	869	117	341	945	831	816	340	37
24	582	423	315	877	098	349	926	839	798	349	36
25	29561	6431	28295	6885	27078	7357	25907	7848	24779	8357	35
26	539	438	274	892	058	365	887	856	761	366	34
27	518	446	253	900	038	373	868	864	742	375	33
28	496	453	233	908	018	381	849	873	724	383	32
29	475	461	212	916	26998	389	830	881	706	392	31
30	29453	6468	28191	6923	26978	7397	25811	7889	24687	8401	30
31	432	475	171	931	959	405	792	898	669	409	29
32	410	483	150	939	939	413	773	906	650	418	28
33	389	490	130	947	919	421	754	914	632	427	27
34	367	498	109	954	899	429	735	923	614	435	26
35	29346	6505	28089	6962	26879	7437	25716	7931	24595	8444	25
36	325	513	068	970	860	445	697	940	577	453	24
37	303	520	048	978	840	454	678	948	559	462	23
38	282	528	027	986	820	462	659	956	541	470	22
39	261	535	006	993	800	470	640	965	522	479	21
40	29239	6543	27986	7001	26781	7478	25621	7973	24504	8488	20
41	218	550	966	009	761	486	602	982	486	496	19
42	197	558	945	017	741	494	583	990	467	505	18
43	176	565	925	024	722	502	564	998	449	514	17
44	154	573	904	032	702	510	545	8007	431	523	16
45	29133	6580	27884	7040	26682	7518	25526	8015	24413	8531	15
46	112	588	863	048	663	527	507	024	395	540	14
47	091	595	843	056	643	535	488	032	376	549	13
48	069	603	823	064	623	543	469	041	358	558	12
49	048	610	802	071	604	551	451	049	340	567	11
50	29027	6618	27782	7079	26584	7559	25432	8058	24322	8575	10
51	006	625	762	087	565	567	413	066	304	584	09
52	28985	633	741	095	545	575	394	075	286	593	08
53	964	640	721	103	526	584	375	083	267	602	07
54	942	648	701	111	506	592	356	092	249	611	06
55	28921	6656	27680	7119	26487	7600	25338	8100	24231	8619	05
56	900	663	660	126	467	608	319	109	213	628	04
57	879	671	640	134	448	616	300	117	195	637	03
58	858	678	619	142	428	624	281	126	177	646	02
59	837	686	599	150	409	633	263	134	159	655	01
60	28816	6693	27579	7158	26389	7641	25244	8143	24141	8664	00
	B 59°	A	B 58°	A	B 57°	A	B 56°	A	B 55°	A	
	A 149°	B	A 148°	B	A 147°	B	A 146°	B	A 145°	B	

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°.
Z IS LESS THAN 90° ONLY WHEN K HAS THE SAME NAME AND IS GREATER THAN L.

'	A 35° B 125°	B A	A 36° B 126°	B A	A 37° B 127°	B A	A 38° B 128°	B A	A 39° B 129°	B A	,
00	24141	8664	23078	9204	22054	9765	21066	10347	20113	10950	60
01	123	672	061	213	037	775	050	357	097	960	59
02	105	681	043	223	020	784	033	367	082	970	58
03	087	690	026	232	003	794	017	376	066	980	57
04	069	699	009	241	21987	803	001	386	050	991	56
05	24051	8708	22991	9250	21970	9813	20985	10396	20035	11001	55
06	033	717	974	259	953	822	969	406	019	011	54
07	015	726	957	269	937	832	953	416	004	022	53
08	23997	734	939	278	920	841	937	426	19988	032	52
09	979	743	922	287	903	851	921	436	973	042	51
10	23961	8752	22905	9296	21887	9861	20905	10446	19957	11052	50
11	943	761	888	306	870	870	889	456	942	063	49
12	925	770	870	315	853	880	872	466	926	073	48
13	907	779	853	324	837	889	856	476	911	083	47
14	889	788	836	333	820	899	840	486	895	094	46
15	23871	8797	819	9343	21803	9909	20824	10496	19880	11104	45
16	854	806	801	352	787	918	808	505	864	114	44
17	836	815	784	361	770	928	792	515	849	125	43
18	818	824	767	370	754	937	776	525	834	135	42
19	800	833	750	380	737	947	760	535	818	145	41
20	23782	8842	22732	9389	21720	9957	20744	10545	19803	11156	40
21	764	851	715	398	704	966	728	555	787	166	39
22	747	859	698	408	687	976	712	565	772	176	38
23	729	868	681	417	671	986	696	575	756	187	37
24	711	877	664	426	654	995	681	585	741	197	36
25	23693	8886	22647	9435	21638	10005	20665	10595	19726	11207	35
26	676	895	630	445	621	015	649	605	710	218	34
27	658	904	613	454	605	024	633	615	695	228	33
28	640	913	595	463	588	034	617	625	680	239	32
29	622	922	578	473	572	044	601	636	664	249	31
30	23605	8931	22561	9482	21555	10053	20585	10646	19649	11259	30
31	587	940	544	491	539	063	569	656	634	270	29
32	569	949	527	501	522	073	553	666	618	280	28
33	552	958	510	510	506	082	537	676	603	291	27
34	534	967	493	520	490	092	522	686	588	301	26
35	23516	8977	22476	9529	21473	10102	20506	10696	19572	11312	25
36	499	986	459	538	457	112	490	706	557	322	24
37	481	995	442	548	440	121	474	716	542	332	23
38	463	9004	425	557	424	131	458	726	527	343	22
39	446	013	408	566	408	141	442	736	511	353	21
40	23428	9022	22391	9576	21391	10151	20427	10746	19496	11364	20
41	410	031	374	585	375	160	411	756	481	374	19
42	393	040	357	595	358	170	395	767	466	385	18
43	375	049	340	604	342	180	379	777	450	395	17
44	358	058	323	614	326	190	364	787	435	406	16
45	23340	9067	22306	9623	21309	10199	20348	10797	19420	11416	15
46	323	076	289	632	293	209	332	807	405	427	14
47	305	085	272	642	277	219	316	817	390	437	13
48	288	094	256	651	261	229	301	827	375	448	12
49	270	104	.239	661	244	239	285	838	359	458	11
50	23253	9113	22222	9670	21228	10248	20269	10848	19344	11469	10
51	235	122	205	680	212	258	254	858	329	479	09
52	218	131	188	689	195	268	238	868	314	490	08
53	200	140	171	699	179	278	222	878	299	501	07
54	183	149	154	708	163	288	207	888	284	511	06
55	23165	9158	22138	9718	21147	10298	20191	10899	19269	11522	05
56	148	168	121	727	131	307	175	909	254	532	04
57	130	177	104	737	114	317	160	919	238	543	03
58	113	186	087	746	098	327	144	929	223	553	02
59	096	195	070	756	082	337	128	940	208	564	01
60	23078	9204	22054	9765	21066	10347	20113	10950	19193	11575	00
'	B 54° A 144°	A B	B 53° A 143°	A B	B 52° A 142°	A B	B 51° A 141°	A B	8 50° A 140°	A B	'

t AND K ARE BOTH GREATER OR BOTH LESS THAN 90°.
Z IS LESS THAN 90° ONLY WHEN K HAS THE SAME NAME AND IS GREATER THAN L.

'	A 40°	B	A 41°	B	A 42°	B	A 43°	B	A 44°	B	'
	B 130°	A	B 131°	A	B 132°	A	B 133°	A	B 134°	A	
00	19193	11575	18306	12222	17449	12893	16622	13587	15823	14307	60
01	178	585	291	233	435	904	608	599	810	319	59
02	163	596	277	244	421	915	595	611	797	331	58
03	148	606	262	255	407	927	581	623	784	343	57
04	133	617	248	266	393	938	568	634	771	355	56
05	19118	11628	18233	12277	17379	12950	16554	13646	15758	14368	55
06	103	638	219	288	365	961	541	658	745	380	54
07	088	649	204	299	351	972	527	670	731	392	53
08	073	660	190	310	337	984	514	682	718	404	52
09	058	670	175	321	323	995	500	694	705	417	51
10	19043	11681	18161	12332	17309	13007	16487	13705	15692	14429	50
11	028	692	146	343	295	018	473	717	679	441	49
12	013	702	132	354	281	030	460	729	666	453	48
13	18998	713	118	365	267	041	446	741	653	466	47
14	983	724	103	376	253	053	433	753	640	478	46
15	18968	11734	18089	12387	17239	13064	16419	13765	15627	14490	45
16	953	745	074	399	225	076	406	777	615	503	44
17	939	756	060	410	212	0B7	392	789	602	515	43
18	924	766	045	421	198	098	379	800	589	527	42
19	909	777	031	432	184	110	366	812	576	540	41
20	18894	11788	18017	12443	17170	13121	16352	13824	15563	14552	40
21	879	799	002	454	156	133	339	836	550	564	39
22	864	809	17988	465	142	145	326	848	537	577	38
23	849	820	974	476	128	156	312	860	524	589	37
24	834	831	959	487	115	168	299	872	511	601	36
25	18820	11842	17945	12499	17101	13179	16285	13884	15498	14614	35
26	805	852	931	510	087	191	272	896	485	626	34
27	790	863	916	521	073	202	259	908	472	639	33
28	775	874	902	532	059	214	245	920	460	651	32
29	760	885	888	543	045	225	232	932	447	663	31
30	18746	11895	17874	12554	17032	13237	16219	13944	15434	14676	30
31	731	906	859	566	018	248	205	956	421	688	29
32	716	917	845	577	004	260	192	968	408	701	28
33	701	928	831	588	16990	272	179	980	395	713	27
34	686	939	816	599	977	283	166	992	382	726	26
35	18672	11949	17802	12610	16963	13295	16152	14004	15370	14738	25
36	657	960	788	622	949	306	139	016	357	750	24
37	642	971	774	633	935	318	126	028	344	763	23
38	628	982	760	644	922	330	113	040	331	775	22
39	613	993	745	655	908	341	099	052	318	788	21
40	18598	12004	17731	12666	16894	13353	16086	14064	15306	14800	20
41	583	015	717	678	880	365	073	076	293	813	19
42	569	025	703	689	867	376	060	088	280	825	18
43	554	036	689	700	853	388	046	100	267	838	17
44	539	047	674	712	839	400	033	112	255	850	16
45	18525	12058	17660	12723	16826	13411	16020	14124	15242	14863	15
46	510	069	646	734	812	423	007	136	229	875	14
47	495	080	632	745	798	435	15994	149	216	888	13
48	481	091	618	757	785	446	980	161	204	900	12
49	466	102	604	768	771	458	967	173	191	913	11
50	18451	12113	17590	12779	16758	13470	15954	14185	15178	14926	10
51	437	123	576	791	744	482	941	197	165	938	09
52	422	134	561	802	730	493	928	209	153	951	08
53	408	145	547	813	717	505	915	221	140	963	07
54	393	156	533	825	703	517	902	234	127	976	06
55	18378	12167	17519	12836	16690	13528	15888	14246	15115	14988	05
56	364	178	505	847	676	540	875	258	102	15001	04
57	349	189	491	859	662	552	862	270	089	014	03
58	335	200	477	870	649	564	849	282	077	026	02
59	320	211	463	881	635	575	836	294	064	039	01
60	18306	12222	17449	12893	16622	13587	15823	14307	15051	15051	00
'	B 49°	A	B 48°	A	B 47°	A	B 46°	A	B 45°	A	'
	A 139°	B	A 138°	B	A 137°	B	A 136°	B	A 135°	B	

Other Applications of the Table

Although designed primarily for sight reduction, the table may be used for the solution of other navigational problems.

Great Circle Distance and Initial Course

Where L_1 and LO_1 are the coordinates of the point of departure, L_2 and LO_2 those of the destination, and DLo the angular difference (difference in longitude) between the two, the following substitutions are made for the purpose of calculation: L_1 for L, L_2 for dec, DLo for t, C for Z.

As DLo may exceed 90°, the following rules must be observed:

1. L_1 and L_2 have the same name.
   a. DLo and K are both greater or both less than 90°.
   b. D is greater than 90° only if DLo and (K ~ L_1) are both greater than 90°.
   c. C is greater than 90° if K is less than L_1; C is less than 90° if K is greater than L_1.

2. L_1 and L_2 have contrary names.
   a. DLo and K are both greater or both less than 90°.
   b. When (K ~ L_1) is more than 180°, subtract 180° before entering the table.
   c. D is less than 90° when DLo and (K ~ L_1) are both less than 90°.
   d. C is greater than 90° when (K ~ L_1) is less than 180°.

The problem of determining rhumb line course and distance between points on the great circle track is lengthy and complex using this table and is best done by calculator or by plotting. See Bowditch, Volume II, §1012 for a discussion of this application of Ageton's Table.

Example of Great Circle Calculation

Find the great circle distance and initial course from Dunedin, Australia (L 27°28'S, Lo 153°02'E), to Balboa, Canal Zone (L 8°5TN, Lo 79°34'W).

	LO_1	153°02' E				
	LO_2	79°34' W				
(I)	DLo	127°24' E	A 9995			
	L_2	8°57' N	+8 532	A80807		
			A 10527	-8 20776	B 20776	A 10527
	K	165°28' N ←	← ← ←	← A 60031		
	L_1	27°28' S				
	K ~ L_1	192°56'				
(2)	-180°	12°56'	....	....	+B 1116	
(3)	D	127°10'	← ← ←	← ← ← ← ←	B 21892	-A 9861
(4)	D	7630 miles		C S 80° E ←	← ← ← ← ← ←	A 666
				Cn 100°		

Notes:

(1) *In this case, OLo = 360° - (La, + LO_2).*

(2) *Subtract 180° to enter the table per rule 2b.*

(3) *By reversing A and B as they appear in the sight reduction format, distance results directly as does C in the next step.*

(4) *C is converted to Cn just as Z to Zn.*

The Time a Body Is on the Prime Vertical

An observation of a body on the prime vertical (Z = 90°) will yield an LOP parallel to the meridian and, hence, the navigator's longitude, provided the sight is accurate and the latitude certain. Also, as a body near the prime vertical is changing direction (azimuth) at its slowest rate, it is an excellent time to check the compass by means of a compass bearing on the body. The sun is used almost exclusively for this purpose.

It must be remembered that the body will cross the prime vertical only when its declination is less than the latitude and has the same name.

Example of the Time a Body Is on the PV

On 21 December 1980, your ZT 1600 DR will be L 28°40' S, Lo 21° 44' W. Using the table, determine the ZT when the sun will be on the afternoon prime vertical, to the nearest minute.

Note in the following calculation the B corresponding to the initial A for declination is subtracted from the B beneath it to give the final A from which t is derived.

ZT	1600		
ZD	+ 1		
UT	1700		

dec sun 17h	23°26' S	A 40046	-B 3738
L	28°40' S	-A 31902	
		A 8144	B 25244
t on PM PV	37°33' W	← ← ← ←	A 21506
Lo	21°44' W		
GHA sun on PM PV	59°17'		
	45°25'	GHA sun for 15h from Almanac	
	13°52'	55m 28s from Increments and Corrections in the Almanac	

Sun on PM PV at	UT 15-55-28	UT	1555
		ZD	+ 1 (rev)
	Sun on PM PV	ZT	1455 to the nearest minute

As it is not normally wanted, altitude is not shown, but it is the angle corresponding to A 8144 in the example and is 56°00'.

The procedure is quite straightforward. For the approximate time a body will be on the PV—mid-morning or mid-afternoon is usually close enough—the declination of the body is taken from the Almanac and the coordinates of the vessel's position for that time from the plot. t is found from the table and the more exact time deduced by applying the longitude; the result should be accurate to the nearest minute. [Interpolation of declination using Bowditch's Table 25 will result in the same value for t as will calculation by Ageton's Table.]

The Identification of an Unknown Body

When the sky is largely obscured by clouds, a sight may be possible but the identity of the body in doubt. Identification is possible by means of this table though it is more easily accomplished by a Star Finder if available.

The declination and SHA of the body are found by means of the table and compared with the values given for the various stars and planets in the Almanac. The reliability of the identification depends largely on the accuracy of the bearing taken on the body.

The problem is essentially the reverse of that for sight reduction. Substitutions are: Z for t, Ho for dec. The values for dec and t are derived from the table. t is converted to GHA by means of the longitude and the required SHA from the relationship: SHA body = GHA body - GHA Aries.

Rules:

1. Give K the same name as L.

2. When Z is greater than 90°, K is also greater than 90°,

3. Declination is always less than 90° and has the same name as L, except when Z and (K ~ L) are both greater than 90°,

4. t is less than 90° when K is greater than L; greater than 90° when K is less than L.

Example of Unknown Body Identification

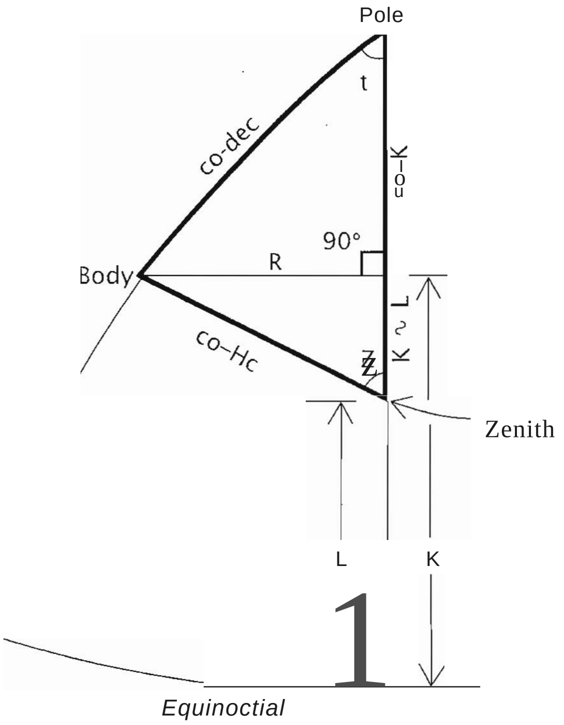
At ZT 05-55-00 on 29 October 1980, an observation of an unknown body results in a corrected sextant altitude, Ho, of 40°17', Its compass bearing is 100° true. The DR position is L 35°20'N, Lo 60° 18'W.

Z	100°		A 665			
Ho	40°17'		+B 11756	A 18939		
			A 12421	-B 18045	B 18045	A 12421
K	101°35'	N ← ← ← ← ←		A 894		
L	35°20'	N				
K ~ L	66°15'	N → → → → → → → →			+B 39497	
dec	15°25'	N ← ← ← ← ← ← ← ←			A57542	-B 1591
			t	51°12' E ← ← ← ←		A 10830
			La	60°18' W		
			GHA body	9°06' =	369°06'	
			GHA Aries		186°38'	
			SHA body		182°28'	

From the calculation: dec 15°25' N, SHA 182°28'
Denebola (Almanac): dec 14°41' N, SHA 182°59'

So, the unknown body is Denebola.

Appendix: The Ageton Formulas



The Divided Navigational Triangle (heavy outline)
on the Plane of the Horizon (after Ageton)

When using the table, the log esc ofan angle is A; the log sec ofan angle is B.

Sight Reduction-Standard Technique

log esc R = log esc t + log sec dec
log esc K = log ese dec - log sec R
log esc He =log see R + log sec (K ~ L)
log esc Z =log esc R - log sec He

Sight Reduction-Sadler's Technique

log ese hI =log esc dec + log ese L
log esc hz =log sec t + log see dee + log sec L -
log sec ([hI + Ho]/2)
He =hI + hz
log esc Z = log esc t + log sec dec - log sec He

Time a Body Is on the Prime Vertical

Z = 90° and K = L or (K ~ L) = 0

log csc Hc = log csc dec - log csc L
log csc t = log sec Hc - log sec dec

Great Circle

Substitute point of departure for Zenith and destination for Body, whence
L_1 = L, L_2 = dec, DLo = t, C = Z, D = co - Hc.

log csc R = log csc DLo + log sec L2
log csc K = log csc L_2 - log sec R
log sec D = log sec R + log sec (K ~ L_1)
log csc C = log csc R - log csc D

Unknown Body Identification

Z, Ho and L are known. To find t and dec:

log csc R = log csc Z + log sec Ho
log csc K = log csc Ho - log sec R
log csc dec = log sec R + log sec (K ~ L)
log csc t = log csc R - log sec dec

Angle R is never used, nor is it ever necessary to find its value from the table; consequently, it is not included in the format of the sight reduction calculation, nor is it shown in any of the examples.

About the Author

Allan E. Bayless, a neurosurgeon, has been an amateur sailor since he taught himself to sail in Newport Bay, California, at the age of sixteen. He has owned several sailboats and has cruised Puget Sound and the coastal waters of Southern California and New England.

Dr. Bayless is a Life Member of the United States Power Squadrons and has been active in the National Educational Department for many years. He has chaired various committees, including the Navigation Committee (1970–1975), and was the Director of Education in 1980. He was a member of the Council (Marine) of the Institute of Navigation for three years and has been on the board of directors of the Navigation Foundation since its inception.

He is the author of numerous articles on nautical subjects and of book reviews for *The Ensign* and other periodicals. He is cited in the prefaces of the 1975 and 1981 editions of *Bowditch,* Volume II; an extract from the Compact Table appears on page 517 and a brief description on page 518 of the latter edition.