ASTRO-NAVIGATION PILOTING & DEAD RECKONING

TAMAYA PRACTICAL NAVIGATOR

NC-88

Precision Marine Sextants Since 1925

TAMAYA

TABLE OF CELESTIAL BODY NUMBERS

NO.	NAME	NO.	NAME	NO.	NAME
0	Sun				
1	Acamar	31	Enif	61	Suhail
2	Achernar	32	Fomalhaut	62	Vega
3	Acrux	33	Gacrux	63	Zuben'ubi
4	Adhara	34	Gienah		
5	Aldebaran	35	Hadar		
6	Alioth	36	Hamal		
7	Alkaid	37	Kaus Aust.		
8	Al Na'ir	38	Kochab		
9	Alnilam	39	Markab		
10	Alphard	40	Menkar	70	Venus
				75	Mars
11	Alhecca	41	Menkent	80	Jupiter
12	Alpheratz	42	Merak	85	Saturn
13	Altair	43	Miaplacidus	90	Moon
14	Ankaa	44	Mimosa		
15	Antares	45	Mirfak		
16	Arcturus	46	Mizar		
17	Atria	47	Nunki		
18	Avior	48	Peacock		
19	Bellatrix	49	Polaris		
20	Betelgeuse	50	Pollux		
21	Canopus	51	Procyon		
22	Capella	52	Rasalhague		
23	Caph	53	Regulus		
24	Castor	54	Riegel		
25	Deneb	55	Rigil Kent.		
26	Denebola	56	Sabik		
27	Diphda	57	Schedar		
28	Dubhe	58	Shaula		
29	Elnath	59	Sirius		
30	Eltanin	60	Spica		

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INTRODUCTION

The TAMAYA NC-88 PRACTICAL NAVIGATOR can digitally solve most navigational problems with scientific accuracy and incredible speed. However it is a fallacy to believe that computers will do everything for you. Safety at sea always depends on sound judgement, whatever tools are used. For this reason this textbook not only explains how to use the NC-88: it also refers to the principles and fundamentals of navigation.
Astro-Navigation is the art of determining a ship's position at sea utilizing celestial bodies. This can be accomplished with the aid of three tools: a marine sextant, a time piece and a computer such as the NC-88. In PART ONE the techniques of employing these tools are explained. In PART TWO basic navigation computations for Dead Reckoning and Piloting by the NC-88 are explained with examples and illustrations. The text is easy and no special knowledge of computer programming or mathematics is required.
For the further study of navigation you are advised to read such classic texts as "American Practical Navigator" (Bowditch) or "Dutton's Navigation and Piloting" (Dunlop and Shufeldt) with your NC-88 at hand. The NC-88 will enable you to avoid unnecessary mechanical computations and will allow you to concentrate on understanding the fundamental principles of navigation.

NOTE

Those who already have a full understanding of Astro-Navigation may advance directly to the Problems in this textbook (page 9, Problem 1). By going through the key sequences in each Problem the operation of the NC-88 should be easily learned.

PART ONE ASTRO-NAVIGATION BY NC-88

CHAPTER I FUNDAMENTALS OF ASTRO-NAVIGATION

1. PRINCIPLE OF ASTRO-NAVIGATION

When we know the distance from two points, the positions of which are already known, we can determine our ship's position. Suppose the distance from our ship is 6 miles to Lighthouse A and 8 miles to Lighthouse B. Draw a circle with a radius of 6 miles and A as center. This is called a Position Circle because our ship must be somewhere on it. Now, draw another position circle with a radius of 8 miles and B as center. Obviously, the intersection of the two position circles is our ship's position. See Fig. 1.

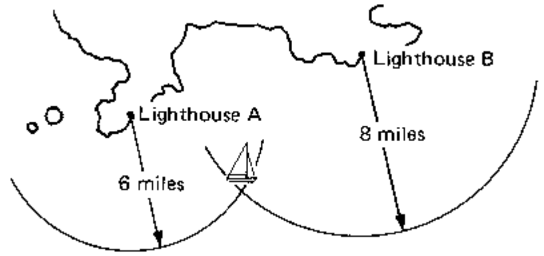


Fig. 1 Finding Ship's Position by Measuring Distance

In Astro-Navigation, the same principle, position circle method, is used to determine the ship's position. Therefore, we must always have at least two known points, and instead of lighthouses we use heavenly bodies; the Sun, Moon, planets and stars.

Then, how do we know the position of any of these heavenly bodies? We will express their position in terms of their Geographical Position (GP). GP is the point where a line, drawn from center of the heavenly body to the center of the earth, would touch the earth's surface. In other words, if a star fell down directly toward the center of the earth, the spot that it would hit on the earth's surface is its GP, and at this point we would see the star directly overhead.

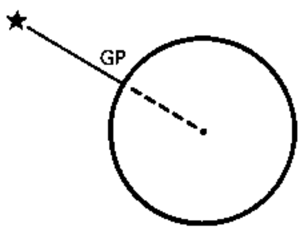
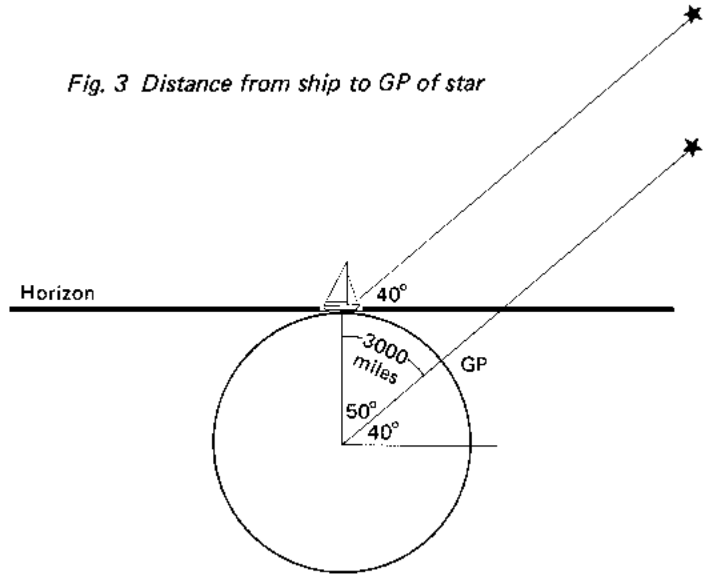


Fig. 2 GP of a heavenly body

The next thing we must know is the distance from our ship to the GP. It can be determined by measuring the altitude of the heavenly body above the horizon. For instance, if we observed a star at the altitude of 40 degrees we can figure out the distance to its GP as 3,000 miles by computation. [The distance from our ship to the GP of a heavenly body = (90° – altitude) x 60 miles]. See Fig. 3.

Fig. 3 Distance from ship to GP of star



Now, if we drew a position circle with a radius of 3,000 miles and the GP as center, our ship must be somewhere on it. See Fig. 4. by drawing another position circle with another heavenly body whose GP and distance are known we can determine our ship's position at their intersection.

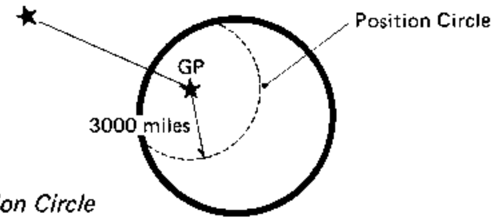


Fig. 4 Position Circle

Since it is not feasible, in practice, to draw a 3,000 miles radius position circle on a chart, only a necessary part of it is drawn as a straight line in the manner explained on P. 13. This is called Position Line or Line of Position. See Fig. 5.

The principle of modern Astro-Navigation is just this simple.

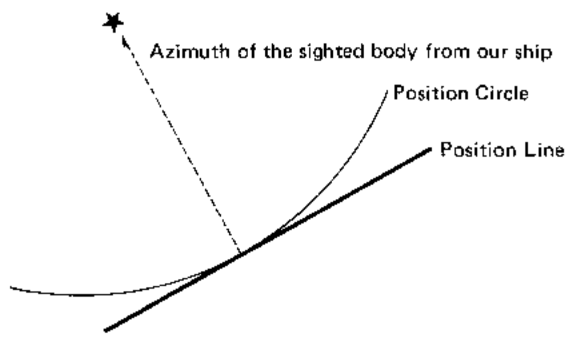


Fig. 5 Position Circle and Position Line

2. BASIC STEPS AND TOOLS FOR ASTRO-NAVIGATION

1. Taking Sight with a Sextant
Measure the altitude of the Sun, Moon, planets or stars above the horizon at your present position by the sextant. (Since the horizon must be visible to take sight, the stars and planets sights are taken during either the dawn or evening twilight time.) Record the exact Greenwich Mean Time (GMT) of the sight.

2. Computing Geographical Position (GP) of the Sighted Body
The GP is the point of the earth directly beneath the heavenly body, and it is expressed by Greenwich Hour angle (GHA) and Declination (DEC). The constant change of the position of the Sun, Moon, planets and stars is computed by NC-88.

3. Computing the Altitude Intercept
At the time of taking sight we only know our Dead Reckoning (DR) Position, which is determined by applying the course and distance travelled from a certain known position such as the departure port or previous position fix. Compute the Altitude at which the Sun should be observed from the DR position at the time of the sight taking. Compare it with the sextant observed true altitude at the actual position. The difference is called "intercept".

4. Computing the Azimuth
Compute the direction to which the Sun should be observed from the DR position. This direction is called Azimuth.

5. Plotting a Line of Position on Chart for Fixing the Position, or Computing the Fix by NC-88
Having obtained the Intercept and Azimuth, we can plot a Line of Position. Move the DR position by the amount of the Intercept along the Azimuth line, and plot a Line of Position (LOP) forming a right angle with it. The LOP is the line on which the ship should be found. When two LOP's are obtained the intersection, Fix, is the ship's exact position. See Fig. 6. Without plotting Lines of Position the fix may be directly computed in digital form by NC-88.

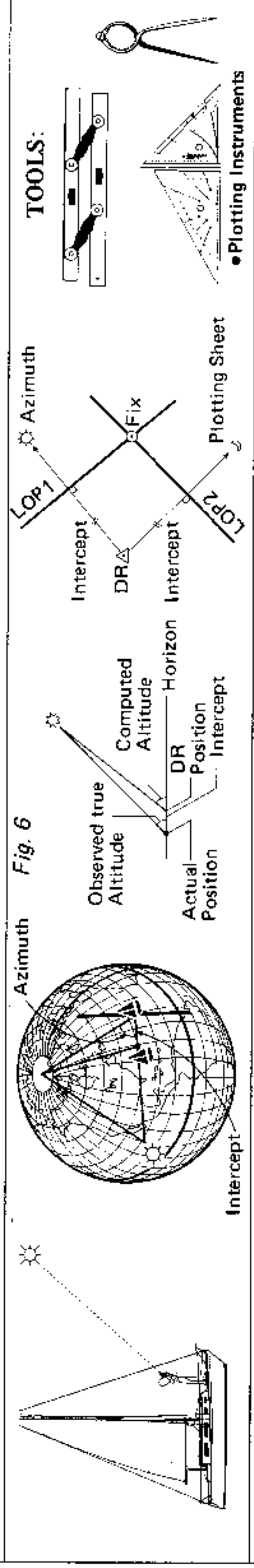
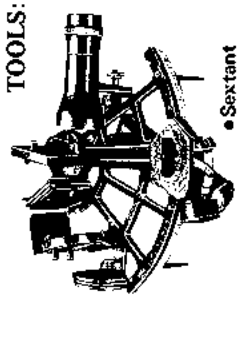


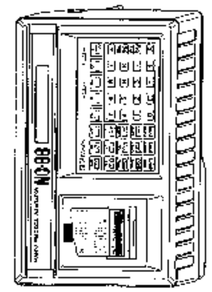
Fig. 6

TOOLS:



•Sextant

•Quartz Watch



NC-88 computes these steps internally, and displays and prints out the necessary data, "Intercept" and "Azimuth" for a Line of Position. Finally, it computes the position fix.

3. SEXTANT AND TIME PIECE

1. Sextant

Taking a sight means to measure the vertical angle or altitude between a heavenly body and the horizon in order to ascertain the ship's position at sea. The sextant is used as a tool to accomplish this aim.

All marine sextants have two mirrors arranged as shown in Fig. 7 and work on the same principle. The index mirror reflects the image of the body to the horizon mirror. The horizon mirror is so constructed that one can see the horizon at the same time he sees the reflected image of the whole body. This aim is achieved by making the right half of the horizon glass mirror and the left half clear glass, or coating the whole glass with see-through reflective chemicals. Both types are available today. Thus, the altitude of the body is measured by adjusting the angle of the index mirror until the reflected image contacts the horizon (Fig. 8).

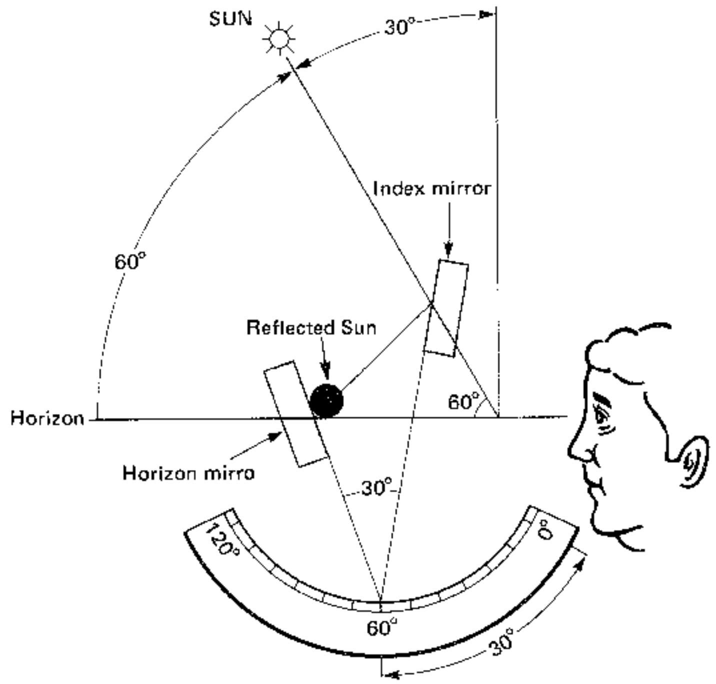


Fig. 7

In a high quality sextant the altitude can be read by degrees, minutes and 1/10 minutes. One minute of the extant reading is equivalent to one nautical mile.

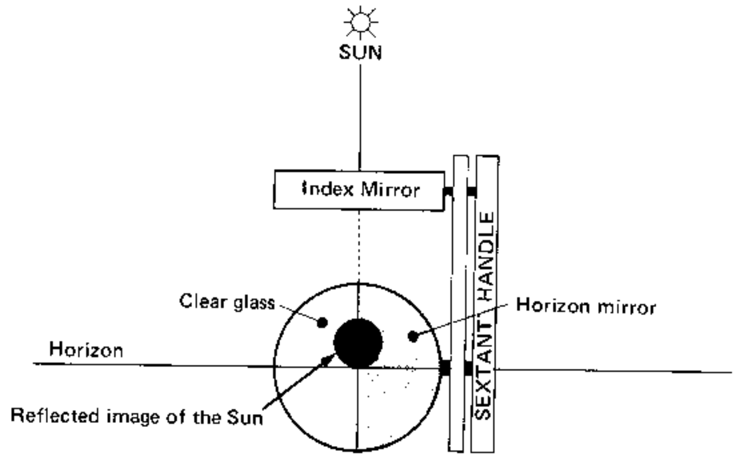


Fig. 8

2. Time Piece (Quartz Watch)

In Astro-Navigation it is necessary to read hours, minutes, and seconds of time, so the digital quartz watch having the seconds display is very convenient for such reading of accurate time. Four seconds of time is equivalent to one minute of longitude (one nautical miles at latitude 0°).

When a sight is taken, record the altitude of the body measured by the sextant and the exact Greenwich Mean Time (GMT) of the sight. Greenwich Mean Time is the time at longitude 0°. Local Mean Time (LMT) will depart 1 hour from GMT for every 15° of longitude. Therefore, Zone Time in New York, based on LMT at 75°W long., is 5 hours before GMT, and Zone Time in San Francisco based on LMT at 120°W long. is 8 hours before GMT. If we go eastward, Tokyo based on LMT at 135°E long. is 9 hours after GMT With this principle in mind, LMT can be easily converted to GMT.

CHAPTER II POSITION FIX BY NC-88 NC-88

The Sun, Moon, Venus, Mars, Jupiter, Saturn, and 63 navigational stars are used for fixing position. The NC-88 Nautical Almanac includes the Sun, Moon, the four planets and all fifty-seven selected stars listed in the daily pages of the conventional Nautical Almanac* and six other stars often used by navigators. The programs are built into NC-88 to compute the position of these heavenly bodies at every second. The NC-88 Nautical Almanac is good through the year 2100 with an accuracy of better than 0:2.

*Nautical Almanac is issued every year by the Nautical Alamanac Office, United States Naval Observatory, Washington, D. C. and Her Majesty's Nautical Almanac Office, London. It gives the position of the celestial bodies used for Astro-Navigation throughout the year.

In the theory of Astro-Navigation as explained at the outset, a ship's position can be determined only after at least two Lines of Position (LOP) are obtained. The intersection of the two LOP's called "Fix" is the ship's position. If three LOP's are given, the centroid of the triangle is computed as the fix. We may also take the fourth and fifth LOP and so forth to refine the fix.

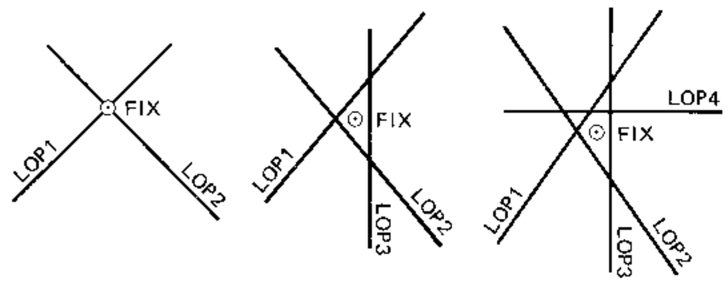
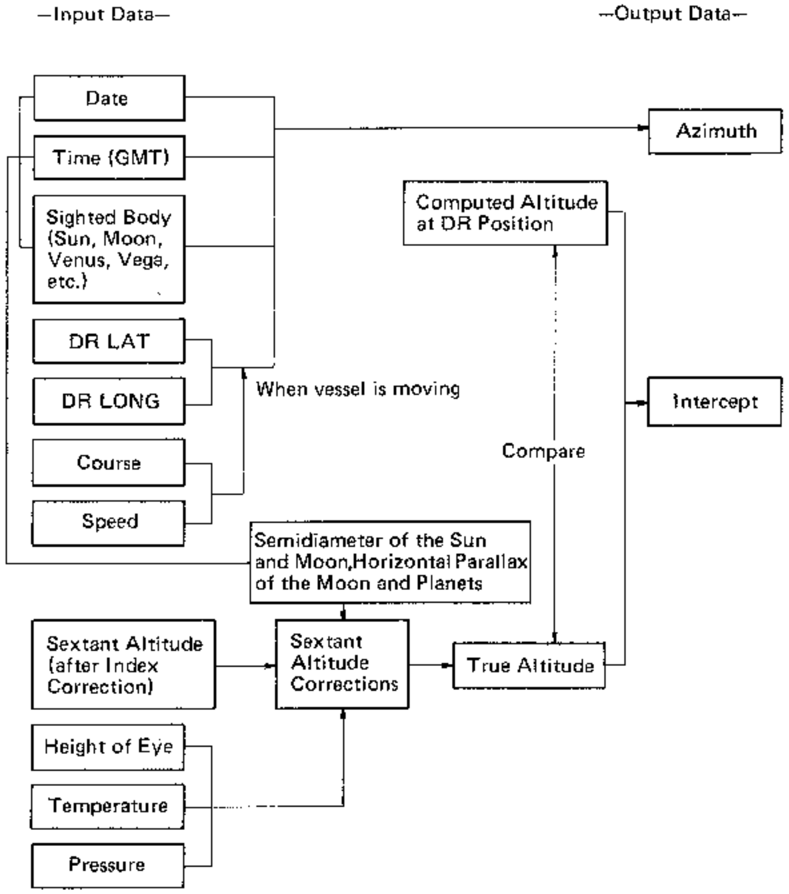


Fig. 9

It is the customary navigation practice to plot Lines of Position on the chart or plotting sheet. Although the fix may be directly computed and displayed in digital form by NC-88, it is still useful to visualize the notion of Lines of Position to assess the quality of the fix. It is for this reason that NC-88 displays and prints out the Altitude Intercept and Azimuth for Lines of Position, not entirely putting them in the black box, in the course of obtaining the final result, the fix. Seasoned navigators know that the accuracy of each Line of Position depends on the exactness of the sight taken with the sextant. Navigators must judge each Line of Position, and try to use only those reliable lines in computing the fix.

Let us follow the practical examples of position fixing, illustrating the key sequence, input data and output data of NC-88.

Input Data and Computation Path of NC-88 LOP Mode



The mathematical equations are found in the Appendix on P.37~39. For sextant Altitude corrections, See Appendix P.33~35.

Note on Angles of LOP's

It should be noted that with two or four observations, the ideal is to have LOP's crossing at angles of 90°. With three observations, the ideal is angles of 60°. With three observations it is good practice to observe bodies differing in azimuth by 120°, as nearly as possible; this provides lines of position crossing at angles of 60°. More than five observations may be made depending on the judgment of the navigator. Whatever the number of observations, common practice, backed by logic, is to take the center of the figure formed unless there is reason for deviating from this procedure. By "center" is meant the point representing the least total error of all lines considered reliable. (See Appendix P. 37 for the formulas of fix computation.)

FIX BY TWO SIGHTS

Problem 1

The DR position of a vessel is 21°10'.0 N, 156°30'.0 W around 15 o'clock GMT on April 4, 1982. It is steering the true course 67° at speed 8 knots when the following sights are taken. The height of eye is 3 m. Compute the fix at the time of the sights and at 15 o'clock.

Date	GMT	Body	Sextant Altitude (after index correction)
April 4, 1982	15h25m43s	Vega (62)	70°00'.3
April 4, 1982	15h28m11s	Venus (70)	21°16'.3

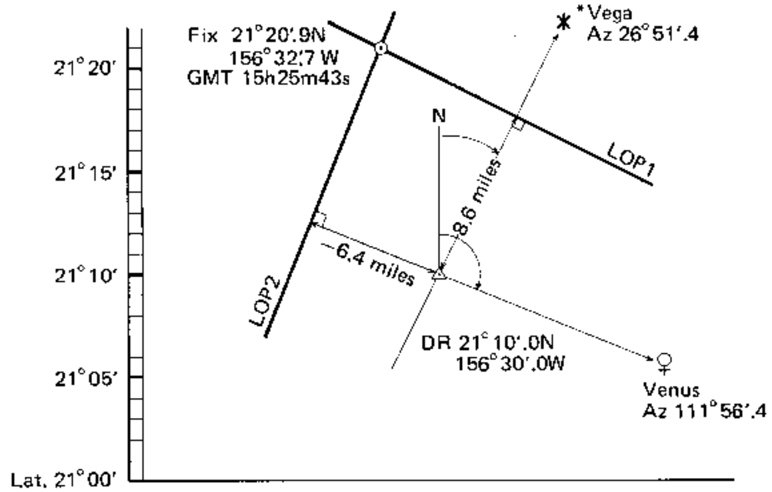


Fig. 10 Lines of Position and Fix

Answer – Fix		
GMT	Lat.	Long.
15h25m43s	21°20'.9 N	156°32'.7 W
15h28m11s	21°21'.0 N	156°32'.4 W
15h00m00s	21°19'.5 N	156°36'.1 W

Step	Input Key		Display		Discription
1	[LOP]		[LOP1]		Line of Position No. 1
2	⊙	15.2543	HMS1	15.2543	Sight Time (Hour, Minutes, Second — GMT)
3	⊙	1982.0404	YMD	1982.0404	Sight Date (Year, Month, Day)
4	⊙	62	CB	62	Celestial Body Number
5	⊙		CB	Vege	Body Name
6	⊙	70.003	ALT1	70.003	Sextant Altitude (After Index correction)
7	⊙	3	HGT	3 m.	Height of Eye
8	⊙		TMP	10 c.	Temperature
9	⊙		PRS	1013.25 mb	Pressure
10	⊙	21.100 [N/E]	LAT	21.100 N	DR Lat.
11	⊙	156.300 [S/W]	LON	156.300 W	DR Long.
12	⊙		CHECK ?		
13	⊙		— PROCESS (Blinks) —		
			AZ	26.514	Azimuth 26°51'.4
14	⊙		INT	8.6	Intercept 8'.6 (miles)
15	[LOP]		[LOP2]		Line of Position No. 2
16	⊙	15.2811	HMS2	15.2811	Sight Time
17	⊙		YMD	1982.0404	Sight Date
18	⊙	70	CB	70	Celestial Body Number
19	⊙		CB	Venus	Body Name
20	⊙	21.163	ALT2	21.163	Sextant Altitude
21	⊙	67	CO	67	True Course
22	⊙	8	SPD	8	Speed
23	⊙		CHECK ?		
24	⊙		— PROCESS —		
			AZ	111.564	Azimuth 111°56'.4
25	⊙		INT	−6.4	Intercept −6'.4 (miles)
26	[FIX]		[FIX]		Position Fix
27	⊙		— PROCESS —		
			LATf	21.209N	Fix Lat. 21°20'.9N
28	⊙		LONf	156.327W	Fix Long. 156°32'.7N
29	⊙		HMSf	15.2543	Fix Time 15h25m43s
30	⊙		YMDf	1982.0404	Fix Date
31	[SERIES]		[FIX SERIES]		Fix Series
32	⊙	15.2811	HMSf	15.2811	Selected Time 15h28m11s
33	⊙		YMDf	1982.0404	
34	⊙		— PROCESS —		
			LAFTf	21.210N	Fix Lat. 21°21'.0N
35	⊙		LONf	156.324W	Fix Long. 156°32'.4W
36	[SERIES]		[FIX SERIES]		Fix Series
37	⊙	15	HMSf	15	Selected Time 15h00m00s
38	⊙		YMDf	1982.0404	
39	⊙		—PROCESS —		
			LATf	21.195N	Fix Lat. 21°19'.5N
40	⊙		LONf	156.361W	Fix Long. 156°36'.1W

Note on Data Entry and Output

LOP1 Step 1 Select [LOP] key from Navigation Mode Keys.

2 The time is entered as Hours, Minutes, Seconds. Place decimal point after the Hours. In this case 15.2543 ($15^h25^m43^s$). The decimal point between Minutes and Seconds may be deleted.

3 Enter Year as 1982, 1983 . . . 2100, etc., Month as 01 (January), 02 (February), . . . 12 (December), Day as 01, 02, . . . 30, 31. Place decimal point between Year and Month. In this case 1982.0404.

4-5 CB Number and the names are listed in Table of Celestial Body Numbers on P. C II. Since the stars are listed alphabetically we may find a particular star, even without consulting the table, by entering an estimated star number. If the one we selected comes up with the wrong name, re-enter an adjacent number until by trial and error we hit the right star.

6 Enter the altitude after the sextant index correction. (See P. 33 for the sextant altitude correction.)

7 Enter Height of Eye above sea level in meters or feet. Make sure the m/f Selection Switch is in the right position.

8 The standard temperature 10°C (50° F.) and pres sure 1013.25 mb. (29.92 in.) are pre-set. We may change them by entering different temperature and pressure in the same frames. They have an effect on the sextant altitude corrections, but in most Astro-Navigation circumstances, standard values are quite adequate. (See P. 35 and 37 for the theoretical explanations.)

10-11 Latitudes and Longitudes are entered as Degrees, Minutes and 1/10 minutes. Place decimal point between Degrees and Minutes. In this case 21.100 [N/E] (21°10'.0 N) and 156.300 [S/W] (156°30'.0 W). [N/E] designates North for Latitude and East for Longitude [S/W] designates South for Latitude and West for Longitude.

12 CHECK function is provided for all navigational mode programs. When the [CHECK] key is pressed the program will return to the beginning of the mode; in this case, the beginning of the LOP1. Then, proceeding by [⊙] Key, all entry data are checked before the computation is started. When there are many entry data, correcting errors beforehand insures the output of the right answer without wasting time.
[CHECK] Key may also be used after the computation process. We can still go back to the beginning of the mode without loosing the entry data.

13 The display "PROCESS" blinks while the data are being processed. At the end of the computation, the Azimuth answer, is displayed and printed out.

14 Intercept is displayed and printed out. Azimuth and Intercept are alternately recalled by [⊙] Key. The answers are accompanied by * mark on the printed sheet.

LOP2 15-25 Enter the data in the same manner as LOP1. For the sight date (steps 3 and 17) the same data are carried forward from the LOP1. Note that at GMT 0 o'clock the date changes. Makes this change at step 17 if the date shifts between the first and second sight. For the Height of Eye, Temperature, Pressure the same data are applied in LOP2 computation. The course and speed (Step 21 and 22) are the additional data required in LOP2.

Fix 26-30 No Data entry is required. Fix time $15^h25^m43^s$ is the time when the sight for LOP1 was taken.
(In computing Fix, if the intercept drawn from DR point extends beyond either North or South Pole, the answer becomes ERROR.)

Fix Series

31-35 The fix, the intersection of LOP1 and LOP2 may be moved in either direction along the course and at the speed entered in LOP 2. In this case the time of the second sight is given to obtain the fix at the time of LOP2 sight.

36-40 Along the same course the position at the whole hour $15^h00^m00^s$ is determined.

Plotting a Line of Position

To clarify the relationship of the LOP1, LOP2 and the Fix, Lines of Position (LOP) may be plotted on the chart or plotting sheet using the following data computed by [LOP] mode (See Fig 10, on P. 9).

DR Lat. DR Long.	21°10'.0N 156°30'.0W
Azimuth 1 Intercept 1	26°51'4 8'.6
Azimuth 2 Intercept 2	111°56'.4 −6'.4

Draw the Azimuch line from the DR position, towards Az26°51'.4. Take the intercept 8'.6 from the latitude scale of the chart by marine dividers and transfer it on to the azimuth line. 8'.6 of latitude is 8.6 nautical miles on the earth's surface. The line crossing the azimuth line at right angles at this point is called Line of Position (LOP).
When the intercept is positive, it means that the sextant observed altitude is greater than the altitude computed with the assumption that our DR position is correct. In this case we should shift our position from the DR position towards the direction of the body (Vega) along the azimuth line. Shift our position away from the direction of the body (Venus) when the intercept is negative. The illustration in Fig. 11 explains the relationship.

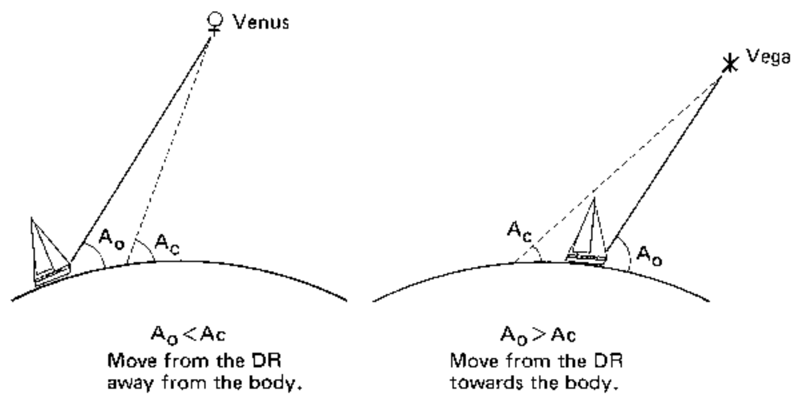


Fig. 11 Altitude Intercept

RUNNING FIX BY SUN SIGHTS

— Morning sight and afternoon sight —

When the fix must be made only by Sun sights we should obtain two LOP's allowing a time interval between the two sights. As the Sun changes in azimuth during the day moving from east to west at considerable speed, we can have two suitable LOP's for a fix within a few hours.

Problem 2

The DR position of a vessel is 21°38'.2 N, 155°54'.7 W around GMT 20 o'clock on April 4, 1982. It is steering the true course 67° at speed 8 knots, and the following Sun sights are taken. The height of eye is 3 m. Compute the fix based on the morning and afternoon sights.

Date	GMT	Body	Sextant Altitude (after index correction)
April 4, 1982	20h18m36s	Sun(0) Morning Sight	55°03'.3
April 4, 1982	23h09m18s	Sun(0) Afternoon Sight	70°33'.1

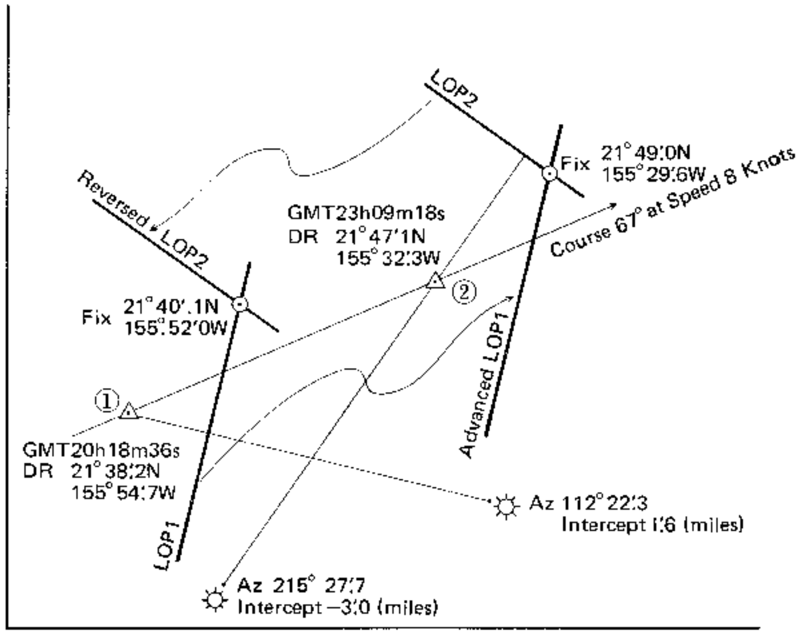


Fig. 12 Lines of Position and Fix

Input Key	Display		Description
[LOP]	[LOP1]		Line of Position No. 1 (Morning)
20.1836	HMS1	20.1836	Sight Time
1982.0404	YMD	1982.0404	Sight Date
0	CB	0	Celestial Body Number
	CB	Sun	Body Name
	UL ?	Sun	Upper or Lower Limb sighted?
	CB	LL Sun	Lower Limb sighted
55.033	ALT1	55.033	Sextant Altitude (After Index correction)
3	HGT	3 m.	Height of Eye
	TMP	10 c.	Temperature
	PRS	1013.25 mb	Pressure
21.382	LAT	21.382 N	DR Lat.
155.547	LON	155.547 W	DR Long.
	CHECK ?		
	— PROCESS —		
	AZ	112.223	Azimuth 112°22'.3
	INT	1.6	Intercept 1'.6 (miles)
[LOP]	[LOP2]		Line of Position No. 2 (Afternoon)
23.0918	HMS2	23.0918	Sight Time
	YMD	1982.0404	Sight Date
0	CB	0	Celestial Body Number
	CB	Sun	Body Name
	CB	LL Sun	Lower Limb sighted
70.331	ALT2	70.331	Sextant Altitude (After Index correction)
67	CO	67	True Course
8	SPD	8	Speed
	CHECK ?		
	— PROCESS —		
	AZ	215.277	Azimuth 215°27'.7
	INT	−3.0	Intercept −3'.0 (miles)
[FIX]	[FIX]		Position Fix
	— PROCESS —		
	LATf	21.401 N	Fix Lat. 21°40'.1N
	LONf	155.520 W	Fix Long. 155°52'.0W
	HMSf	20.1836	Fix Time 20h18m36s (Morning Sight)
	YMDf	1982.0404	
[SERIES]	[FIX SERIES]		
23.0918	HMSf	23.0918	Selected Time 23h09m18s (Afternoon Sight)
	YMDf	1982.0404	
	— PROCESS —		
	LATf	21.490 N	Fix Lat. 21°49'.0N
	LONf	155.296W	Fix Long. 155°29'.6W

The relationship of the DR's at the morning sight and afternoon sight, LOP1 and LOP2 is illustrated in Fig. 12.
When there is no external power supply, and NC-88 must be operated only by the internal batteries, in order to conserve power it is recommended to switch off the power after the LOP1 computation, and switch on when we make the LOP2 computation. In this case the DR position where the second sight is taken in the afternoon should be computed by [DR] mode. When the afternoon LOP has been obtained, the intersection with the morning LOP shifted accordingly shall be computed by [ExFIX] mode as shown in the following examples.

	Input Key		Display		Description
DR	[DR]		[DR]		
	[⊙]	21.382 [N]	LAT	21.382 N	Depart Lat. 21°38'.2N
	[⊙]	155.547 [W]	LON	155.547 W	Depart Long. 155°54'.7W
	[⊙]	67	CO	67	True Course
	[⊙]	22.76	DST	22.76	Distance run between the morning & afternoon sight
	[⊙]		– PROCESS –		
			LAT	21.471 N	DR Lat. 21°47'.1 N
	[⊙]		LON	155.323 W	DR Long. 155°32'.3 W
LOP1	[LOP]		[LOP]		Line of Position No. 1 (Afternoon)
	[⊙]	23.0918	HMS1	23.0918	Sight Time
	[⊙]	1982.0404	YMD	1982.0404	Sight Date
	[⊙]	0	CB	0	Celestial Body Number
	[⊙]		CB	Sun	Body Name
	[⊙]	[N] [⊙]	CB	LL Sun	Lower Limb sighted
	[⊙]	70.331	ALT1	70.331	Sextant Altitude (After Index correction)
	[⊙]	3	HGT	3 m.	Height of Eye
	[⊙]		TMP	10 c.	Temperature
	[⊙]		PRS	1013.25 mb	Pressure
	[⊙]		LAT	21.471 N	DR Lat.
	[⊙]		LON	155.323 W	DR Long.
	[⊙]		CHECK?		
	[⊙]		– PROCESS –		
			AZ	215.277	Azimuth 215°27'.7
	[⊙]		INT	–3.0	Intercept –3.0 (miles)

From the morning and afternoon sights we have the following data with which the fix is computed in [ExFIX] mode.

DR Lat. DR Long.	21°47' 1N 155°32'.3W	
	Morning	Afternoon
Azimuth Intercept	112°22'.3 1'.6	215°27'.7 –3'.0

Input Key		Display		Description
[ExFIX]		[EXTRA FIX]		Extra Fix
[⊙]	21.471 [N]	LAT	21.471 N	DR Lat. 21°47'.1N
[⊙]	155.323 [W]	LON	155.323 W	DR Long. 155°32'.3 W
[⊙]	112.223	AZ	112.223	Azimuth 1 112°22'.3
[⊙]	1.6	INT	1.6	Intercept 1 1'.6 (miles)
[⊙]	215.277	AZ	215.277	Azimuth 2 215°27'.7
[⊙]	3.0 [–]	INT	–3.0	Intercept 2 –3'.0 (miles)
[⊙]		– PROCESS –		
		LATf	21.490 N	Fix Lat. 21°49'.0 N
[⊙]		LONf	155.296 W	Fix Long. 155°29'.6 W (Fix at the time of the afternoon sight)

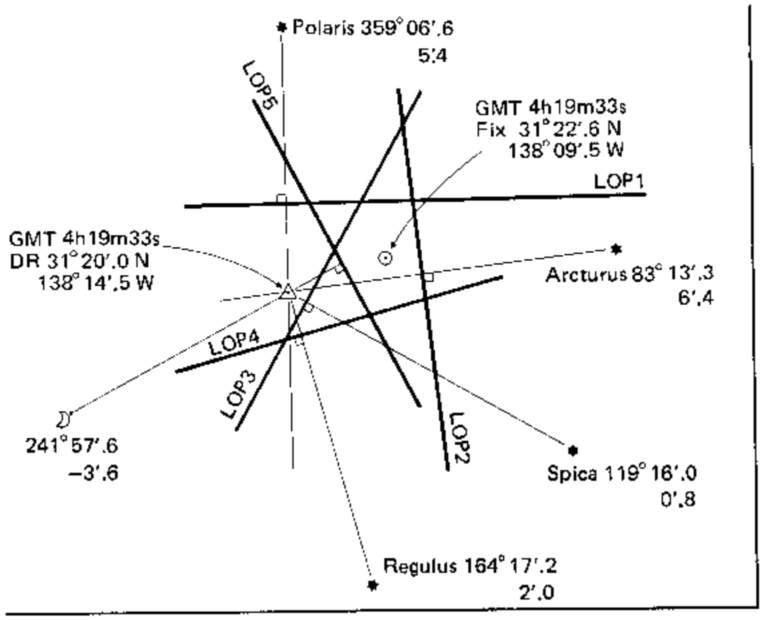
FIX BY MULTIPLE SIGHTS

Problem 3

The DR position of a vessel is 31°20'.0 N, 138°14'.5 W on April 30, 1982. The true course is 60° and speed is 5 knots when the following sights are taken. The height of eye is 3 m. Plot the Lines of Position and compute the fix at the time of the first sight (4h19m33s) and at 5 o'clock.

Date	GMT	Body	Sextant Altitude (after index correction)
April 30, 1982	4h19m33s	Polaris (49)	31°12'.0
April 30, 1982	4h21m22s	Arcturus (16)	27°45'.8
April 30, 1982	4h24m06s	Spica (60)	22°08'.1
April 30, 1982	4h27m31s	Regulus (53)	70°10'.2
April 30, 1982	4h29m54s	Moon (90)	69°23'.3 (Lower Limb)

Fig. 13 Lines of Position and Fix



Input Key	Display		Description
LOP	[LOP1]		Line of Position No. 1
4.1933	HMS1	4.1933	Sight Time
1982.0430	YMD	1982.0430	Sight Date
49	CB	49	Celestial Body Number
	CB	Polaris	Body Name
31.120	ALT1	31.120	Sextant Altitude (After Index correction)
3	HGT	3 m.	Height of Eye
	TMP	10 c.	Temperature
	PRS	1013.25 mb.	Pressure
31.200	LAT	31.200 N	DR Lat.
138.145	LON	138.145 W	DR Long.
	CHECK ?		
	– PROCESS –		
	AZ	359.066	Azimuth 359°06'.6
	INT	5.4	Intercept 5'.4 (miles)
LOP	[LOP2]		Line of Position No. 2
4.2122	HMS2	4.2122	
	YMD	1982.0430	
16	CB	16	
	CB	Arcturus	
27.458	ALT2	27.458	
60	CO	60	True Cource
5	SPD	5	Speed
	CHECK ?		
	– PROCESS –		
	AZ	83.133	Azimuth 83°13'.3
	INT	6.4	Intercept 6'.4 (miles)
LOP	[LOP 3]		Line of Position No. 3
4.2406	HMS3	4.2406	
	YMD	1982.0430	
60	CB	60	
	CB	Spica	
22.081	ALT3	22.081	
	CHECK ?		
	– PROCESS –		
	AZ	119.160	Azimuth 119°16'.0
	INT	0.8	Intercept 0'.8 (miles)
LOP	[LOP4]		Line of Position No. 4
4.2731	HMS4	4.2731	
	YMD	1982.0430	
53	CB	53	
	CB	Regulus	
70.102	ALT4	70.102	
	CHECK ?		
	– PROCESS –		
	AZ	164.172	Azimuth 164°17'.2
	INT	2.0	Intercept 2'.0 (miles)
LOP	[LOP5]		Line of Position No. 5
4.2954	HMS5	4.2954	
	YMD	1982.0430	
90	CB	90	
	CB	Moon	
	CB	LL Moon	
69.233	ALT5	69.233	
	CHECK ?		
	– PROCESS –		
	AZ	241.576	Azimuth 241°57'.6
	INT	–3.6	Intercept –3.6 (miles)
FIX	[FIX]		Position Fix
	– PROCESS –		
	LATf	31.226 N	
	LONf	138.095 W	
	HMSf	4.1933	
	YMDf	1982.0430	
SERIES	[FIX SERIES]		
5.00	HMSf	5.00	
	YMDf	1982.0430	
	– PROCESS –		
	LATf	31.243 N	
	LONf	138.061 W	

Note: Position Fix by LOP No. 1 and 2, LOP No. 1, 2 and 3, etc.
[FIX] key at the end of the fifth LOP computation produces the position fix with five LOP's at the time of the first sight (GMT $4^h19^m33^s$). Likewise, if the [FIX] key is used after the second LOP computation, the position fix by two LOP's is given. After this fix we may still continue to the third LOP by pressing [LOP] key. Then, the [FIX] key will give the position fix by thee LOP's. We could go on to the fourth and fifth LOP in the same manner. The number of sights and LOP's is unlimited.

EXTRA-FIX

When two or more LOP's are available externally, not going through [LOP] mode, we can get an extra fix by applying their intercepts and Azimuth lines.

Problem 4
Compute the fix with the following LOP's.

	Azimuth	Intercept	DR Lat.	DR Long.
LOP1	26°51'.4	8'.6	21° 10'.0N	156° 30'.0W
LOP2	111°56'.4	–6'.4		

Input Key	Display		Description
EX-FIX	[EXTRA FIX]		Extra Fix
21.100	LAT	21.100 N	DR Lat.
156.300	LON	156.300 W	DR Long.
26.514	AZ	26.514	Azimuth 1
8.6	INT	8.6	Intercept 1
111.564	AZ	111.564	Azimuth 2
6.4	INT	–6.4	Intercept 2
	– PROCESS –		
	LATf	21.209 N	Fix Lat.
	LONf	156.327 W	Fix Long.

The fix with three or more LOP's can be solved similarly by feeding their Azimuth Lines and intercepts in [EX-FIX] mode. Or else, we can add another LOP on the fix by [Add LOP] key.

ADD LOP Problem: Add LOP3 on the fix made in Problem 4.

	Azimuth	Intercept
LOP3	359°58'.3	3'.2

[Continued from Problem 4]

Input Key	Display		Description
Add LOP	[ADD LOP FIX]		Add LOP Fix
359.583	AZ	359.583	Azimuth 3
3.2	INT	3.2	Intercept 3
	– PROCESS –		
	LATf	21.169 N	Fix Lat.
	LONf	156.325 W	Fix Long.

We can add more LOP('s) to the fix by repeating [Add LOP] mode.

Note: See Note on Angles of LOP's on P.8.

CHAPTER III NC-88 NAUTICAL ALMANAC

The Nautical Almanac produces the Geographical Position (GP) of celestial bodies. As explained in the Fundamentals of Astro-Navigation, GP is the point where a line, drawn from the center of the body to the center of the earth, would touch the earth's surface (See P. 2). GP is expressed in terms of Greenwich Hour Angle (GHA) and Declination (DEC). By finding the GHA and DEC of a particular celestial body, we can compute the Altitude and Azimuth at which it should be observed from a certain position on the earth.

Note: The NC-88 Nautical Almanac is good through the year 2100 with an accuracy better of 0'.2 for the GHA and DEC of the Sun, Moon, planets and stars.

Problem 5 SUN

Find the GHA and DEC of the Sun at GMT 20h18m36s on April 4, 1982. Then compute, its Azimuth and Altitude from the DR position 21°38'.2 N, 155°54'.7 W.

Input Key		Display		Description
[ALM]		[ALM]		Almanac
[⊙]	20.1836	HMS	20.1836	GMT
[⊙]	1982.0404	YMD	1982.0404	Date
[⊙]	0	CB	0	Celestial Body Number
[⊙]		CB	Sun	Body Name
[⊙]		– CB Sun –		
		SD	0.160	Semidiameter
[⊙]		DEC	5.483 N	Declination
[⊙]		GHA	123.543	Greenwich Hour Angle
[⊙]		EQT	−0.0259	Equation of Time
[Ac-Z]		[ALTc-AZ]		Altitude-Azimuth
[⊙]	21.282 [N/S]	LAT	21.382 N	DR Lat.
[⊙]	155.547 [E/W]	LON	155.547 W	DR Long.
[⊙]		– PROCESS –		
		ALTc	55.141	Altitude
[⊙]		AZ	112.223	Azimuth

Note: GHA and DEC

DEC is measured like latitude, from the equator to 90° north and 90° south. However, GHA is measured from the Greenwich meridian only westward up to 360°. Therefore, it is not accompanied by East/West designation.

SD (Sun's Semidiameter)

SD is applied to the sextant Altitude of the Sun to find its true altitude. Since we are observing the Sun's lower or upper limb the semidiameter correction must be made. In [LOP] mode this correction is applied automatically when the [N/S] or LL or [E/W] or UL Key is activated after celestial body input. (See P. 34 Sextant Altitude corrections)

EQT (Equation of Time)

Equation of Time is the difference in time between the True Sun and the Mean Sun. In conventional sailing, the longitude was often found by the Sun's Meridian passage with the application of EQT (See the Fix by Noon Sight in Appendix on P. 36)

Altitude and Azimuth Computation

The spherical triangle shown in Fig. 14 is solved in [Ac-Z] program to find the Altitude and Azimuth at which the center of the Sun should be observed. See Appendix P. 37 for the Mathematics.

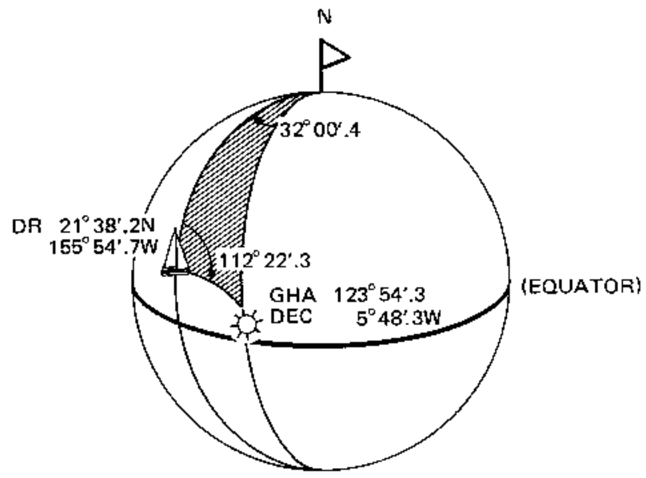


Fig. 14 Spherical Triangle

STAR FINDER

Since we can compute the Azimuth and the Altitude of a particular celestial body with [ALM] [Ac-Z] key combination the program can be used as a star or planet finder.

[Problem 6] VENUS

Find the GHA and DEC of Venus at GMT 15h30m00s on April 4, 1982. Then, compute its Azimuth and Altitude from the DR position, 21°10'.0 N, 156°36'.0 W.

Input Key		Display		Description
[ALM]		[ALM]		Almanac
[⊙]	15.3000	HMS	15.3000	GMT
[⊙]	1982.0404	YMD	1982.0404	Date
[⊙]	70	CB	70	Celestial Body Number
[⊙]		CB	Venus	Body Name
[⊙]		– CB Venus –		
		HP	0.002	Horizontal Parallax
[⊙]		DEC	11.095 S	Declination
[⊙]		GHA	95.116	Greenwich Hour Angle
[Ac-Z]		[ALTc-AZ]		Altitude-Azimuth
[⊙]	21.100 [N/S]	LAT	21.100 N	DR Lat.
[⊙]	156.300 [E/W]	LON	156.300 W	DR Long.
[⊙]		– PROCESS –		
		ALTc	21.407	Altitude (Computed)
[⊙]		AZ	112.097	Azimuth

Note: Horizontal Parallax

Horizontal parallax is applied to the sextant altitude to find the true altitude of the Moon and planets. (See P. 34 for theoretical explanations in Appendix.)

[Problem 7] STARS AND MOON

Where do we find Polaris, Arcturus, Spica, Regulus and the Moon at GMT $4^h30^m00^s$ on April 30, 1982 from the DR position 31°20'.0 N, 138°4'.5W?

The key sequence for finding the position of the stars successively is like this. By using the [CHECK] key to proceed to the next star we can avoid the repeated input of the same data; date, time, DR position every time, just change the star number, and we will get its altitude and azimuth.

Input Key		Display	
[ALM]		[ALM]	
[⊙]	4.3000	HMS	4.3000
[⊙]	1982.0430	YMD	1982.0430
[⊙]	49	CB	49
[⊙]		CB	Polaris
[⊙]		– CB Polaris –	
		DEC	89.109 N
[⊙]		GHAa	285.176
[⊙]		SHA	326.562
[⊙]		GHA	252.139
[ALT-AZ]		[ALTc-AZ]	
[⊙]	31.200 [N/S]	LAT	31.200 N
[⊙]	138.145 [E/W]	LON	138.145 W
[⊙]		– PROCESS –	
		ALTc	30.599
[⊙]		AZ	359.077
[CHECK]			

Input Key		Display	
[⊙]		"	
[⊙]		"	
[⊙]	16	CB	16
[⊙]		CB	Arcturus
[⊙]		– CB Arcturus –	
		DEC	19.165 N
[⊙]		GHAa	285.176
[⊙]		SHA	146.171
[⊙]		GHA	71.347
[ALT-AZ]		[ALTc-AZ]	
[⊙]		"	
[⊙]		"	
[⊙]		– PROCESS –	
		ALTc	29.246
[⊙]		AZ	84.141
[CHECK]			

Input Key		Display	
[⊙]		"	
[⊙]		"	
[⊙]	60	CB	60
[⊙]		CB	Spica
[⊙]		– CB Spica –	
		DEC	11.042 S
[⊙]		GHAa	285.176
[⊙]		SHA	158.561
[⊙]		GHA	84.137
[ALT-AZ]		[ALTc-AZ]	
[⊙]		"	
[⊙]		"	
[⊙]		– PROCESS –	
		ALTc	23.074
[⊙]		AZ	120.175
[CHECK]			

Input Key		Display	
[⊙]		"	
[⊙]		"	
[⊙]	53	CB	53
[⊙]		CB	Regulus
[⊙]		– CB Regulus –	
		DEC	12.033 N
[⊙]		GHAa	285.176
[⊙]		SHA	208.087
[⊙]		GHA	133.263
[ALT-AZ]		[ALTc-AZ]	
[⊙]		"	
[⊙]		"	
[⊙]		– PROCESS –	
		ALTc	70.131
[⊙]		AZ	165.599
[CHECK]			

Input Key		Display	
[⊙]		"	
[⊙]		"	
[⊙]	90	CB	90
[⊙]		CB	Moon
[⊙]		– CB Moon –	
		HP	0.588
[⊙]		DEC	20.346 N
[⊙]		GHA	157.036
[ALT-AZ]		[ALTc-AZ]	
[⊙]		"	
[⊙]		"	
[⊙]		– PROCESS –	
		ALTc	69.599
[⊙]		AZ	241.596

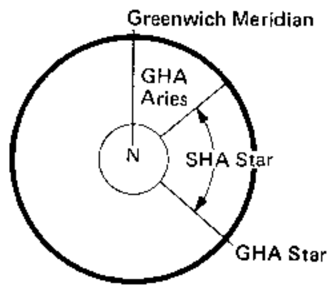
It is sufficient to present to final answer: Altitude and Azimuth of the celestial body; however, instead of putting the GHA, DEC, GHA Aries and SHA (SHA Star) completely in the black box, they are shown here in the computation process to enable us to compare these data with those found in the conventional Nautical Almanac.

Answer

	Polaris	Arcturus	Spica	Regulus	Moon
Altitude	30°59'.9	29°24'.6	23°07'.4	70°13'.1	69°59'.9
Azimuth	359°07'.7	84°14'.1	120°17'.5	165°59'.9	241°59'.6

GHA aries (GHAa) is a reference meridian for establishing celestial longitude of stars. It is constantly changing, and expressed in terms of westward angle from Greenwich meridian. SHA star is the westward distance of the particular star from this meridian. Thus the rule to compute the GHA star is:

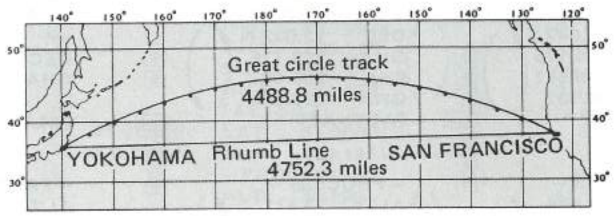
GHA Star = GHA Aries + SHA Star



PART TWO: BASIC NAVIGATION COMPUTATIONS FOR DEAD RECKONING AND PILOTING BY NC-88

CHAPTER I MERCATOR SAILING AND GREAT CIRCLE SAILING

Mercator Sailing and Great Circle Sailing:
The course obtained by Mercator Sailing is a rhumb line, appearing as a straight line on the Mercator chart. It makes the same angle with all meridians it crosses, and maintains constant true direction. The Great Circle track is the shortest distance between any two points on the earth. On the Mercator chart a great circle appears as a sine curve extending equal distances each side of the equator. The comparison of rhumb line and great circle track is shown in the illustration.



MERCATOR CHART

Note on Accuracy:
The principle of [DR] and [CD] computation is Mercator Sailing. The oblate shperoid characteristics of earth (flattened at the poles and bulged at the equator) are taken into consideration in the programming. The most up-to-date WGS-72, World Geodetic System 1972 spheroid (Eccentricity = 0.08182), is being used to guarantee the utmost accuracy. When the course is exactly 090° or 270° the program automatically switches to Parallel Sailing. In this case the earth is considered as a shpere.

DEAD RECKONING BY MERCATOR SAILING

[DR] Dead Reckoning mode computes the latitude and longitude of the point of arrival.

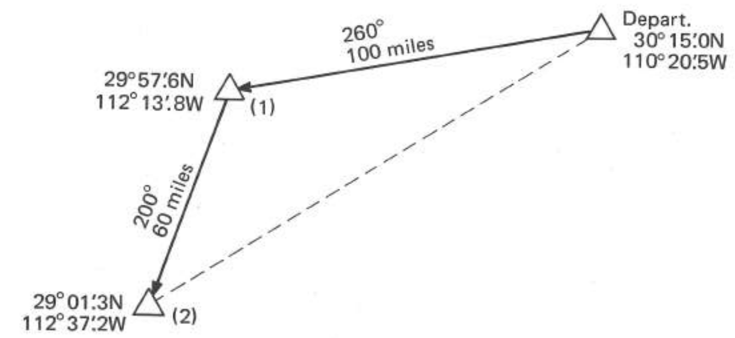
Problem 8

Departure Point	Course	Distance
30° 15'.0 N 110° 20'.5 W	(1) 260° (2) 200°	100 miles 60 miles

Find the DR position after the first and the second run.

Input Key		Display		Description
[DR]			[DR]	Dead Reckoning
[⊙]	30.150 [N/E]	LAT	30.150 N	Depart Lat.
[⊙]	110.205 [S/W]	LON	110.205 W	Depart Long.
[⊙]	260	CO	260	Course (1)
[⊙]	100	DST	100	Distance (1)
[⊙]		– PROCESS –		
		LAT	29.576 N	DR Lat. 29° 57'.6 N
[⊙]		LON	112.138 W	DR Long. 112° 138'.0 W
[SERIES]		[DR SERIES]		Dead Reckoning Series
[⊙]	200	CO	200	Course (2)
[⊙]	60	DST	60	Distance (2)
[⊙]		– PROCESS –		
		LAT	29.013 N	DR Lat. 29° 01'.3 N
[⊙]		LON	112.372 W	DR Long. 112° 37'.2 W

More courses and distances may be added in DR series mode by using [SERIES] key repeatedly.



COURSE AND DISTANCE BY MERCATOR SAILING

[CD] Course and Distance mode computes the course and distance from the departure point to the arrival point.

Problem 9

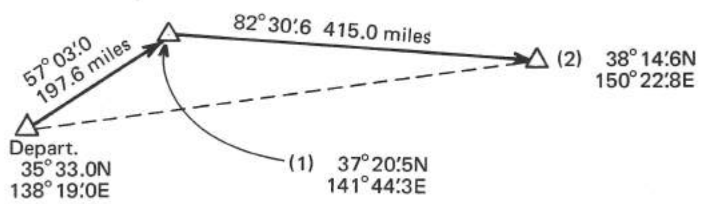
	Departure Point	Arrival Point (1)	Arrival Point (2)
Lat.	35°33'.0 N	37°20'.5 N	38°14'.6 N
Long.	138°19'.0 E	141°44'.3 E	150°22'.8 E

Find the distance from the departure point to the arrival point (1), from the point (1) to the point (2), and the total distance run.

Input Key		Display		Description
[CD]		[CD]		Course and Distance
[⊙]	35.330 [N/E]	LATd	35.330 N	Depart. Lat.
[⊙]	138.190 [N/E]	LONd	138.190 E	Depart. Long.
[⊙]	37.205 [N/E]	LATa	37.205 N	Arrival Lat. (1)
[⊙]	141.443 [N/E]	LONa	141.443 E	Arrival Long. (1)
[⊙]		– PROCESS –		
		CO	57.030	Course 57°03'.0
[⊙]		DST	197.6	Distance 197.6 miles
[SERIES]		[CD SERIES]		Course and Distance Series
[⊙]	38.146 [N/E]	LATa	38.146 N	Arrival Lat. (2)
[⊙]	150.228 [N/E]	LONa	150.228 E	Arrival Long. (2)
[⊙]		– PROCESS –		
		CO	82.306	Course 82°30'.6
[⊙]		DST	415.0	Distance 415.0 miles
*[+]	197.6 [=]		612.6	Total Distance 612.6 miles

Courses and distances to more continuing points of arrival may be determined in CD series mode by using [SERIES] key repeatedly.

*Before making this input, be sure that Distance value, not course value is showing on display.



GREAT CIRCLE SAILING AND COMPOSITE SAILING
GREAT CIRCLE SAILING

[GC] Great Circle Sailing mode computes the great circle distance between two points and also the initial course from the departure point. The program continues to compute the latitude and longitude of the vertex. By proceeding to [SERIES] mode the latitude at any selected longitude on the great circle track is determined. By continuing to [CMPST] mode the composite track with a limiting latitude is established.

Problem 10

A vessel is leaving San Francisco for Yokohama

Find the great circle distance, initial great circle course, vertex latitude and longitude, and latitude at 145° W and 150°W.

	Depart. Point (San Francisco)	Arrival Point (Yokohama)
Lat.	37°50'.8 N	34°52'.0 N
Long.	122°25'.5 W	139°42'.0 E

Input Key		Display		Description
[GC]		[GC]		Great Circle Sailing
[⊙]	37.508 [N/E]	LATd	37.508 N	Depart. Lat.
[⊙]	122.255 [S/W]	LONd	122.255 W	Depart. Long.
[⊙]	34.520 [N/E]	LATa	34.520 N	Arrival Lat.
[⊙]	139.420 [N/E]	LONa	139.420 E	Arrival Long.
		– PROCESS –		
		CO	302.379	Initial Great Circle Cource 302°37'.9
[⊙]		DST	4488.8	Great Circle Distance 4488.8 miles
[⊙]		LATv	48.190 N	Vertex Lat. 48°19'.0 N
[⊙]		LONv	168.388 W	Vertex Long. 168°38'.8 W
[SERIES]		[LATi SERIES]		Intermediate Latitude Series
[⊙]	145 [S/W]	LONi	145 W	Intermediate Long.
[⊙]		– PROCESS –		
		LATi	45.487 N	Intermediate Lat. 45°48'.7 N
[CHECK]		LONi	145.000 W	(change to 150° W)
	150 [S/W]	LONi	150 W	Intermediate Long.
[⊙]		– PROCESS –		
		LATi	46.467 N	Intermediate Lat. 46°46'.7

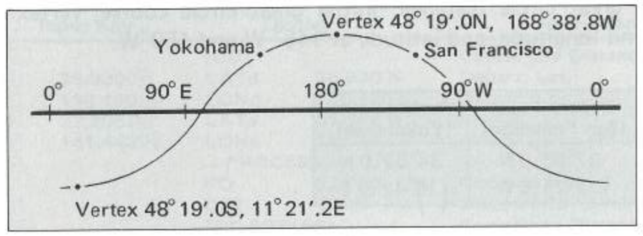
More Intermediate Longitude may be entered by [CHECK] key for Latitude determination.

Note:

In cpmputing the great circle distance the earth is considered as a sphere. The vertex is computed between the departure point and the arrival point. If there is no vertex to be found between them the next vertex on the same great circle track beyond the arrival point is computed.

Vertex:

Every great circle lies half in the northern hemisphere and half in the southern hemisphere. Any two points 180° apart on a great circle have the same latitude numerically, but contrary names, and are 180° apart in longitude. The point of greatest latitude is called the vertex.



Point to point planning:

Since a great circle, except the equator and any meridian line, is continuously changing direction as one proceeds along it, no attempt is customarily made to follow it exactly. Rather, a number of points are selected along the great circle, and rhumb lines are followed from point to point, taking advantage of the fact that for short distances a great circle and a rhumb line almost coincide. These points usually are selected every 5° of longitude for convenience (the number of points to use is a matter of personal preference), and the corresponding latitudes are computed by NC-88.

COMPOSITE SAILING

When the great circle would carry a vessel to a higher latitude than desired, a modification of great circle sailing called composite sailing, may be used to good advantage. The composite track consists of a great circle from the point of departure and tangent to the limiting parallel, a course line along the parallel, and a great circle tangent to the limiting parallel and through the destination.

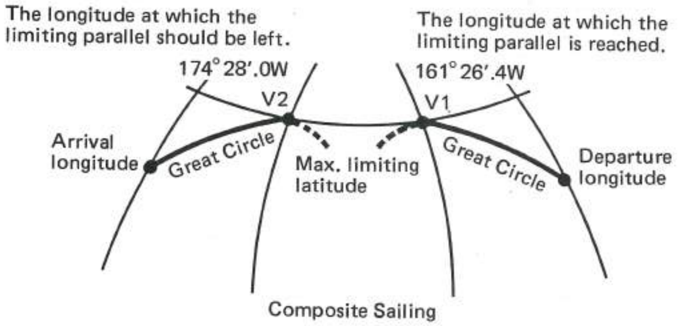
Problem 11

A vessel is leaving San Francisco for Yokohama.

Find the composite track with the maximum limiting latitude of 45° N based on the great circle track determined in problem 10.

Input Ket		Dispaly		Description
[GC]		[GC]		Great Circle Sailing
[⊙]	37.508 [N/E]	LATd	37.508 N	Depart. Lat.
[⊙]	122.255 [S/W]	LONd	122.255 W	Depart. Long.
[⊙]	34.520 [N/E]	LATa	34.520 N	Arrival Lat.
[⊙]	139.420 [N/E]	LONa	139.420 E	Arrival Long.
[⊙]		– PROCESS –		
		CO	302.379	Initial Great Circle Course 302°37'.9
[⊙]		DST	4488.8	Great Circle Distance 4488.8 miles
[⊙]		LATv	48.190 N	Vertex Lat. 48°19'.0 N
[⊙]		LONv	168.388 W	Vertex Long. 168°38'.8 W
[CMPST]		[COMPOSITE]		Composite Sailing
[⊙]	45 [N/E]	LAT↑	45 N	Limiting Latitude
[⊙]		– PROCESS –		
		CO	296.259	GC Course to Vx 296°25'.9
[⊙]		LONt	161.264 W	Tangent Long. V1 161°26'.4 W
[⊙]		LONt	174.280 W	Tangent Long. V2 174°28'.0 W
[⊙]		DST	4504.4	Composite Sailing Distance 4504.4 miles

More Limiting Latitude may be examined by [CHECK] key, which brings the program back to the beginning of [CMPST] mode.



Note: If the composite sailing mode is tried when there is no vertex on the Great Circle Course between point of departure and point of arrival, "CMPST NO NEED" appears on the display.

CHAPTER II

TIME ⇄ ARC CONVERSION AND NORMAL CALCULATIONS

TIME ⇌ ARC CONVERSION

TIME mode make hours, minutes, seconds computation; ARC mode makes degrees, minutes, and 1/10 minute computation. TAMAYA NC-88 follows the customary navigation rule of expressing seconds in terms of 1/10 of a minute in arc mode.

Problem 12a	Input Key	Display
Arc 35°41′.8	[▸TIME]	[TO TIME]
↓	[⊙]	D. Mm ?
2h22m47s	35.418	D. Mm 35.418
	[⊙]	H. MS 2.2247
(14h59m23s + 15h01m59s)	[C]	H. MS 0 c
÷ 2 = 15h00m41s	14.5923 [+]	H. MS 14.5923 +
	15.0159 [÷]	H. MS 30.0122
	2 [=]	H. MS 15.0041

Problem 12b	Input Key	Display
Time 3h51m03s	[▸ARC]	[TO ARC]
↓	[⊙]	H. MS ?
57°45′.8	3.5103	H. MS 3.5103
	[⊙]	D. Mm 57.458
(38°29′.8 + 39°48′.8)	[C]	D. Mm 0 c
÷ 2 = 39°09′.3	38.298 [+]	D. Mm 38.298 +
	39.488 [÷]	D. Mm 78.186
	2 [=]	D. Mm 39.093

In [▸ARC] and [▸TIME] mode it is also possible to make [+][−][×][÷] computation.

To go directly to time computation without going through an arc-to-time conversion, use the [▸ARC] key followed directly by the [⊙] key. Likewise, to go directly to arc computation without going through a time-to-arc conversion, use the [▸TIME] key followed directly by the [⊙] key.

NORMAL CALCULATIONS

1. Four rules of arithmetic calculation

Problem 13a	Key	Display	Note
123−45.6+789 =	[CAL]	[CALCULATOR]	
	[⊙]	0	
	123 [−]	123 −	
	45.6 [+]	77.4	123−45.6
	789 [=]	866.4	Answer
365x(−1.15)÷0.5 =	[CAL] [⊙]	0	
	365 [×]	365 x	
	1.15 [◎] [÷]	−419.75	365x (−1.15)
	.5 [=]	−839.5	Answer

To enter negative number, depress the [◎] Key after the number.

2. Constant calculation

Problem 13b	Key	Display	Note
Constant addition	[CAL] [⊙]	0	
	5 [+]	5 +	
5+3 =	3 [=]	8	5+3
10+3 =	10 [=]	13	10+3
15+3 =	15 [=]	18	15+3
Constant subtraction	[CAL] [⊙]	0	
	5 [−]	5 −	
5−3 =	3 [=]	2	5−3
10−3 =	10 [=]	7	10−3
15−3 =	15 [=]	12	15−3
Constant multiplication			
	[CAL] [⊙]	0	
	295 [×]	295 x	
295x8 =	8 [=]	2360	295x8
295x6 =	6 [=]	1770	295x6
295x (−12) =	12 [◎] [=]	−3540	295x (−12)
Constant division	[CAL] [⊙]	0	
(Divisions will be constant)	32 [÷]	32 ÷	
32÷2 =	2 [=]	16	32÷2
24÷2 =	24 [=]	12	24÷2
(−16)÷2 =	16 [◎] [=]	−8	(−16)÷2

3. Chain multiplication and division

Problem 13c	Key	Display	Note
5 x 3 ÷ 9 =	[CAL] [⊙]	0	
	5 [×]	5 x	
	3 [÷]	15	5 x 3
	9 [=]	1.6666666	Answer

4. Square and power calculation

Problem 13d	Key	Display	Note
$[(2^3)^2]^2 = 2^{12} =$	[CAL] [⊙]	0	
	2 [×]	2 x	
	[=]	4	2^2
	[=]	8	2^3
	[×] =	64	$(2^3)^2 = 2^6$
	[×] =	4096	$(2^6)^2 = 2^{12}$

5. Reciprocal calculation

Problem 13e	Key	Display	Note
$\frac{1}{5} =$	[CAL] [⊙]	0	
	5 [÷]	5 ÷	
	[=]	1	
	[=]	0.2	$\frac{1}{5}$

6. Mixed calculation

Problem 13f	Key	Display	Note
$\left\{\frac{(5+12) \times 18 \div 3 - 16}{4}\right\}^2 =$	[CAL] [⊙]	0	
	5 [+] 12 [×]	17	5+12
	18 [÷] 3 [−]	102	(5+12)x18÷3
	16 [÷] 4 [×]	21.5	$\frac{(5+12) \times 18 \div 3 - 16}{4}$
	[=]	462.25	Answer

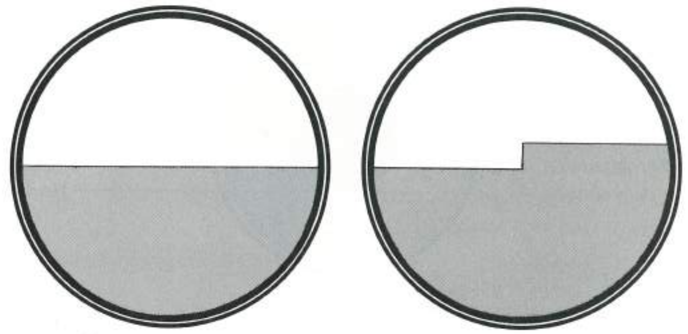
Appendix

1. Sextant Altitude Corrections

After taking a sight of a celestial body we must make necessary corrections to the direct sextant reading to obtain the true altitude. The corrections to be made are (1) Index correction (2) Dip correction (3) Refraction correction (4) Semidiameter correction, and (5) Parallax correction. All these corrections, except index correction, are made in LOP program internally. This chapter is provided to explain the theories and mathematics of these corrections.

(1) Index correction

Index error is the error of the sextant itself. This error can be checked by looking at the horizon with the sextant with its reading set at 0°00'.0. If the reflected image of the horizon in the horizon mirror does not form a straight line with the directly viewed horizon through the clear part, an error exists caused by the lack of parallelism of the two mirrors. Then, move the index arm slowly until the horizon line is in alignment, and see how much the reading is off the "0". This amount should be added to or subtracted from the sextant reading depending on the direction of the error (Fig. 15).



Horizon in alignment　　Horizon out of alignment Index error present

Fig. 15 Index Error

(2) Dip correction

Dip is the discrepancy in altitude reading due to the height of the observer's eye above sea level. If we could measure the altitude of a body with our eye at the sea water level this correction would not be necessary (Fig. 16).

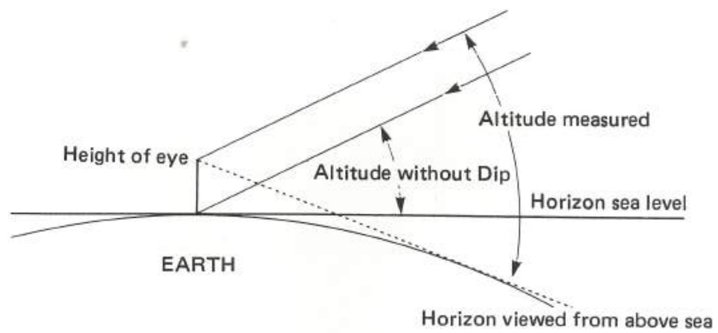


Fig. 16 Dip

(3) Refraction correction

Refraction is the difference between the actual altitude and apparent altitude due to the bending of the light passing through media of varying densities (Fig. 17).

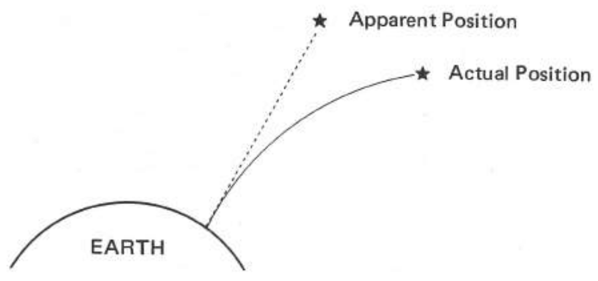


Fig. 17 Refraction

(4) Semidiameter correction

When measuring the altitude of the Sun or Moon by sextant it is customary to observe the upper or lower limb of the body because the center of the body cannot be easily judged. In this case the semidiameter of the disk of the body must be subtracted from or added to the measured angle (Fig. 18).

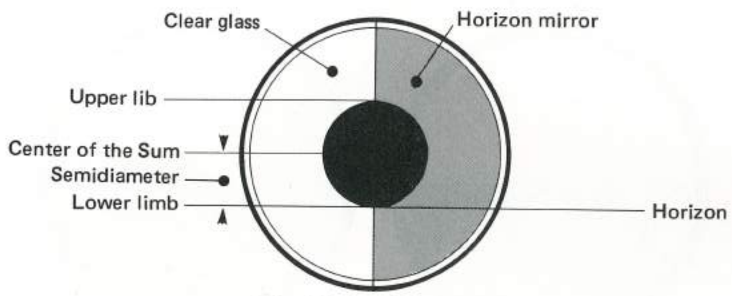


Fig. 18 Semidiameter

(5) Parallax correction

Parallax is the difference in the apparent position of the body viewed from the surface of the earth and the center of the earth. While the angle must be measured from the center we can view the body only from the surface, and the difference must be adjusted (Fig. 19).

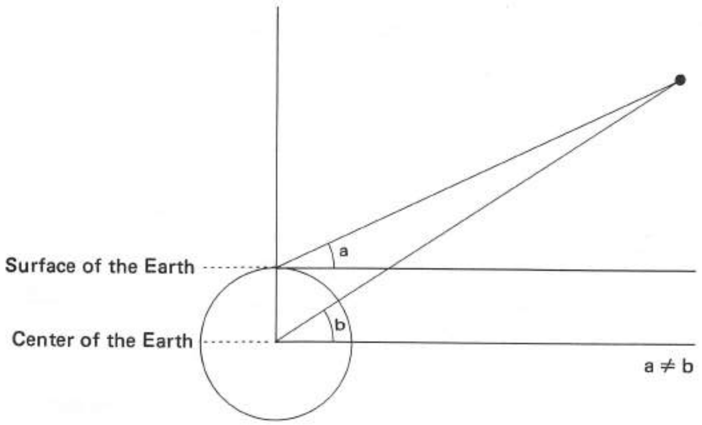


Fig. 19 Parallax

This correction is applied to the Sun, Moon, Venus and Mars. In NC-88 the Sun's and the Moon's Parallax correction is made in combination with its semidiameter correction.

(6) Temperature and Pressure

In computing sextant altitude corrections, the standard temperature 10°C (50°F) and pressure 1013.25 mb. (29.92 in.) are pre-programmed in NC-88. Although in most cases the standard data would provide sufficiently accurate results, some might desire to input other temperature and pressure values, particularly in case of low altitude, less than 10°, where these factors affect the refraction more significantly. (See the mathematics in Appendix 2 P. 37)

2. Application of Equation of Time

Fix by Noon Sight

We can find our latitude and longitude at the same time if we measure the Sun's highest altitude of the day and record the time. Before the introduction of computers, this simple method of finding the longitude and latitude was favored by many navigators.

Longitude:

The Sun travels from east to west at an equatorial speed of 15 nautical miles per minute. It crosses the Greenwich meridian at about GMT 12 o'clock. At this moment on the Greenwich line the Sun has reached its highest altitude of the day, and we observe the Sun due South or North. This is called Meridian Passage. If we were not on the Greenwich line (longitude 0°) we would observe the Sun reach its highest altitude at a different time. For instance, if we observed the Sun's meridian passage at GMT 14 o'clock, we can judge from the Sun's speed that our longitude is two hours (or 30° of Arc) west of the Greenwich line. This is the basic principle of finding longitude by Sun's Meridian Passage; however, an adjustment, with Equation of Time, must be introduced to obtain our exact longitude because the earth's rotation is not truly at a constant speed. Since for convenience we use a fictitious constant Mean Sun at the basis for measurement of time the True Sun is not necessarily at the highest altitude at noon by the Mean Sun. Equation of Time is the difference in time between the True Sun and the Mean Sun.

Latitude:

After measuring the highest true altitude of the Sun by sextant our latitude can be determined by the following rules.

(1) If DR latitude and declination have contrary names.
    Lat. = (90° – Alt.) – dec.

(2) If DR latitude and declination have the same name (North or South)
    a) When Lat. > dec. Lat. = dec. + (90° – Alt.)
    b) When Lat. < dec. Lat. = dec. – (90° – Alt.)

3. Mathematics for Sextant Altitude Corrections and Navigation

1. Altitude and Azimuth

Altitude $a_c = \sin^{-1}(\cos h \cdot \cos d \cdot \cos \ell + \sin d \cdot \sin \ell)$

Azimuth $Z = \cos^{-1}\left(\dfrac{\sin d - \sin a_c \cdot \sin \ell}{\cos a_c \cdot \cos \ell}\right)$

ℓ : DR Lat.
L : DR Long.
h : Local Hour Angle

2. Sextant Altitude Correction

Apparent Alt. $a_a = a_s - 0\overset{\circ}{.}0296\sqrt{H}$

Observed Alt. $a_o = a_a - \dfrac{P}{1013.25} \cdot \dfrac{283}{273 + t} \cdot Rm$

$$Rm \begin{cases} = -0\overset{\circ}{.}0317 + 0\overset{\circ}{.}0257 \cot(a_a + 2\overset{\circ}{.}4);\ a_a \leq 7^\circ \\ = 0\overset{\circ}{.}0162 \cot a_a - 0\overset{\circ}{.}000018 \cot^3 a_a;\ a_a > 7^\circ \end{cases}$$

$$\text{True Alt. } a_t \begin{cases} = a_o + SD + HP \cdot \cos a_o; & \text{Lower limb} \\ = a_o - SD + HP \cdot \cos a_o: & \text{Upper limb} \end{cases}$$

Sun : SD obtained by ALM, HP = $0\overset{\circ}{.}00244$
Moon : SD = $0\overset{\circ}{.}2725 \cdot HP$, HP obtained by ALM
Planets : SD = 0°, HP obtained by ALM
Stars : SD = 0°, HP = 0°

Intercept I. = $a_t - a_c$

a_s : Sextant Alt.
H : Height of eye
t : Temperature
P : Pressure
SD : Semi Dia.
HP : Horizontal Parallax
a_c : Calculated Alt.

3. Fix

Difference of lat. $D.\ell = \dfrac{1}{D}(D_{12} \cdot IS + D_{22} \cdot IC)$

Difference of Long. $D.L = \dfrac{1}{D}(D_{11} \cdot IS + D_{12} \cdot IC) \cdot \dfrac{1}{\cos\ell}$

$D_{11} = \Sigma \cos^2 Z_i$
$D_{12} = -\Sigma \cos Z_i \cdot \sin Z_i$
$D_{22} = \Sigma \sin^2 Z_i$
$D = D_{11} \cdot D_{22} - D_{12}{}^2$
$IS = \Sigma I_i \cdot \sin Z_i$
$IC = \Sigma I_i \cdot \cos Z_i$

Fixed lat. $\ell fix = \ell + D.\ell$
Fixed Long. $Lfix = L + D.L$

ℓ : DR Lat.
L : DR Long.
Z : Azimuth
I : Intercept

4. Dead Reckoning

DR Lat. $\ell_2 = \text{Dist} \times \cos\text{Co} + \ell_1$

DR Long.

$$L_2 = \begin{cases} \dfrac{180^\circ}{\pi}(mp_2 - mp_1)\cdot \tan\text{Co} + L_1 & ;\cos\text{Co} \neq 0 \\ \dfrac{\text{Dist}\cdot\sin\text{Co}}{\cos\ell_1} + L_1 & ;\cos\text{Co} = 0 \end{cases}$$

$$mp_i = \ell n\cdot\tan\left(45^\circ + \frac{\ell_i}{2}\right) - e^2\cdot\sin\ell_i - \frac{1}{3}e^4\sin^3\ell_i$$

Eccentricity $e = 0.08182$

ℓ_1 : Deperting Lat.
L_1 : Deperting Long.
Co : Course
Dist : Distance

5. Course and Distance

Course $\text{Co} = \tan^{-1}\left\{\dfrac{\pi}{180}\cdot\dfrac{D\cdot L}{mp_2 - mp_1}\right\}$

Distance

$$\text{Dist} \begin{cases} = \dfrac{60 \times D\cdot L \times \cos\ell_1}{\sin\text{Co}} & ;\cos\text{Co} = 0 \\ = \dfrac{60 \times D\cdot\ell}{\cos\text{Co}} & ;\cos\text{Co} \neq 0 \end{cases}$$

D.ℓ : Difference of Lat.
D.L : Difference of Long.
mpi : Meridional Parts.
ℓ_1 : Departing Lat.

6. Great Circle Sailing

$$\text{Dist} - 90^\circ = \sin^{-1}\{\cos(L_1 - L_2)\cdot\cos\ell_2\cdot\cos\ell_1 + \sin\ell_2\cdot\sin\ell_1\}$$

$$\text{Co} = \cos^{-1}\left\{\frac{\sin\ell_2 - \sin(\text{Dist} - 90^\circ)\cdot\sin\ell_1}{\cos(\text{Dist} - 90)\cdot\cos\ell_1}\right\}$$

Vertex Long.

$$L_V = \sin^{-1}\left\{\frac{\cos\text{Co}}{\sin\cdot\cos^{-1}(\cos\ell_1\cdot\sin\text{Co})}\right\}$$

Vertex Lat.

$$\ell_V = \tan^{-1}\left\{\frac{\tan\ell_2\cdot\sin(L_V - L_1) - \tan\ell_1\cdot\sin(L_V - L_2)}{\sin(L_2 - L_1)}\right\}$$

Intermediate Lat.

$$\ell_i = \tan^{-1}\left\{\frac{\tan\ell_2\cdot\sin(L_i - L_1) - \tan\ell_1\cdot\sin(L_i - L_2)}{\sin(L_2 - L_1)}\right\}$$

ℓ_1 : Departing Lat.
L_1 : Departing Long.
$\ell 2$: Arriving Lat.
L_2 : Arriving Long.
L_i : Intermediate Long.

7. Composite Sailing

Course

$$\text{Co} = \sin^{-1}\left(\frac{\cos\ell_L}{\cos\ell_1}\right)$$

Distance

$$\text{Dist} = 60\left[\cos^{-1}\left(\frac{\sin\ell_1}{\sin\ell_L}\right) + \cos^{-1}\left(\frac{\sin\ell_2}{\sin\ell_L}\right) + \cos^{-1}\left\{\cos(L_{L_2} - L_{1L})\right\}\cos\ell_L\right]$$

Tangent Long.

$$L_{1L} = L_1 + \cos^{-1}\left(\frac{\tan\ell_1}{\tan\ell_L}\right)$$

$$L_{L_2} = L_2 - \cos^{-1}\left(\frac{\tan\ell_2}{\tan\ell_L}\right)$$

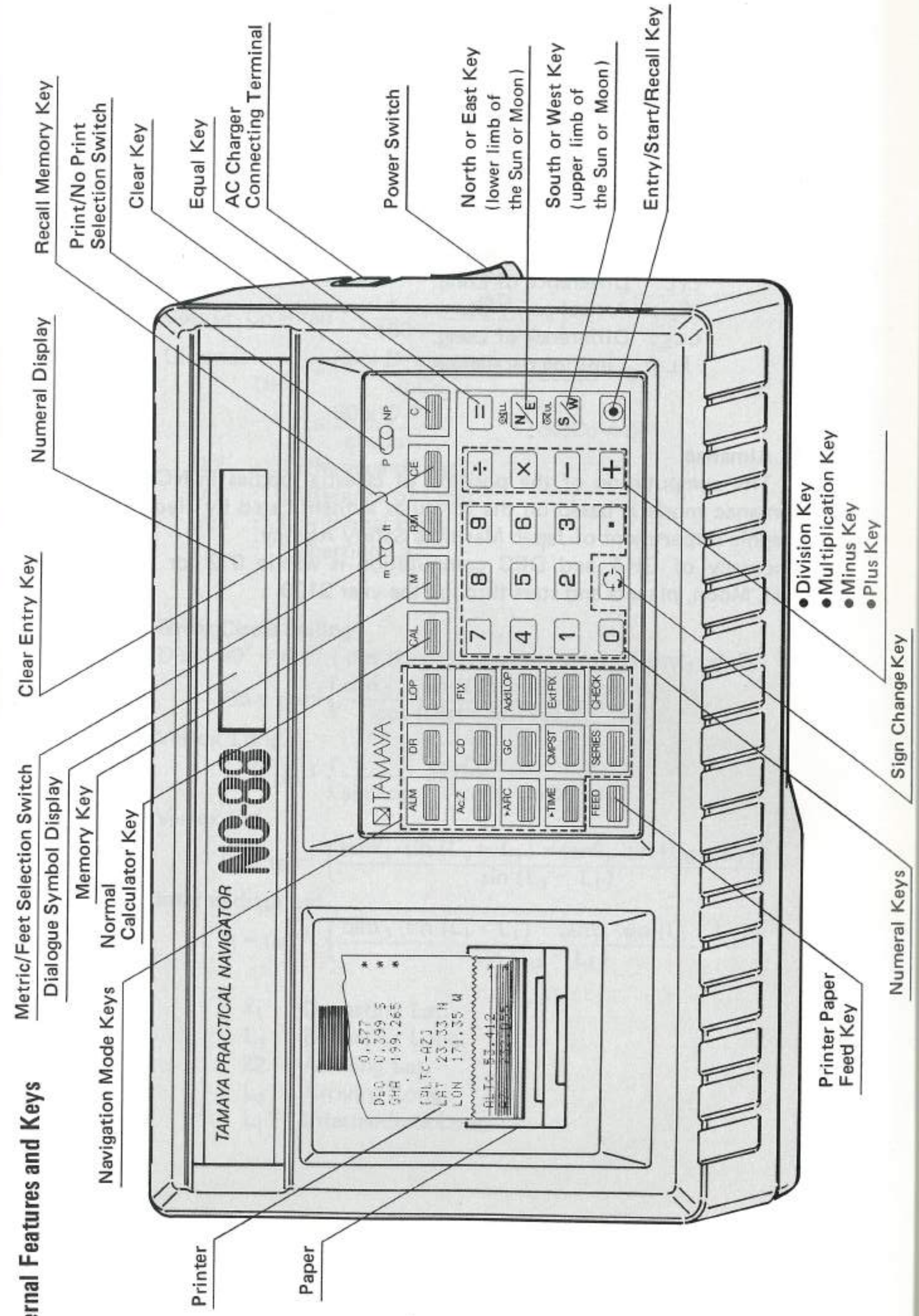
Here

ℓ_1 : Departure point lat.
L_{1L} : Difference of Long.
ℓ_2 : Arrival point lat.
L_{L_2} : Difference of Long.
ℓ_L : Limiting parallel lat.

8. Almanac

The computation of the position of celestial bodies in NC-88 Almanac mode is based on the formulas authenticated by Hydrographic Department of Japan Maritime Safety Agency.
Accuracy of GHA and DEC computation is within 0'.2 for the Sun, Moon, planets and stars through the year 2100.

NC-88 External Features and Keys



(1) Navigation Mode Keys

[ALM] mode key computes the Sun's GHA, DEC, Equation of Time; the Moon's GHA, DEC, Horizontal Parallax; the planets' GHA, DEC, Horizontal Parallax; the stars' GHA Aries, SHA, GHA, Horizontal Parallax.

[Ac.Z] mode key computes, continuing from the [ALM] key, the Altitude and Azimuth of the heavenly body from the point of the observer.

[LOP] mode key computes the Altitude Intercept and Azimuth for plotting a Line of Position. When used successively it computes the second set of Altitude Intercept and Azimuth. It can be used successively as many times as the number of LOP's desired.

[FIX] mode key computes the latitude and longitude of fix, the intersection or centroid of two or more Lines of Position. The fix is accompanied by the time, hours, minutes, seconds in GMT. By using [SERIES] key successively, the fix at various times may be found along the course used in obtaining the Lines of Position.

[AddLOP] mode adds another LOP to the ones with which the fix was computed in [FIX] mode. After wards, [FIX] will compute the position refined by the new LOP.

[ExtFIX] when the LOP's are available externally, not going through LOP mode, the Fix can be computed by this key.

[DR] mode key computes the Dead Reckoning Position by Mercator Sailing or Parallel Sailing.

[CD] mode key computes the Course and Distance by Mercator Sailing or Parallel Sailing.

[GC] mode key computes the Great Circle Distance and the Initial Course by Great Circle Sailing. The program continues to compute Latitude and Longitude of the vertex, and by using [SERIES] key, the latitude at any selected Longitude on the Great Circle track.

[CMPST] when a limiting latitude should be applied on the Great Circle track [CMPST] key computes initial Great Circle Course to point of tangency with limiting parallel, the longitude at which the limiting parallel is reached, the longitude at which it should be left, and the composite sailing distance.

[SERIES] 1) When the fix has been computed, it may be moved along the course used in obtaining the Lines of Position, by feeding various times in [SERIES] mode.

2) when the Great Circle Track has been found, the corresponding latitude on the track is computed, by feeding the intermediate longitude in [SERIES] mode.

[CHECK] 1) Before proceeding to computation by [⊙] key the entered data may be checked by going back to the beginning of the program* in each mode by [CHECK] key.

2) After the computation, if the result seems inadequate, it is still possible to go back to the beginning of the program by [CHECK] key.

In both cases, any incorrect data may be rectified by simply entering the new data in the same frame. The provision of [CHECK] function saves time greatly in spotting out the entry data errors, and obtaining the required results quickly.

* : The exception is [A-Z] mode. In this case [CHECK] key will bring the step back to the beginning of [ALM] mode program. This provision is made to facilitate the star finding function.

[▸ARC] key sets the input in hours, minutes and seconds, and converts them into degrees, minutes and 1/10 minutes.

[▸TIME] key sets to input in degrees, minutes and 1/10 minutes, and converts them into hours, minutes and seconds.

[N/E] Key designates North in latitude and East in longitude. It also indicates the sighting of lower limb of the Sun or Moon in computing sextant altitude correction in [LOP] mode.

[S/W] Key designates South in latitude and West in longitude. It also indicates the sighting of the upper limb of the Sun or Moon.

[⊙] Enters a number, starts the programmed computation or recalls the programmed memories in Navigation mode.

(2) Other Keys and Switches

[CAL] Followed by [⊙] sets normal calculation.

[C] Clears all the computation registers, error, etc. Resumes the beginning of the program in the navigation programs.

[CE] Clears only displayed register.

[0]~[9] Numeral keys to enter a number.

[•] Designates the decimal point of a set number.

[+][−][×][÷] Sets the order of each function.

[=] Completes the addition, subtraction, multiplication, division functions.

[±] Changes the sign of displayed number.

[FEED] Feeds the printer paper.

When the power switch is in "ON" position the computer is powered, automatically cleared and ready for operation in normal calculation mode.

Metric/Feet Selection Swtich

m⊂⊃ft When metric system is selected the inputs should be made in meters, Celsius (temperature) and millibars (pressure).

When fee system is selected the inputs should be made in feet, Fahrenheit and inches of mercury.

P⊂⊃*NP* Select P for printing out of data and NP for non-printing function.

Memory Keys

[M] memory key

[RM] recall memory key

(3) Notes on Decimal Point

In the NC-88 TIME is always expressed as Hours, Minutes, Seconds, and ARC as Degrees, Minutes, 1/10 minutes to follow conventional navigation practice. The decimal point should be entered as follows. The same rule applies to the reading of the outputs.

TIME	$12^h15^m33^s$		12.1533
	15^m33^s		.1533
	5^h33^s		0.533
	33^s		.0033
	3^s		.0003
ARC	180°35ʹ.5	Enter	180.355
	35ʹ.5		.355
	5ʹ.5		.055
	0ʹ.5		.005

In [ALM] (Nautical Almanac) and [LOP] (Line of Position) modes the year, month and day are entered as follows:

April 4, 1982	Enter	1982.0404
$12^h06^m08^s$		12.0608

(4) Overflow Error

An overflow error will occur in the following cases. When an overflow error is detected, all keys electronically are interlocked except the [C] and the [CHECK] keys.

Overflow error is cleared by pressing the [C] key.

1. When the integer portion of sum, difference, product or quotient exceeds 8 digits.
2. When a number is divided by zero.
3. In [▸ARC] and [▸TIME] modes when an entered integer portion exceeds 4 digits in H. MS and 5 digits in D.Mm.
4. In DR mode when D.R. Lat. >90°
5. In [FIX] and [ExFIX] mode Lat. Fix >90° or Long. Fix − DR. Long. >360°
6. In Vertex of GC mode when Departing Lat. = Arriving Lat. = 0° or Departing Long. = Arriving Long.
7. In Navigation mode when any one of the conditions stated in 1 and 2 above occurs.

Note: In all cases 1 to 6, above the memory retains the contents before the overflow error is detected.

(5) Printer Error

If a defect should occur in the printer mechanism or in its control circuits, the printer stops automatically and displays "PRINTER ERROR" in LCD display. In this case, turn to NP (non-orint) position by P/NP slide switch and press [C] key. The NC-88 works at non-print position.

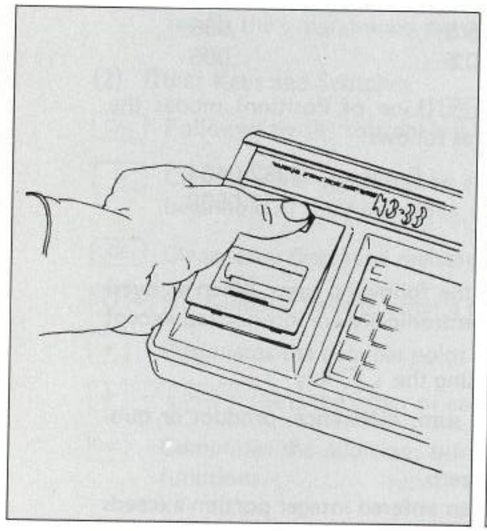
(6) Blocking of Incorrect Data Entry

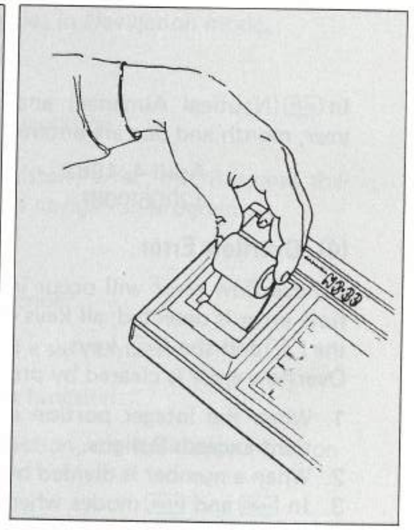
In the following cases if obviously wrong data is attempted to be entered, the program blocks it.

Integer portion exceeds 2 digits in LAT. (e.g. LAT 150.000)
Integer portion exceeds 3 digits in LON. (e.g. LON 1800.0000)
Integer portion exceeds 4 digits in YMD (e.g. YMD 19820.1215)
Integer portion exceeds 2 digits in HMS (e.g. HMS 125.0000)

(7) Installation of the Paper

1. Open the transparent plastic paper cover.
2. Insert the end of the roll paper into the paper feed slot in the paper housing as far as possible.
3. Set the power switch to ON, press the paper feed key [FEED] to start. Press the key until the paper comes through the paper cutter.
4. Close the paper cover.





Paper

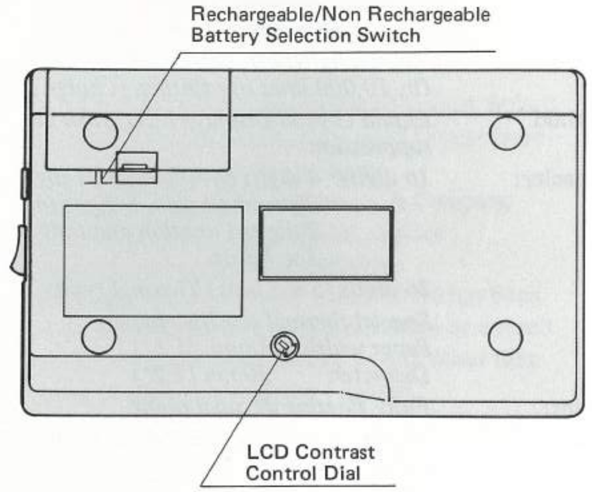
The printer in your calculator is a thermal printer and you are required to use special thermal sensitive paper. When additional paper is required, please make sure to check the size of paper as follows.

Paper width: 1.5" (38mm)
Diameter : 1.2" (30mm)

Note: Make sure not to operate the calculator in PRINT MODE without paper; it may damage your calculator.

Warning

REMOVING THE PAPER: Feed until the end of the paper. Do not pull the paper through the paper feed slot. Especially, pulling it against the normal paper flow direction may damage the printer mechanism.



(8) Lower Ambient Temperature and LCD

In the lower ambient temperature the contrast of the Liquid Crystal Display becomes less distinct. This phenomenon is controlled by the LCD Contrast Control Dial found at the bottom of the NC-88 housing. The clockwise turning sharpens the contrast of LCD.

(9) Power Source

AC: With charger and rechargeable Ni-Cd. batteries for 100, 120, 220, 240V, 50/60 Hz.

DC: With Rechargeable Ni-Cd. batteries
1.2V x 4 pcs. = 4.8V (Standard)
With Non-rechargeable batteries SUM-2
1.5V x 4 pcs. = 6.0V

(10) Rechargeable/Non-Rechargeable Battery Selection Switch

Make sure the switch must be in "Non Rechargeable Battery Only" position if NC-88 operates with Non rechargeable batteries.

(11) Precaution on Ni-Cd. Batteries

The treatment of the Ni-Cd. batteries is very easy and they are resistant to over-charging. However, take the following precautions to insure proper battery life.

1. Power should be turned off when not in use.
2. Do not totally discharge batteries.
3. Recharge batteries periodically, if batteries are not to be used for periods longer than 30 days.
4. Do not dispose of batteries by fire.
5. If batteries do not hold a charge, they should be replaced.
6. Do not expose to direct heat. Particulary avoid leaving battery unattended in a car or boat where it may be affected by the Sun.

Keep NC-88 away from water, moisture or extreme heat or low temperature. Use the storage case as protection against vibration and shock.

SPECIFICATIONS

Power Source:	*AC – Charger with rechargeable Ni-Cd. batteries for 100, 120, 220, 240 V, 50/60 Hz.* *DC – Rechargeable batteries* *1.2V x 4 pcs. = 4.8V (Standard)* *Dry batteries SUM-2* *1.5V x 4 pcs. = 6V*
Operating Hours:	*9 hours by Ni-Cd. batteries when not in print. Or, 10,000 lines of printing. (Charge 35 hours)*
Display Method:	*Liquid Crystal Display (LCD) with zero suppression*
Display Capacity:	*16 digits: 4 digits Symbol Sign, 1 digit space, 1 digit minus sign, 8 digits input/output, 2 digits Function and unit sign.* *5 x 7 dots.*
Printer:	*16 digits (5 x 7 dots) Thermal type.*
Paper:	*Special thermal sensitive paper* *Paper width: 38mm (1.5")* *Diameter: 30mm (1.2")*
Decimal Point:	*Fully floating decimal point*
Calculations:	*Four arthmetic calculations, constant calculations, chain multiplication & division, square and power calculation, reciprocal calculation, mixed calculation*
Programmed Navigation Functions:	*Nautical Almanac for Sun, Moon, 4 planets and 63 stars, Altitude and Azimuth, Line of Position, Fix, Extra Fix, Dead Reckoning, Dead Reckoning Series, Course and Distance, Course and Distance Series, Course and Distance by Great Circle Sailing, Vertex, Latitude on Great Circle Track, Composite Great Circle Sailing, Time and Arc Conversion and compution.*
Accuracy of Nautial Almanac:	*Within 0'.2 for GHA and DEC of the Sun, Moon, planets and stars through the year 2100.*
Memory:	*1 user accessible memory, and 4 extra memories for the output of ALM, GC and COMPOSIT and 3 memories for FIX, ADD LOP FIX, and 2 memories for LOP, FIX SERIES, DR, DR SERIES, CD, CD SERIES, ALTc-AZ.*
Components:	*LSI, etc.*
Operating Temperature:	*0–40°C (32–104°F)*
Power Consumption	*4.8 W MAX.*
Dimensions:	*230(W) x 50(H) x 140(D) mm*
Weight:	*900 gr.*
Protection Case:	*Hand-made wooden box*

WARRANTY

The NC-88 is automatically warranted against defects in materials and workmanship for one (1) year from date of delivery to original purchaser.
During the warranty period, Tamaya & Company Limited will repair or at its option, replace components that prove to be defective.
This warranty does not apply if the NC-88 has been damaged by accident or through misuse or as a result of service or modification by any person other than at Tamaya's authorized service facilities.
No other warranty is expressed or implied. Tamaya is not liable for consequential damages.

TAMAYA & COMPANY LIMITED
Tokyo Japan

TAMAYA & COMPANY LIMITED
5-8 Ginza 3-chome Chuo-ku, Tokyo 104 Japan