TAMAYA

SIMPLE & SERIOUS

DIGITAL

ASTRO-NAVIGATION
PILOTING
&
DEAD RECKONING

BY TAMAYA DIGITAL NAVIGATION COMPUTER NC-77

Semidiameter (S.D.) of the Sun and Horizontal Parallax (H.P.) of Venus and Mars.

For Sextant Altitude Corrections

S.D. Sun ☉

January	16.3	July	15.8
February	16.2	August	15.8
March	16.1	September	15.9
April	16.0	October	16.1
May	15.9	November	16.2
June	15.8	December	16.3

H.P. Mars ♂

1978	Jan. 1 – Mar. 19	0.2
	Mar. 20 – Dec. 31	0.1
1979	Jan. 1 – Dec. 31	0.2
1980	Jan. 1 – Apr. 25	0.2
	Apr. 26 – Dec. 31	0.1
1981	Jan. 1 – Dec. 31	0.1
1982	Jan. 1 – Feb. 2	0.1
	Feb. 3 – Jun. 15	0.2
	Jun. 16 – Dec. 31	0.1
1983	Jan. 1 – Dec. 31	0.1
1984	Jan. 1 – Mar. 4	0.1
	Mar. 5 – Aug. 27	0.2
	Aug. 28 – Dec. 31	0.1
1985	Jan. 1 – Dec. 31	0.1
1986	Jan. 1 – Apr. 6	0.1
	Apr. 7 – May 25	0.2
	May 26 – Jul. 2	0.3
	Jul. 3 – Jul. 31	0.4
	Aug. 1 – Sep. 12	0.3
	Sep. 13 – Nov. 13	0.2
	Nov. 14 – Dec. 31	0.1
1987	Jan. 1 – Dec. 31	0.1
1988	Jan. 1 – May 22	0.1
	May 23 – Jul. 24	0.2
	Jul. 25 – Sep. 2	0.3
	Sep. 3 – Oct. 10	0.4
	Oct. 11 – Nov. 13	0.3
	Nov. 14 – Dec. 31	0.2
1989	Jan. 1	0.2
	Jan. 2 – Dec. 31	0.1

H.P. Venus ♀

1978	Jan. 1 – Jul. 23	0.1
	Jul. 24 – Sep. 10	0.2
	Sep. 11 – Oct. 3	0.3
	Oct. 4 – Oct. 19	0.4
	Oct. 20 – Nov. 29	0.5
	Nov. 30 – Dec. 14	0.4
	Dec. 15 – Dec. 31	0.3
1979	Jan. 1 – Jan. 6	0.3
	Jan. 7 – Feb. 27	0.2
	Feb. 28 – Dec. 31	0.1
1980	Jan. 1 – Mar. 1	0.1
	Mar. 2 – Apr. 21	0.2
	Apr. 22 – May 14	0.3
	May 15 – May 30	0.4
	May 31 – Jul. 1	0.5
	Jul. 2 – Jul. 17	0.4
	Jul. 18 – Aug. 9	0.3
	Aug. 10 – Sep. 29	0.2
	Sep. 30 – Dec. 31	0.1
1981	Jan. 1 – Nov. 21	0.2
	Nov. 22 – Dec. 15	0.3
	Dec. 16 – Dec. 30	0.4
	Dec. 31	0.5
1982	Jan. 1 – Feb. 10	0.5
	Feb. 11 – Feb. 25	0.4
	Feb. 26 – Mar. 20	0.3
	Mar. 1 – May 9	0.2
	May 10 – Dec. 31	0.1
1983	Jan. 1 – May 13	0.1
	May 14 – Jul. 1	0.2
	Jul. 2 – Jul. 23	0.3
	Jul. 24 – Aug. 8	0.4
	Aug. 9 – Sep. 11	0.5
	Sep. 12 – Sep. 28	0.4
	Sep. 29 – Oct. 21	0.3
	Oct. 22 – Dec. 13	0.2
	Dec. 14 – Dec. 31	0.1
1984	Jan. 1 – Dec. 13	0.1
	Dec. 14 – Dec. 31	0.2
1985	Jan. 1 – Feb. 4	0.2
	Feb. 5 – Feb. 28	0.3
	Mar. 1 – Mar. 17	0.4
	Mar. 18 – Apr. 21	0.5
	Apr. 22 – May 7	0.4
	May 8 – May 29	0.3
	May 30 – Jul. 17	0.2
	Jul. 18 – Dec. 31	0.1
1986	Jan. 1 – Jul. 20	0.1
	Jul. 21 – Sep. 8	0.2
	Sep. 9 – Oct. 1	0.3
	Oct. 2 – Oct. 16	0.4
	Oct. 17 – Nov. 26	0.5
	Nov. 27 – Dec. 12	0.4
	Dec. 13 – Dec. 31	0.3
1987	Jan. 1 – Jan. 4	0.3
	Jan. 5 – Feb. 25	0.2
	Feb. 26 – Dec. 31	0.1
1988	Jan. 1 – Feb. 27	0.1
	Feb. 28 – Apr. 19	0.2
	Apr. 20 – May 11	0.3
	May 12 – May 28	0.4
	May 29 – Jun. 28	0.5
	Jun. 29 – Jul. 15	0.4
	Jul. 16 – Aug. 6	0.3
	Aug. 7 – Sep. 27	0.2
	Sep. 28 – Dec. 31	0.1
1989	Jan. 1 – Sep. 28	0.1
	Sep. 29 – Nov. 19	0.2
	Nov. 20 – Dec. 12	0.3
	Dec. 13 – Dec. 28	0.4
	Dec. 29 – Dec. 31	0.5

TABLE 1

SIMPLE & SERIOUS

DIGITAL

ASTRO-NAVIGATION
PILOTING
&
DEAD RECKONING

BY TAMAYA DIGITAL NAVIGATION COMPUTER NC-77

Contents

Introduction

With TAMAYA NC-77 DIGITAL NAVIGATION COMPUTER we can digitally solve most navigational problems with scientific accuracy and incredible speed in a very easy way. However, it is a fallacy to believe that computers will do everything for us. Safety at sea always depends on our sound judgement, whatever tools we may use to facilitate our work. For this reason, this textbook not only explains how to use NC-77 Computer but also refers to the principles and fundamentals of navigation.

In PART ONE determining our position by Astro-Navigation is expounded fully from the principle to the actual steps of computation. In PART TWO Basic Navigation Computations for Dead Reckoning and Piloting are explained with examples and illustrations. The text is very easy, and no special knowledge of computer programming or mathematics is required.

In the course of learning in this textbook, if any question arises about the meaning of keys and dialogue symbols of NC-77 we can refer to the Appendix where full explanation is given with illustrations.

For further study on navigation, it is recommended to read such classical textbooks as "American Practical Navigator" by Bowditch or "Dutton's Navigation and Piloting" by Dunlop and Shufeldt, with NC-77 computer at hand. Comprehension of these textbooks is greatly advanced because with NC-77 we can save a lot of time otherwise spent unnecessarily on acquiring techniques on mechanical computations. Consequently, we can concentrate on understanding of more important fundamentals and principles of navigation.

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.

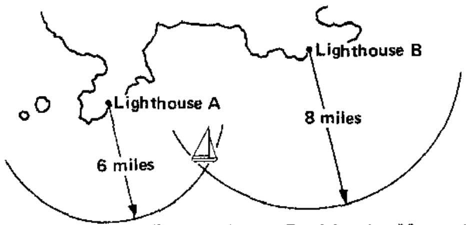


Fig. 1 Finding Ship's Position by Measuring Distance

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.

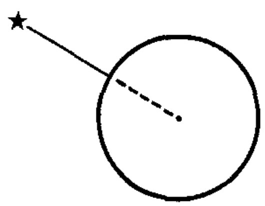
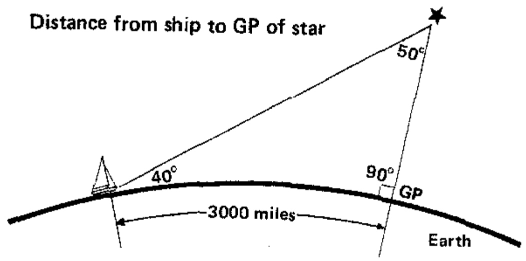


Fig. 2 GP of a heavenly body

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, and supplementary note on page 33.

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.

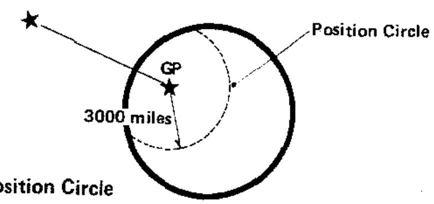


Fig. 4 Position Circle

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 in Chapter IV. This is called Position Line or Line of Position. See Fig. 5.

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

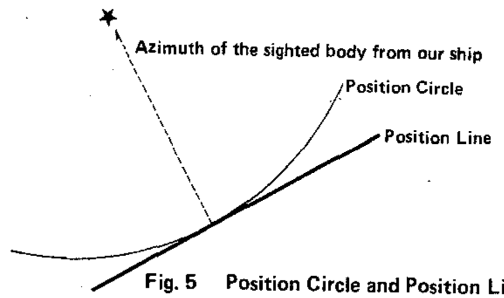


Fig. 5 Position Circle and Position Line

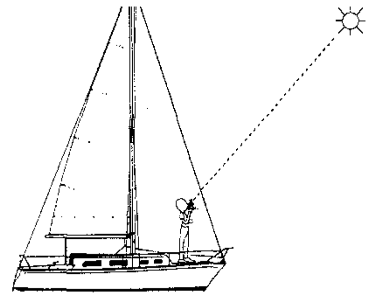
2. BASIC STEPS AND TOOLS FOR ASTRO-NAVIGATION

It takes some steps and tools to determine our ship's position by Astro-Navigation as summarized in Fig. 6.

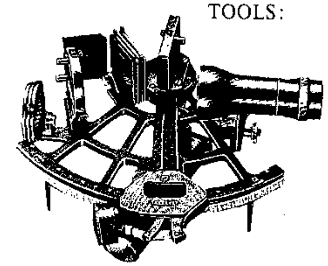
Fig. 6

1. TAKING SIGHT WITH A SEXTANT.

Measure the altitude of the heavenly body (Sun, Moon, planet or star) above the horizon at your position.
Record the exact Greenwich Mean Time (GMT) of the sight.



TOOLS:

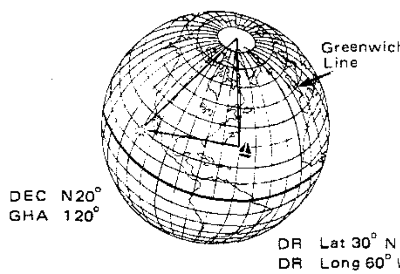


• Sextant

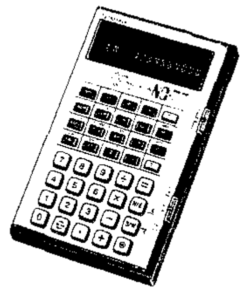
• Quartz Watch

2. FINDING GEOGRAPHICAL POSITION (GP) OF THE SIGHTED BODY:

The GP is the point on the earth directly beneath the heavenly body, and it is expressed by Greenwich Hour Angle (GHA) and Declination (DEC). They are computed by NC-77 or found in the Nautical Almanac.

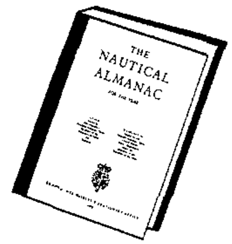


TOOLS:



• NC-77 Computer

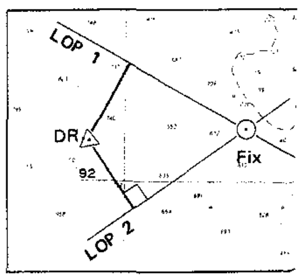
or



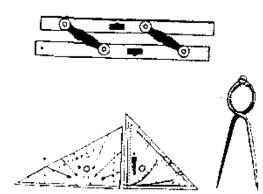
• Nautical Almanac

3. COMPUTATION BY NC-77 AND PLOTTING:

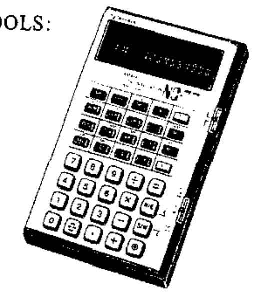
Compute the Azimuth (Ξ) and Altitude (A) of the same body by NC-77 using the factors found in Steps (1) and (2), and the DR position. (A ship's position determined by applying the cource and distance travelled from some known position, e.g., the departing port, is called Dead Reckoning Position.) Compare the computed Altitude (A) with the actually observed True Altitude (A_o). From the above factors we can plot a line of position (LOP) on the chart or plotting sheet. Plot two LOP's to determine our ship's position at their intersection (FIX), or compute it digitally by NC-77.



TOOLS:



• Plotting Instruments



• NC-77 Computer

CHAPTER II

Taking Sight with a Sextant

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 mirros 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 constracted that one can see the horizon at the same time he sees the reflected image of the whole body. 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).

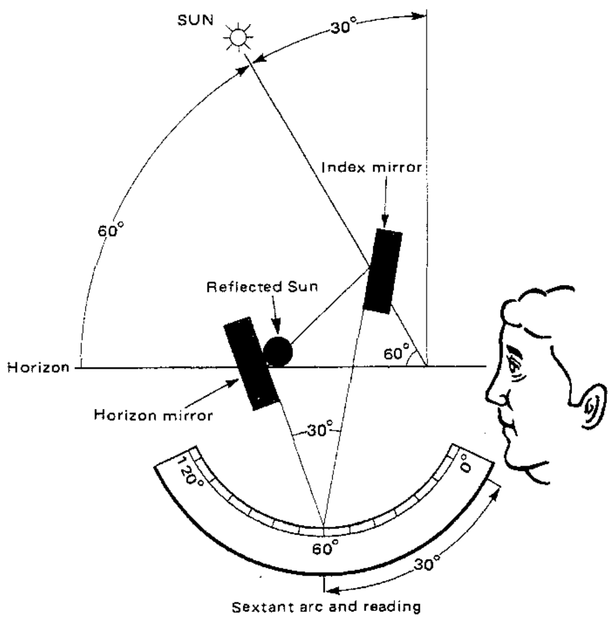


Fig. 7

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

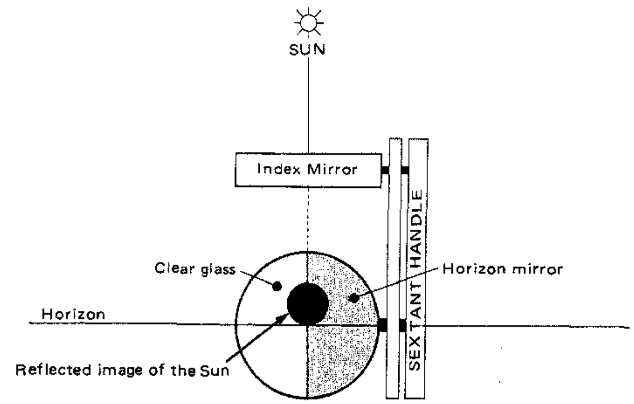


Fig. 8

2. 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 mile 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 III

Finding The Geographical Position of Heavenly Bodies (Greenwich Hour Angle and Declination)

The Geographical Position is the point on the earth directly beneath the heavenly body, and it is expressed in terms of Greenwich Hour Angle (GHA) and Declination (DEC). GHA and DEC are like longitude and latitude that are used to designate positions on the earth. In Astro-Navigation we use the Sun, Moon, Venus, Mars, Jupiter, Saturn and selected navigational stars as reference bodies. We can obtain GHA and DEC of the Sun by NC-77 Almanac [ALM] mode. For the other bodies we use NC-77 and the Nautical Almanac. Let us work on examples.

Problem 1. Find the GHA and DEC of the Sun at GMT 14ʰ 35ᵐ 43ˢ on Jan. 1, 1978 by NC-77.

Key	Display	Note:
[ALM]	y 0.	Year Month Day
78.0101	y 78.0101	78 01 01
[⊛]	h 0.	
14.3543	h 14.3543	Hour Minute Second 14 35 43
[⊛]	Ho 319.492	GHA Aries
[⊛]	d −22.599	DEC Sun
[⊛]	H 38.025	GHA Sun
[⊛]	Eo −0.0333	Equation of Time
[⊛]	Repeat d and H	

Answer: GHA Sun (Dialogue Symbol : H) 38°02′.5
DEC Sun (Dialogue Symbol : d) S22° 59′.9

We will make use of GHA Aries (Ho) later in the star problem, and Equation of Time (Eo) in the noon sight problem.

GHA/DEC vs. Longitude/Latitude

DEC is measured like latitude, from the equator to 90° north and 90° south. It should be noted that GHA and longitude are not expressed exactly the same. Whereas longitude is measured from the Greenwich meridian (longitude 0° line) to 180° east and to 180° west, GHA is measured only westward up to 360° from it. Therefore, longitude 90° east, for instance, is equivalent to GHA 270°.

Problem 2. Find the GHA and DEC of the Moon at GMT 05ʰ 25ᵐ18ˢ on Jan. 1, 1978. We need Nautical Almanac to find GHA and DEC of the Moon, planets and stars. NC-77 greatly facilitates the procedure of deriving the required information from the Nautical Almanac. Nautical Almanac is published every year by the U.S. Naval observatory or equivalent authorities in other countries.

As an example, we will find the following data in the 1978 Nautical Almanac for Sunday, January 1. See Table 2 – Excerpt from Nautical Almanac.

G.M.T. d h		MOON G.H.A. ° ′	MOON Dec. ° ′	MOON H.P. ′
	1 00	288 01.3	N 1 38.0	56.3
	01	302 33.5	1 27.9	56.3
	02	317 05.7	1 17.8	56.3
	03	331 37.8	1 07.7	56.4
	04	346 10.0	0 57.5	56.4
	05	0 42.1	0 47.4	56.4
	06	15 14.1	N 0 37.2	56.4
	07	29 46.2	0 27.0	56.5
	08	44 18.2	0 16.8	56.5
S	09	58 50.2	N 0 06.6	56.5
U	10	73 22.1	S 0 03.6	56.6
N	11	87 54.0	0 13.8	56.6
D	12	102 25.9	S 0 24.0	56.6
A	13	116 57.8	0 34.3	56.7
Y	14	131 29.6	0 44.5	56.7
	15	146 01.4	0 54.8	56.7
	16	160 33.1	1 05.0	56.8
	17	175 04.8	1 15.3	56.8
	18	189 36.5	S 1 25.6	56.8
	19	204 08.1	1 35.9	56.9
	20	218 39.7	1 46.2	56.9
	21	233 11.2	1 56.5	56.9
	22	247 42.7	2 06.7	57.0
	23	262 14.2	2 17.0	57.0

STARS Name	S.H.A. ° ′	Dec. ° ′
Acamar	315 38.4	S40 23.8
Achernar	335 46.6	S57 21.2
Acrux	173 39.1	S62 58.4
Adhara	255 33.1	S28 56.7
Aldebaran	291 19.8	N16 27.9
Alioth	166 44.2	N56 04.5
Alkaid	153 20.2	N49 25.1
Al Na'ir	28 17.6	S47 04.2
Alnilam	276 13.2	S 1 13.1
Alphard	218 22.1	S 8 33.9
Alphecca	126 33.9	N26 47.3
Alpheratz	358 11.2	N28 58.3
Altair	62 34.6	N 8 48.7
Ankaa	353 42.1	S42 25.8
Antares	112 59.4	S26 22.9
Arcturus	146 20.3	N19 17.7
Atria	108 25.7	S68 59.1
Avior	234 28.3	S59 26.3
Bellatrix	279 00.4	N 6 19.7
Betelgeuse	271 29.9	N 7 24.1
Canopus	264 07.4	S52 41.[illegible]
Capella	281 13.5	N45 5[illegible]

TABLE 2

(Continue to page 12)

	G.M.T. d h	SUN G.H.A. ° ′	SUN Dec. ° ′	ARIES G.H.A. ° ′	VENUS G.H.A. ° ′	VENUS Dec. ° ′
	1 00	179 10.8	S23 02.8	100 17.5	184 41.5	S23 38.2
	01	194 10.5	02.6	115 20.0	199 40.5	38.1
	02	209 10.2	02.4	130 22.4	214 39.5	38.1
	03	224 09.9	·· 02.2	145 24.9	229 38.5	·· 38.1
	04	239 09.6	02.0	160 27.4	244 37.6	38.1
	05	254 09.4	01.8	175 29.8	259 36.6	38.0
	06	269 09.1	S23 01.6	190 32.3	274 35.6	S23 38.0
	07	284 08.8	01.4	205 34.8	289 34.7	38.0
	08	299 08.5	01.2	220 37.2	304 33.7	37.9
S	09	314 08.2	·· 01.0	235 39.7	319 32.7	·· 37.9
U	10	329 07.9	00.8	250 42.2	334 31.7	37.9
N	11	344 07.6	00.6	265 44.6	349 30.8	37.8
D	12	359 07.3	S23 00.4	280 47.1	4 29.8	S23 37.8
A	13	14 07.0	00.2	295 49.5	19 28.8	37.7
Y	14	29 06.7	23 00.0	310 52.0	34 27.9	37.7
	15	44 06.4	22 59.8	325 54.5	49 26.9	·· 37.7
	16	59 06.1	59.6	340 56.9	64 25.9	37.6
	17	74 05.8	59.3	355 59.4	79 24.9	37.6
	18	89 05.5	S22 59.1	11 01.9	94 24.0	S23 37.5
	19	104 05.2	58.9	26 04.3	109 23.0	37.5
	20	119 04.9	58.7	41 06.8	124 22.0	37.4
	21	134 04.6	·· 58.5	56 09.3	139 21.1	·· 37.4
	22	149 04.3	58.3	71 11.7	154 20.1	37.3
	23	164 04.0	58.1	86 14.2	169 19.1	37.3

	G.M.T. d h	MARS G.H.A. ° ′	MARS Dec. ° ′	JUPITER G.H.A. ° ′	JUPITER Dec. ° ′	SATURN G.H.A. ° ′	SATURN Dec. ° ′
	1 00	327 42.6	N21 43.3	10 26.2	N23 12.3	307 32.1	N12 44.6
	01	342 45.7	43.5	25 29.0	12.3	322 34.7	44.6
	02	357 48.8	43.8	40 31.9	12.3	337 37.2	44.7
	03	12 51.9	·· 44.1	55 34.7	·· 12.3	352 39.8	·· 44.7
	04	27 55.0	44.4	70 37.5	12.3	7 42.3	44.8
	05	42 58.2	44.6	85 40.3	12.3	22 44.9	44.8
	06	58 01.3	N21 44.9	100 43.1	N23 12.3	37 47.4	N12 44.9
	07	73 04.4	45.2	115 46.0	12.3	52 50.0	44.9
	08	88 07.5	45.4	130 48.8	12.3	67 52.5	44.9
S	09	103 10.6	·· 45.7	145 51.6	·· 12.3	82 55.1	·· 45.0
U	10	118 13.7	46.0	160 54.4	12.3	97 57.6	45.0
N	11	133 16.9	46.2	175 57.2	12.3	113 00.2	45.1
D	12	148 20.0	N21 46.5	191 00.1	N23 12.3	128 02.7	N12 45.1
A	13	163 23.1	46.8	206 02.9	12.4	143 05.3	45.1
Y	14	178 26.2	47.1	221 05.7	12.4	158 07.8	45.2
	15	193 29.4	·· 47.3	236 08.5	·· 12.4	173 10.4	·· 45.2
	16	208 32.5	47.6	251 11.3	12.4	188 12.9	45.3
	17	223 35.6	47.9	266 14.2	12.4	203 15.5	45.3
	18	238 38.7	N21 48.2	281 17.0	N23 12.4	218 18.0	N12 45.4
	19	253 41.9	48.4	296 19.8	12.4	233 20.6	45.4
	20	268 45.0	48.7	311 22.6	12.4	248 23.1	45.4
	21	283 48.1	·· 49.0	326 25.4	·· 12.4	263 25.7	·· 45.5
	22	298 51.3	49.3	341 28.3	12.4	278 28.2	45.5
	23	313 54.4	49.5	356 31.1	12.4	293 30.8	45.6

TABLE 2

In order to find the GHA and DEC of the Moon at GMT 05^h25^m-18^s, we first find the data for GMT 05^h and 06^h, and feed them to NC-77 in the following manner.

Problem 2	GHA		DEC	
Moon	Key	Display	Key	Display
GMT GHA DEC	[F] [P.P.]	h 0.	[F] [P.P.]	h 0.
05^h 0°42′.1 N0°47′.4	5	h 5.	5	h 5.
06 15 14.1 N0 37.2	◉	d 0.	◉	d 0.
	0.421	d 0.421	0.474	d 0.474
	◉	h 0.	◉	h 0.
From Nautical Almanac (Table 2)	6	h 6.	6	h 6.
	◉	d 0.	◉	d 0.
	15.141	d 15.141	0.372	d 0.372
	◉	h′ 0.	◉	h′ 0.
	5.2518	h′ 5.2518	5.2518	h′ 5.2518
	◉	d′ 6.498	◉	d′ 0.431

Answer GHA 6°49′.8 DEC N 0°43′.1

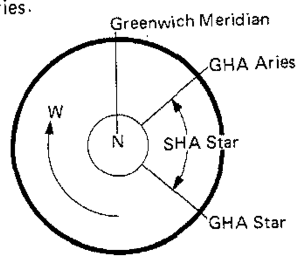
Problem 3. Find the GHA and DEC of Venus at GMT 14^h45^m-52^s on Jan. 1, 1978.

Problem 3	GHA		DEC
Venus	Key	Display	Key Display
GMT GHA DEC	[F] [P.P.]	h 0.	Interpolation is unnecessary as DEC in this case does not change during one hour.
14^h 34°27.9 S23°37.7	14	h 14.	
15 49 26.9 S23 37.7	◉	d 0.	
	34.279	d 34.279	
	◉	h 0.	
	15	h 15.	
From Nautical Almanac (Table 2)	◉	d 0.	
	49.269	d 49.269	
	◉	h′ 0.	
	14.4552	h′ 14.4552	
	◉	d′ 45.551	

Answer GHA 45°55′.1 DEC S23°37′.7

For other plants, Mars, Jupiter and Saturn, GHA and DEC are found in the same manner.

Probelm 4. Find the GHA and DEC of Arcturus at $16^h16^m39^s$ on Jan. 1, 1978.
GHA of the Star, Arcturus, is found by adding SHA of Arcturus (Sidereal Hour Angle) to the GHA Aries.



GHA Aries is a reference meridian for establishing celestial longitude of Stars. It is constantly changing, and expressed in terms of westward angle from the Greenwich meridian. SHA Star is the westward distance of the particular star from this meridian. So, the rule to compute GHA star is:

GHA Star = GHA Aries + SHA Star.

GHA Aries is computed by NC-77 [ALM] mode, and SHA's of fifty-seven navigational stars are found in Nautical Almanac.

Key	Display	
[ALM] 78.0101	y 78.0101	date
[☉] 16.1639	h 16.1639	GMT
[☉]	Ho 345.074	GHA Aries
[+] 146.203	Ho 146.203	SHA Arcturus *1
[=]	Ho 491.277	GHA Arcturus
[−] 360 [=]	Ho 131.277	*2

*1. SHA Arcturus is found in Nautical Almanac. See Table 2.

*2. When GHA becomes greater than 360° we customarily subtract 360° to express it within one round of the earth. If GHA becomes negative it is also common practice to add 360° to express it as a positive value.

DEC of Arcturus is found in Nautical Almanac. (See Table 2) as N19° 17.'7. It does not change for the whole day.

Answer: GHA 131°27.'7 DEC N19°17.'7

CHAPTER IV

Computation and Plotting for Fix

Now we are ready to compute and plot our position. As mentioned in the Principle of Astro-Navigation, it is impractical to draw a position circle with radius of hundreds or thousands miles on the chart. So, we plot only a necessary part of the position circle as a straight line, and call it a Line of Position (LOP).

LOP is obtained by comparing the computed altitude and the actually observed true altitude. The former is the altitude computed on the assumption that our DR is correct, and the latter is the altitude measured by sextant at the actual position. (True Altitude is obtained by adding corrections to the direct sextant reading. See Chapter V Sextant Altitude Corrections.)

If there is a difference between the two altitudes the assumption was wrong by the amount of the difference (Altitude Intercept). So, we will correct our DR position so that there will be no difference between the two altitudes. It is best to follow the actual steps to understand this principle.

Problem 1 The DR position of a vessel is 30°22'.8N69°35'.5W at GMT $14^h35^m43^s$ on Jan. 1, 1978. The lower limb of the Sun is sighted by the sextant at this monent, and the true altitude (Ho) after sextant altitude corrections is 28°32.'6.

Required: (1) Compute the Altitude and Azimuth of the Sun.
(2) Compute Altitude Intercept.
(3) Plot the Line of Position.
(4) Obtain "FIX" by two Lines of Position.

1. COMPUTATION OF ALTITUDE (H) AND AZIMUTH (Z) BY NC-77

A convenient NC-77 LOP COMPUTATION CARD has been prepared to assure the proper order of input data. See the enclosed card and Table 3.

Enter the date, GMT, name of body, DR Lat. and DR Long. in the blanks so designated. The GHA and DEC at GMT $14^h35^m43^s$ on Jan. 1, 1978 have been obtained in Chapter III Problem (1) as 38°02'.5 and S22°59'.9. Fill in the appropriate blanks with these data. Then, follow the steps shown on page 16.

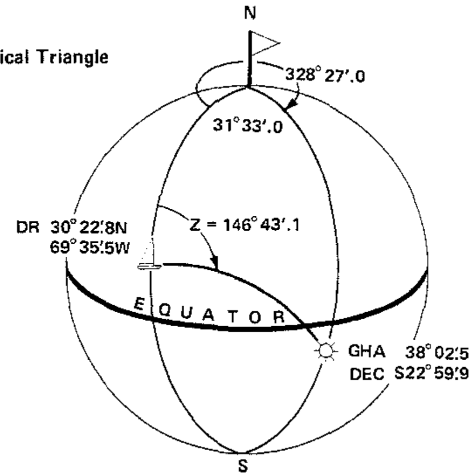
Key	Display	Answer
[LOP]	LH 0.	Computed Altitude 28°37.'8
38.025	LH 38.025	Azimuth 146°43.'1 T
[+] 69.355 [E/W]	LH -69.355 *1	(measured clockwise
[=]	LH -31.330 *2	from north)
[◉]	d 0.	
22.599 [E/W]	d -22.599	
[◉]	L 0.	
30.228 [E/W]	L 30.228	
[◉]	A 28.378	
[◉]	Z 146.431	(A and Z can be repeated by [◉] key)

***1 GHA and LHA:**

When continuing directly to [LOP] mode from [ALM] mode do not confuse H and LH. H stands for Greenwich Hour Angle (GHA) and LH for Local Hour Angle (LHA). LHA = GHA ± DR Longitude. Since [E/W] key changes the sign to negative this rule is automatically observed if we always add longitude.
This computation may be made in either [ALM] or [LOP] mode, but the dialogue symbol does not change from H to LH until [LOP] mode key is pressed.

*2 Some navigators are accustomed to expressing LHA always as a positive value by applying 360°: LHA = 360° − 31°33.'0 = 328° 27'.0. In such a case we may enter LHA 328° 27'.0 instead of -31°33'.0. The end result is the same.

Fig. 9
Spherical Triangle



Mathematics for Altitude and Azimuth Computation

The spherical triangle as formed on Fig. 9 is solved by the following equations to obtain computed Altitude (A) and Azimuth (z: NC-77 symbol Z)

$$A = \sin^{-1} [\cos h \cdot \cos d \cdot \cos L + \sin d \cdot \sin L]$$

$$Z = \cos^{-1}\left[\frac{\sin d - \sin A \cdot \sin L}{\cos A \cdot \cos L}\right]$$

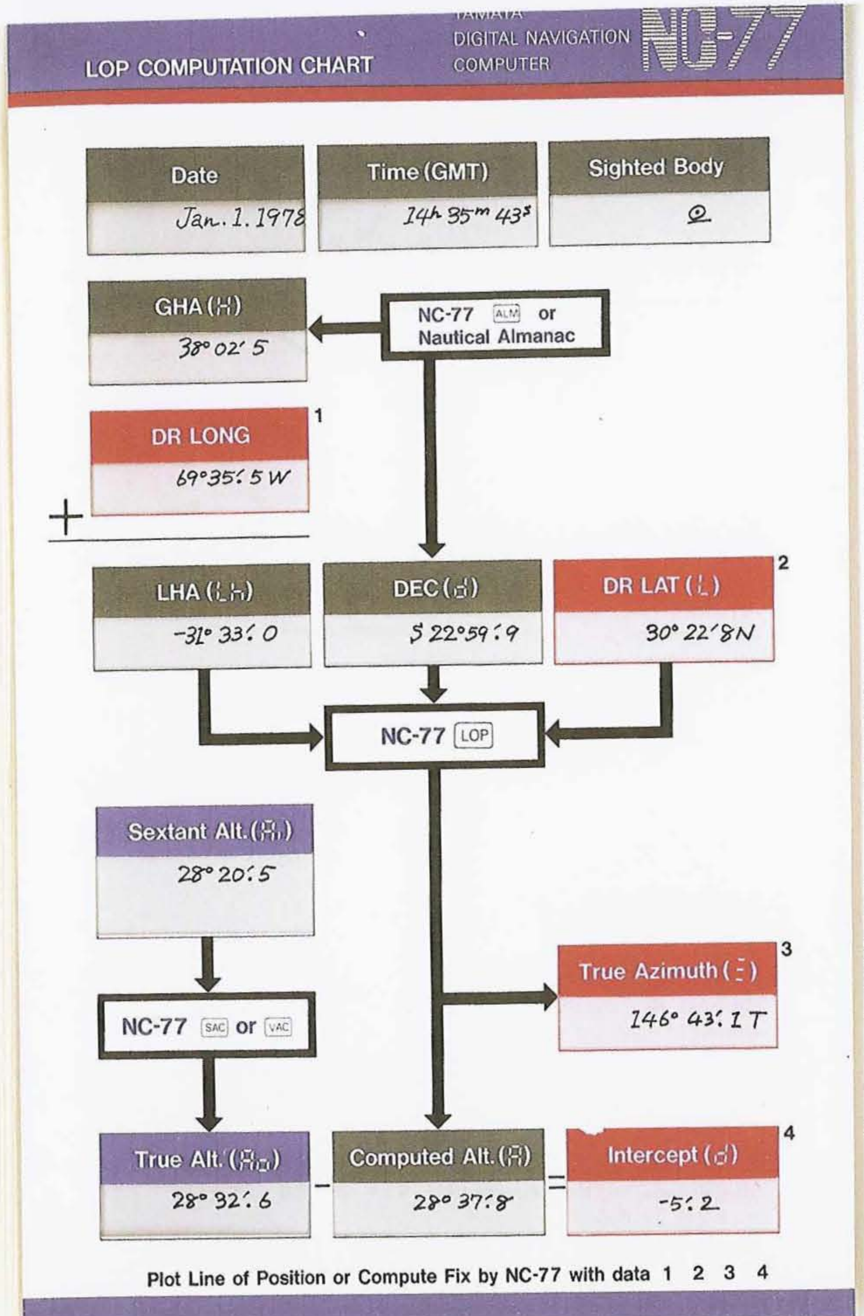
Where d: declination A: Computed Altitude
L: DR Lat. Z: Computed Azimuth
h: LHA (obtained by GHA ± DR Long.)

Since these equations are programmed in the NC-77 [LOP] mode A and Z are computed simply by feeding d, L and h.

2. COMPUTATION OF ALTITUDE INTERCEPT

The intercept is simply the difference between the observed true altitude (Ao) and the computed altitude (A). The observed true altitude is obtained by adding corrections to the direct sextant reading. These altitude corrections, consisting of multiple factors, are easily computed by NC-77, and are explained separately in CHAPTER V Sextant Altitude Corrections (See problem 1 on page27).

For purposes of this problem, just take 28°32.'6 as the observed true altitude, and the Intercept (Ao − A) = (28°32.'6 - 28°37.'8) = -5.'2 (5.2 miles).



SUMMARY OF NC-77 KEY SEQUENCE FOR LOP COMPUTATION

For Chapter IV Problem (1)

Preparation of the data: LHA DEC DR LAT (See page 10)

Data	Data Source	Key	Display
Jan. 1, 1978	Chapter III Problem (1)	[ALM] 78.0101	y 78.0101
GMT $14^h35^m43^s$	Chapter III Problem (1)	[◎] 14.3543	h 14.3543
GHA ARIES 319°49'.2	Computed by NC-77	[◎]	Ho 319.492
DEC ⊙ S22°59'.9	Computed by NC-77	[◎] [MI]	d −22.599
GHA ⊙ 38°02'.5	Computed by NC-77	[◎]	H 38.025
DR LONG 69°35.5W	Chapter IV Problem (1)	[+] 69.355 [°/W]	H −69.355 *1
LHA −31°33'.0	Computed by NC-77	[=]	H −31.330 *2

For *1 and *2 see page 16

Computation of Altitude and Azimuth (See page 15)

Data	Data Source	Key	Display
LHA	Continued from above	[LOP]	LH −31.330
DEC	Recall Memory 1	[◎] [F] [RM1]	d −22.599
DR LAT	Chapter IV Problem (1)	[◎] 30.228 [°/N]	L 30.228
ComputedAltitude	Computed by NC-77	[◎]	A 28.378
True Azimuth	Computed by NC-77	[◎]	Z 146.431

Sextant Altitude Corrections for True Altitude (See page 27)

Data	Data Source	Key	Display
Sextant reading 28°20'.5	Directly from sextant	[ARC] 28°20'.5	d 28.205
Index error 0'.5 too low	Check sextant	[+] .005 [=]	d 28.210
Index error corrected alt.		[SAC]	Ai 28.210
Height of eye 3m	from water level	[◎] 3	ht 3.
Dip corrected alt.	Computed by NC-77	[◎]	Ar 28.179
Refraction corrected alt.	Computed by NC-77	[◎]	An 28.161
Sun sight		[ ]	Sd 0.
Sun's Semidiameter 16'.3	Table 1 of this booklet	.163	Sd 0.163
Lower limb	lower limb was sighted	[⊙]	Sd 0.163
		[◎]	Ao 28.326

Altitude Intercept (See page 20)

Data	Data Source	Key	Display
Ao 28.326	Computed by NC-77	[ARC] 28.326	d 28.326
A 28.378	Computed by NC-77	[−] 28.378	d 28.378
		[=]	d −0.052

Note: We may use memory keys for the data used repeatedly. It is recommendable, however, to write down the data in LOP Computation Chart whenever they become available. Errors, if there was any, can be easily traced by this way.

3. PLOTTING A LINE OF POSITION

Now, we can plot the Line of Position on the chart or plotting sheet with our DR Lat. 30° 22'.8N, 69° 35'.5W and Intercept- 5'.2, Azimuth 146° 43'.1. We take the intercept 5'.2 from the latitude scale of the chart by marine dividers and tranfer it onto the azimuth line. 5'.2 of latitude is 5.2 nautical miles on the earth's surface. The line crossing the azimuth line at right angle at this point is called Line of Position (LOP). (Fig. 10)

Looking at the illustration in Fig. 11, we can figure out that when Ho (the true altitude) is greater than H (the computed altitude with the assumption that our DR position is correct), we should shift our position from the DR position towards the Sun along the Azimuth line. The opposite should be done if Ho is less than H.

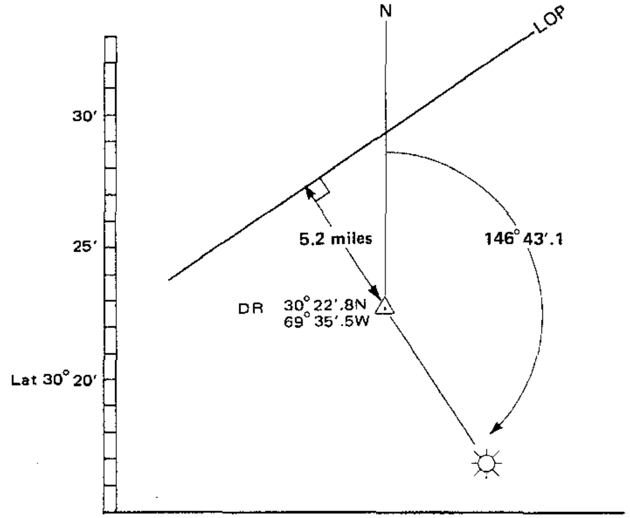


Fig. 10 Plotting a Line of Position

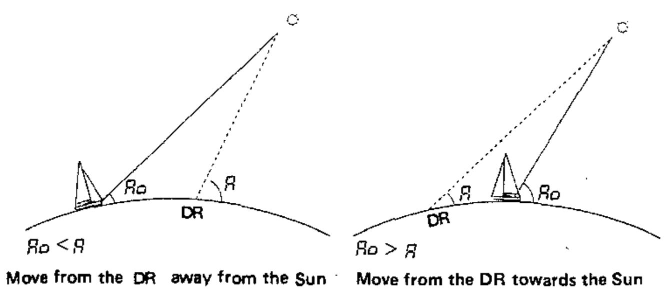


Fig. 11 Direction of Intercept

4. FIX BY TWO LOP'S

In the theory of Astro-Navigation as explained at the outset, a ship's position can be determined only after at least two LOP's are obtained. The intersection of the two LOP's called "fix" is the ship's position (Fig. 6 on page 6).

RUNNING FIX

If the " fix " must be made only by Sun sights, we should obtain two LOP's by allowing a time interval between the two sights as the Sun changes its azimuth in a day moving from east to west at a considerable speed.

In this case, the first LOP is advanced along the ship's course by the amount of the distance run between the two sights. The crossing point of the advanced LOP and the second LOP is the ship's position at the time of the second sight (Fig. 12) This is called Running Fix.

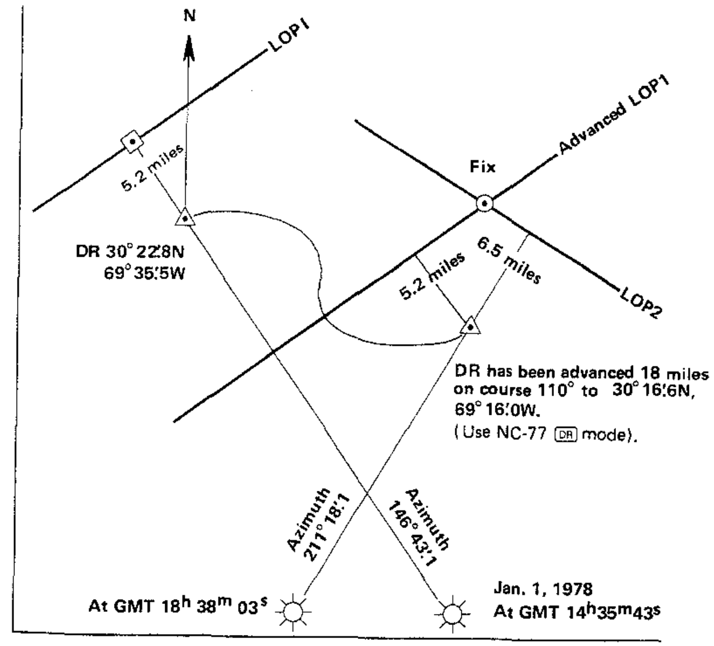


Fig. 12 Running Fix

In order to advance LOP1, first, compute the new DR position applying the course and distance. For this computation see Dead Reckoning by Mercator Sailing by NC-77 on page 38. At this position plot the advanced **LOP1** repeating the same procedure. Suppose we took the second Sun sight at this new DR position and computed the azimuth 211° 18.'1 and intercept 6.5 miles away. This result is also plotted on the chart as LOP2. The intersection of the advanced LOP1 and LOP2 is our ship's position.

DIGITAL FIX BY NC-77

While we are able to read the plotted fix position from the chart, or plotting sheet, it may be digitally computed more precisely by NC-77 as follows.

Input: Data from fig. 12	Key	Display	Answer
DR Lat. 30° 16'.6N	[F] [FIX]	L 0.	Lat. 30° 23.'5N
DR Long. 69° 16.'0W	30.166 [N/S]	L 30.166	Long. 69° 14.'7W
Alt. Intercept (1)	[◉]	H 0.	(Fix at GMT $18^h38^m03^s$)
5.2 miles away	69.160 [S/W]	H −69.160	
Azimuth (1) 146° 43.'1	[◉]	d 0.	
Alt. Intercept (2)	5.2 [±]	d −5.2	
6.5 miles away	[◉]	Ξ 0.	
Azimuth (2) 211° 18.'1	146.431	Ξ 146.431	
	[◉]	d 0.	
	6.5 [±]	d −6.5	
	[◉]	Ξ 0.	
	211.181	Ξ 211.181	
	[◉]	L 30.235	
	[◉]	H −69.147	
	[◉] Repeat L and H		

Note: In [FIX] mode, if 90° or 270° is entered as the first azimuth the answer will become "E" as tan 90° or tan 270° included in the program produces "E". However, a 90° or 270° can be accepted as the second azimuth.

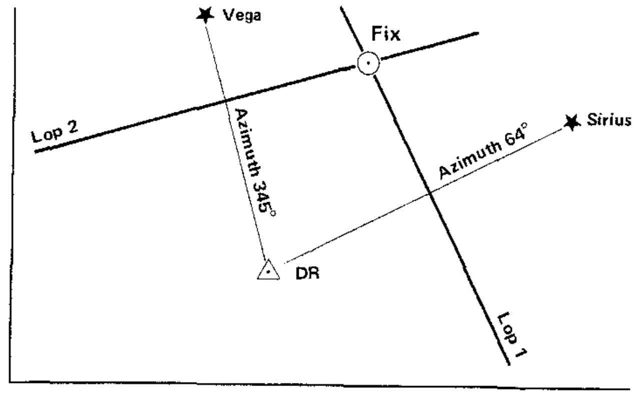


Fig. 13 Fix by Two Stars

FIX BY TWO CELESTIAL BODIES

We may take sights of two different celestial bodies like the Sun and Moon, the Moon and a star, two different stars etc.
If we take sights of two bodies in a very short time interval we can consider it as a simultaneous observation, and a Line of Position can be plotted from one DR position as illustrated in Fig. 13.
The position "fix" has the best reliability when the two LOP's are at right angle to each other. (This is also true with running fix.)
For star sights, suitable stars to make an ideal fix can be selected from the list of fifty-seven navigational stars, Polaris and four planets in the Nautical Almanac. Before taking a sight the azimuth and altitude of the desired star may be precomputed using the approximate time of the sight to be taken. In this way the star can be found very easily.

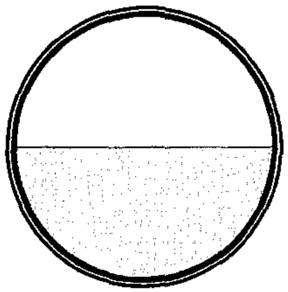
CHAPTER V

Sextant Altitude Corrections

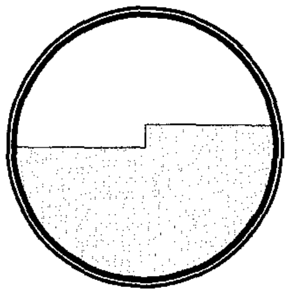
After taking a sight of a celestial body we must make necessary corrections to the direct sextant reading to obtain the true altitude. The corrections to be made are (1) Index correction (2) Dip correction (3) Refraction correction (4) Semidiameter correction, and (5) Parallax correction.

(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. 14).



Horizon in alignment



Horizon out of alignment
Index error present

Fig. 14 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 neccessary (Fig. 15).

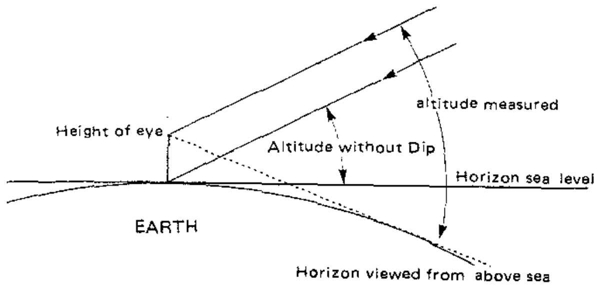


Fig. 15 Dip

(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. 16).

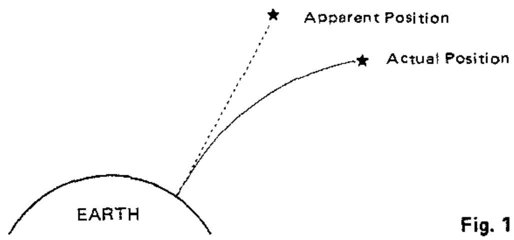


Fig. 11.

Fig. 16 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. 17).

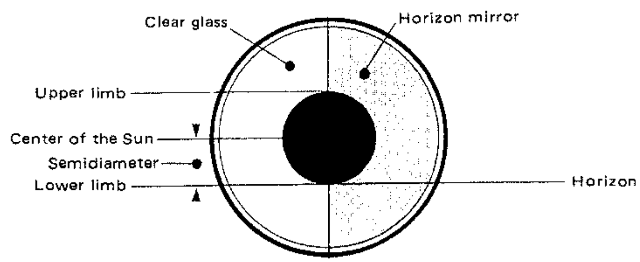


Fig. 17 Semidiameter

(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. 18).

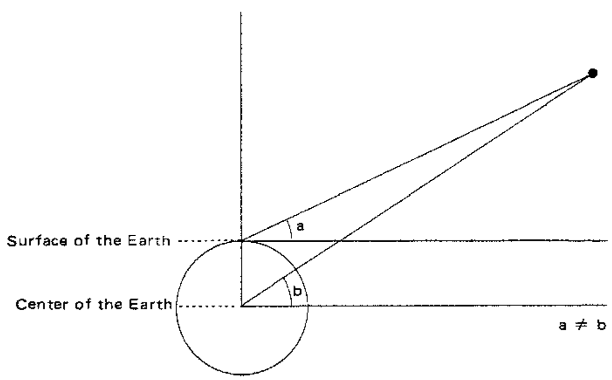


Fig. 18 Parallax

This correction is applied to the Sun, Moon, Venus and Jupiter. In NC-77 the Sun's Parallax correction is made in combination with its semidiameter correction. On the other hand, the Moon's semidiameter correction is made together with its parallax correction.

It is easy to make the first Index correction mentally, but the other corrections are based on rather complex equations, and it is best to solve them by NC-77 programs.

SEXTANT ALTITUDE CORRECTIONS BY NC-77

NC-77 has [SAC] (Standard Altitude Corrections) and [VAC] (Variable Altitude Corrections) modes for sextant altitude corrections. [SAC] is used to make altitude corrections under the standard temperature and atmospheric pressure (10°C, 1013.25mb, or 50°F, 29.92 in.).

[VAC] is used when the corrections under varying temperature and pressure are desired. These factors affect the refraction correction.

STANDARD ALTITUDE CORRECTIONS

Problem 1. The sextant reading of the lower limb of the Sun is 28°20'.5 on Jan.1, 1978. The sextant reads 0'.5 too low because of the index error. The height of eye above sea level is 3 meters. Find the true altitude of the Sun.

First, make the index correction.

Sextant Reading	28°20'.5
Index Correction	+ 0.5
	28°21.0

Then, select NC-77 [SAC] mode, and make computation as follows.

Problem 1	Key	Display	Answer
SUN(lower limb of the Sun)	[SAC]	A, 0	
Sextant Altitude (Index error corrected) 28° 21'.0	28.210	A, 28.210	
	[◎]	ht 0.	
Height of eye	3	ht 3.	Height of eye
3.0 meters(9.84 ft)	[◎]	Ar 28.179	Dip corrected alt.
Semidiameter	[◎]	An 28.161	Refract. corrected alt.
16'.3 (Jan. 1, 1978)	[☉]	Sd 0.	
	0.163 [⊙☾ lower]	Sd 0.163	Semidiameter of the Sun (lower limb)
	[◎]	Ao 28.326	True alt. 28° 32'.6

The true altitude is 28° 32'.6. Before entering the data make sure whether computation is made in meter or feet, checking the side selector switch.

Choose upper or lower limb by [⊙☾ upper] or [⊙☾ lower] key depending on which side was sighted. The Sun's S.D. (Semidiameter) is given in the Nautical Almanac. The summarized data is given in TABLE 1. It varies from 15'.8 to 16'.3 in any year (15'.8 – 16'.0 April – September and 16'.1 – 16'.3 October – March). So, we could safely use the average 15'.9 for the first, and 16'.2 for the second six months and be within 0'.1 of the true altitude. If S.D. or H.P. is entered with a wrong decimal point position, for instance, 16.3 instead of 0.163 in the above case, the program blocks it and asks the re-entry of the correct information without having to go back to the very beginning.

Problem 2. The Moon's upper limb is sighted.
Compute the true altitude with the following data.

Problem 2	Key	Display	Answer
MOON ☾ (upper limb)	[SAC]	A, 0.	
Sextant Altitude (Index error corrected) 18° 46'.5	18.465	A, 18.465	
	[◎]	ht 0.	
	6.5	ht 6.5	
Height of Eye 6.5 meter (21.3 ft)	[◎]	Ar 18.420	
	[◎]	An 18.391	
H.P. 58'.9 (Jan. 25, 1978)	[☾]	hP 0.	
	0.589	hP 0.589	H.P.Moon
	[⊙☾ upper]	hP -0.589	
	[◎]	Ao 19.189	True altitude 19° 18'.9

The Moon's H.P. (Horizontal Parallax) at every hour of the day is found in the Nautical Almanac.

Problem 3. Venus is sighted. Compute the true altitude with the following data.

Problem 3	Key	Display	Answer
VENUS			
Sextant Altitude (Index error corrected) 34° 20'.5	[SAC]	A, 0.	
	34.205	A, 34.205	
Height of Eye 6.5 meters (21.3 ft)	[◎]	ht 0.	
	6.5	ht 6.5	
H.P. 0'.3 (Sep. 15, 1978)	[◎]	Ar 34.160	
	[◎]	An 34.146	
	[F] [♀♂]	hP 0.	
	0.003	hP 0.003	
	[◎]	Ao 34.148	True altitude 34° 14'.8

H.P. (Horizontal Parallax) applies only to Venus ♀ and Mars ♂ (See TABLE 1 of this booklet for H.P. data). There is no H.P. for the other navigational planets, Jupiter and Saturn. Altitude corrections for these two planets are, therefore, made as for the stars, which have no H.P.

Problem 4. Arcturus is sighted. Compute the true altitude with the following data.

Problem 4	Key	Display	Answer
ARCTURUS			
Sextant Altitude (Index error	[SAC]	Ai 0	
corrected) 58° 27'.9	58.279	Ai 58.279	
Height of Eye 6.5 meters	[⊙]	hE 0.	
(21.3 ft.)	6.5	hE 6.5	
	[⊙]	Ar 58.234	
	[⊙]	An 58.228	True altitude 58° 22'.8

Since there is no H.P. for the stars, the refraction corrected altitude An is the true altitude.

[SAC] SUMMARY

Sun		Moon		Venus, Mars		Jupiter, Saturn, Stars	
Key	Display	Key	Display	Key	Display	Key	Display
[SAC]	Ai						
Sextant Alt. (Index error corrected)	Ai						
[⊙]	hE						
Height of Eye	hE	••••••••••SAME AS SUN	••••••••	••••••••	••••••••	••••••••	••••••••
[⊙]	Ar						
[⊙]	An						
[ ]	Sd	[ ]	hP	[F] [ ]	hP		
S.D. (TABLE 1) [ ] or [ ]	Sd	H.P. (Almanac) [ ] or [ ]	hP	H.P. (TABLE 1)	hP		
[⊙]	Ao	[⊙]	Ao	[⊙]	Ao		

- Ai Sextant Altitude
- Ar Dip Corrected
- An Refraction Corrected
- Ao True Altitude
- hE Height of eye
- Sd Sun's Semidiameter
- hP Horizontal Parallax of Moon, Venus or Mars

VARIABLE SEXTANT ALTITUDE CORRECTIONS

When a low altitude body is sighted refraction becomes a relatively significant factor in computing the true altitude. In such a case, say, less than 10° of altitude, temperature and pressure factors should be introduced for more precise computations.

[VAC] mode computes the True Altitude by Var: ble Sextant Altitude Corrections when the use of varying temperature and atmospheric pressure is desired.

Problem 5. The upper limb of the Sun is sighted. Compute the true altitude using the measured temperature and pressure.

Problem 5	Key	Display	Answer
SUN (Upper limb)			
Sextant Altitude (Index	[F] [VAC]	Ai 0.	
error corrected) 5° 20'.2	5.202	Ai 5.202	
Height of Eye 6.5 meters	[⊙]	hE 0.	
(21.3 ft.)	6.5	hE 6.5	
Temperature −3° C (26.6° F)	[⊙]	Ar 5.157	Dip corrected alt. 5° 15'7
Pressure 986mb (29.12 in.)	[⊙]	t 0.	
S.D. 16'.2	3 [−]	t −3.	
	[⊙]	P 0.	
	986	P 986.	
	[⊙]	An 5.059	Refraction corrected alt. 5° 05'.9
	[−]	Sd 0.	
	0.162 [ ]	Sd −0.162	
	[⊙]	Ao 4.499	True alt. 4° 49'.9

The key sequence for [VAC] until Refraction Correction is uniform for all Sun, Moon, planets and stars.
In the case of Jupiter, Saturn and Stars An equals the True Altitude since there is no Horizontal Parallax or Semidiameter to be taken into consideration.

Accuracy:
In [SAC] [VAC] mode programs, correction for dip = −1'.776 $\sqrt{\text{height of eye in meters}}$ = −0'.98 $\sqrt{\text{height of eye in feet}}$ is used based on F.W. Bessel's terrestrial refraction theory.
For astronomical refraction R. Radau's mean refraction table is simulated by the program. There is no significant difference in accuracy between the various refraction theories.

CHAPTER VI

Identification of Unknown Star

If we know the altitude and bearing of a star, and want to find out what star it is, NC-77 is used in the following manner.

Problem 1. At GMT19h32m16s on Jan. 1, 1978 an unknown star is observed at altitude 62°36'.3 and approximate azimuth 72°T. The ship's DR position is 12°40'N 152°22'E.

Required: Identity of the star

Key	Display		
[LOP]	LH	0.	
72	LH	72.	
[•]	d	0.	
62.363	d	62.363	
[•]	L	0.	
12.40 [N/E]	L	12.40	
[•]	A	19.286	Approximate declination
[•]	=	332.206	Approximate local hour angle

Then compute the following in ARC mode.

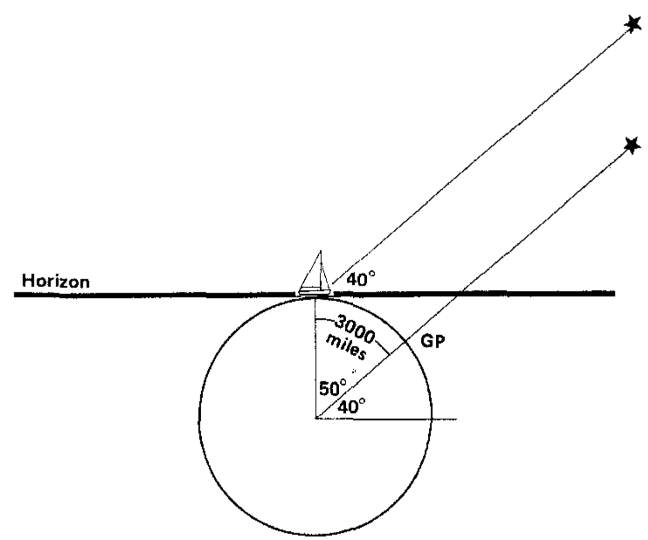
Local hour angle of star (LHA)	332°20'.6	
Subtract DR longitude of ship	-152 22 0E	*1
Greenwich hour angle of star (GHA)	179 58 6	
Subtract GHA Aries for 19h32m16s (GHA) Jan. 1, 1978	-34°09'.6	*2
Sidereal hour angle of star (SHA)	145 49 0	*3

Entering Star table on Pages 268–273 of the Nautical Almanac with SHA 145°49'.0 and DEC 19°28'.6N, the star with the closest values is found to be α Bootis (SHA 146°20'.2 DEC N19°17'.7), another name of which is Arcturus, star No. 37. In the event that a reasonably close match of the computed SHA and DEC values cannot be found in the Star table, it is possible that the body observed was actually a planet, and the SHA values of the four navigational planets at the bottom of the STARS table of the daily pages also should be checked.

*1 Add if longitude is west.
*2 See Chapter III for how to find GHA ARIES by NC-77 [ALM] mode.
*3 If the answer becomes negative, add 360° to get SHA. If the answer is greater than 360°, subtract 360°

Note on Fig. 3 on page 5.

The more theoretical presentation, at the expense of difficulty in comprehension of the relations among the star, ship and GP, is illustrated as supplement to Fig. 3.



CHAPTER VII

Fix by Noon Sight and Other Sextant Applications

1. 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.

Longitude:

The Sun travels from east to west at an equatorial speed of 15 miles per minute. It crosses the Greenwich meridian at 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 as 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. It is computed by NC-77 [ALM] mode or found in the Nautical Almanac.

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.)

Problem 1. The Sun's meridian passage (the highest altitude) was observed as 34° 19′.7 at GMT $21^h42^m38^s$. Declination of the Sun is S22°58′.4 and we are in north latitude. Equation of time is 3^m42^s.

Step by step Computation

Longitude:	$21^h42^m38^s$	GMT of Meridian Passage
	-12 00 00	Greenwich Noon
	9 42 38	Difference in time
	- 3 42	Equation of time for Jan. 1, 1978 at GMT 21h42m38s computed by NC-77 [ALM] mode *1
	9 38 56	Total difference in time
	↓ 144°44′.0	Time to Arc conversion (use NC-77) Longitude of our ship : 144° 44′.0W

Latitude: In this case Lat. = (90°–Alt.) – dec.

90°	
-34°19′.7	Noon Altitude
55°40.3	
- 22.58.4	Declination of the Sun
32.41.9N	Latitude of our ship

Noon Latitude and Longitude Computation by NC-77

If it is difficult to remember the rules, the same computation can be automatically made by NC-77 [MPS] (Meridian Passage) mode as follows.

Problem 1	Key	Display
	[F] [MPS]	h 0.
GMT of Meridian Passage	21.4238	h 21.4238
21h42m38s	[◎]	Ro 0.
Noon Altitude, Bearing South	34.197 [S/W] *2	Ro -34.197
34° 19′.7	[◎]	d 0.
Declination of the Sun	22.584 [S/W]	d -22.584
S22° 58′.4	[◎]	to 0.
Equation of Time for Jan. 1, 1978	0.0342 [−]	to -0.0342
GMT21h42m38s -3m42s *1	[◎]	L 32.419
	[◎]	// -144.440
	Repeat L and //	

Answer: Lat. 32° 41′.9N
Long. 144° 44′.0W

*1 Equation of Time is (True Sun – Mean Sun). Eqn. of T. computed by NC-77 is accompanied by (–) minus sign when Mean Sun is faster than True Sun. In this case make input with the (–) minus sign here.

*2 Here, indicate if the Sun was due North or South at noon.

Noon Longitude by NC-77

Longitude alone can be obtained quickly by NC-77 in the course of computing Equation of Time by [ALM] mode. In the above example before the Equation of Time (-3m42s), NC-77 [ALM] mode computes the GHA of Sun at Jan. 1, 1978, GMT21h-42m38s as 144°44'.1W (H−144.441), which is the longitude of the ship. If GHA of Sun exceeds 180°, the ship is in east longitude. For instance, if GHA of Sun is 200°, the ship's position is 160°E (360° - 200° = 160°). One tenths of a mininute (0'.1) difference between the longitude computed by NC-77 [MPS] mode and [ALM] mode (144°44'.0W vs. 144°44'.1W) in the example is accounted for by rounding to one decimal place in [MPS] computation.

Note:

Time of meridian passage can best be determined by plotting on cross-section paper a series of observed altitudes versus times (GMT) of observation, commencing several minutes before estimated local apparent noon (based on the DR longitude) and continuing until several minutes after meridian passage. From a curve faired through the plotted points, the time of maximum altitude can be established. DEC Sun and Eqn. of Time are derived by NC-77 [ALM] mode or taken from the Nautical Almanac.

2. APPLICATION OF MARINE SEXTANT IN MEASURING DISTANCE

The marine sextant may be used to measure the vertical angle subtended by the height of an object. Distance to the object is then computed by the equation shown in Fig. 19 on page 37 which is programmed in the NC-77 [DTO] mode.

Problem 2. The altitude of a mountain top was measured by sextant. Compute the distance to it with the following data.

Problem 2	Key	Display	Answer
Sextant Altitude 0°35'.2	[F] [DTO]	Al 0.	
(corrected for index error)	0.352	Al 0.352	
Height of Eye 15 meters	[◎]	ht 0.	
(49.2ft.)	15	ht 15.	
Height of the mountain 1000	[◎]	ht 0.	
meters (3281ft.)	1000	ht 1000.	
	[◎]	d 40.3	40.3 n.m.

Select meters or feet by the selector switch before entering the data. The answer is always given in nautical miles. Note that α (dip corrected angle) is automatically computed, if we enter sextant altitude and height of eye. Needless to say, any index error, (the error of sextant itself) must be corrected before entering Al .

Equation:

$$D = \sqrt{\left(\frac{\tan\alpha}{0.000246}\right)^2 + \frac{H-h}{0.74736}} - \frac{\tan\alpha}{0.000246}$$

where

D = distance to object in nautical miles
H = height of object beyond horizon in feet
h = height of the observer's eye in feet above see level
α = dip corrected sextant vertical angle
(Dip is $-0'.98\sqrt{\text{h in feet}}$)

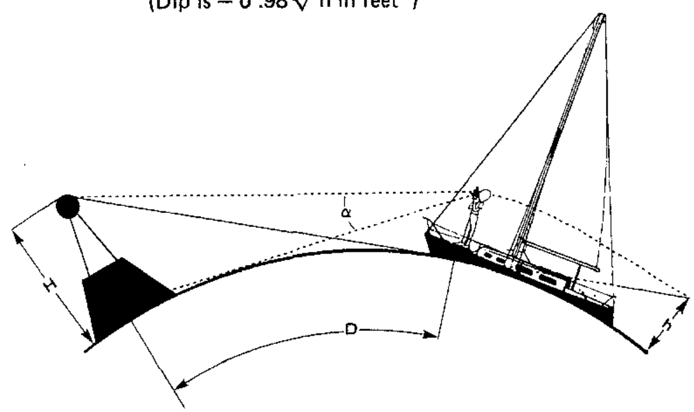


Fig. 19 Distance to Object

PART TWO: BASIC NAVIGATION COMPUTATIONS
FOR DEAD RECKONING AND PILOTING BY NC-77

CHAPTER I

Mercator Sailing and Great Circle Sailing

1. Dead Reckoning by Mercator Sailing

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

Problem 1	Key	Display	Answer
Departure Point Lat.	[DR]	L 0.	D.R. Lat. 30°34'.2N
32°30'.6N	32.306 [N/E]	L 32.306	D.R. Long. 123°34'.6W
Departure Point Long.	[◎]	// 0.	
118°36'.2W	118.362 [S/W]	//-118.362	
Course 245°30'	[◎]	c 0.	
Distance 280.8 miles	245.3	c 245.3	
	[◎]	d 0.	
	280.8	d 280.8	
	[◎]	L 30.342	
	[◎]	//-123.346	
	[◎]	Repeat L and //	

2. 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 2	Key	Display	Answer
Departure Point Lat.	[F] [CD]	L 0.	Course made good
35°22'.4N	35.224 [N/E]	L 35.224	203°40'.5
Departure Point Long.	[◎]	// 0.	Distance 3480.5n.m.
125°08'.2W	125.082 [S/W]	//-125.082	
Arrival Point Lat.	[◎]	L 0.	
17°45'.2S	17.452 [S/W]	L -17.452	
Arrival Point Long.	[◎]	// 0.	
149°30'.0W	149.30 [S/W]	//-149.30	
	[◎]	c 203.405	
	[◎]	d 3480.5	
	[◎]	Repeat c and d	

Note on Accuracy:
The principle of [DR] and [CD] computation is Mercator Sailing. The oblate spheroid characteristics of earth (flattened at the poles and bulged at the equator) is 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 sphere.

3. Great Circle Sailing

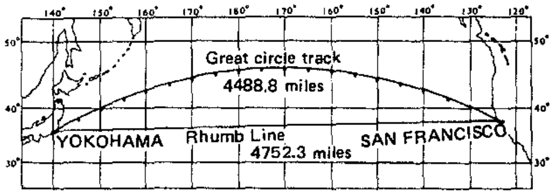
[GC] Great Circle Sailing mode computes the great circle distance between two points and also the initial course from the departure point. The program continues to compute the latitude and longitude of the vertex, and the latitude at any selected longitude on the great circle track.

Problem 3	Key	Display	Answer
Departure Point Lat.	[GC]	L 0.	Great circle distance
37°50'.8N	37.508 [N/E]	L 37.508	4488.8 n.m.
Departure point Long.	[◎]	// 0.	Initial great circle course
122°25'.5W	122.255 [S/W]	// -122.255	302°37'.9
(San Francisco)	[◎]	L 0.	Vertex Lat. 48°19'.0N
Arrival point Lat.	34.520 [N/E]	L 34.520	Vertex Long. 168°38'.8W
34°52'.0N	[◎]	// 0.	Latitude at
Arrival Point Long.	139.420 [N/E]	// 139.420	145°W 45°48'.7N
139°42'.0E	[◎]	d 4488.8	150°W 46°46'.7N
(Yokohama)	[◎]	c 302.379	
	[◎]	Lu 48.190	
	[◎]	//u-168.388	
	[◎]	//' 0.	
	145 [S/W]	//' -145	
	[◎]	L' 45.487	
	[◎]	//' 0.	
	150 [S/W]	//' -150	
	[◎]	L' 46.467	
	[◎]	//' 0.	
		Continue	

Note:
In computing the great circle distance the earth is considered as a sphere. The vertex is computed between the departure 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.

Mercator Sailing and Great Circle Sailing:

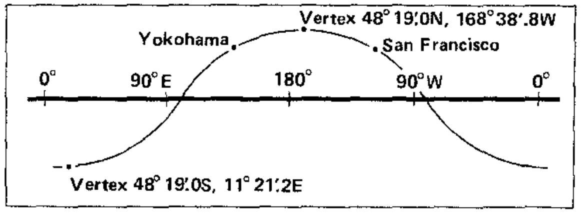
The course obtained by Mercator Sailing is a rhumb line, appearing as a straight line on the Mercator chart. It makes the same angle with all meridians it crosses, and maintains constant true direction. The Great Circle track is the shortest distance between any two points on the earth. On the Mercator 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

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 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 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-77 as in problem 3.

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. If such a course is desired, it can be computed by NC-77 with the equations and key sequence shown inthe example below.

Problem: Between San Francisco, 37°50'.8N, 122°25'.5W and Yokohama 34°52'.0N, 139°42'.0E, find the composite track with the maximum limiting latitude of 45°N.

Equations:

$$DLov1 = \cos^{-1}\left(\frac{\tan L_1}{\tan L_{max}}\right) \qquad DLov2 = \cos^{-1}\left(\frac{\tan L_2}{\tan L_{max}}\right)$$

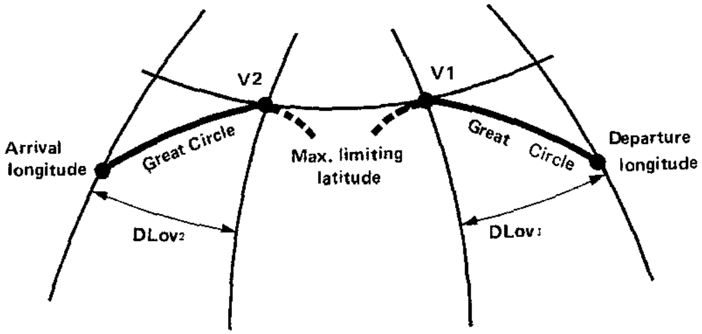
Key sequence:

DLov1; [N] 37.508 [tan] [÷] 45 [tan] [=] [F] [cos⁻¹] → 39.009

DLov2; [N] 34.520 [tan] [÷] 45 [tan] [=] [F] [cos⁻¹] → 45.500

Answer: V1: The longitude at which the limiting parallel is reached is 39°00'.9 west of the departure point, which is 161°26'.4W.

V2: The longitude at which the limiting parallel should be left is 45°50'.0 east of the arrival point, which is 174°28'.0W.



Composite Sailing

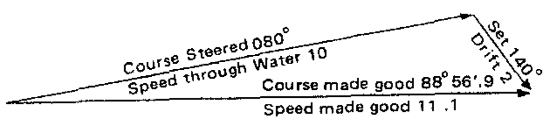
CHAPTER II

Plane Sailing and Navigation through Current and Wind

1. Finding the Course and Speed Made Good through a current

[CU1] Current 1 mode computes the course made good and speed made good when the course steered and speed through water are given, and set and drift are known.

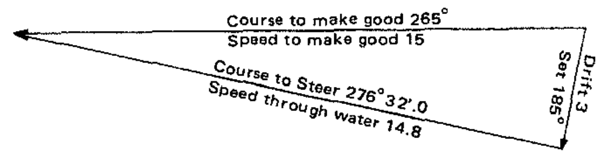
Problem 1	Key	Display	Answer
Course steered 080°	[CU1]	c 0.	Course Made Good
Speed through Water	80	c 80.	88°56'.9
10 knots	⊙	d 0.	Speed Made Good
Set (toward) 140°	10	d 10.	11.1 knots
Drift 2 knots	⊙	c 0.	
	140	c 140.	
	⊙	d 0.	
	2	d 2.	
	⊙	c 88.569	
	⊙	d 11.1	
	⊙	Repeat c and d	



2. Finding the Course to steer and Speed to use (through water) to make good a given course and speed through a current.

[CU2] Current 2 mode computes the course to steer and speed through water when the course to make good and speed to make good are given, and set and drift are known. [CU1] and [CU2] programs are common, but the drift is entered with the reversed sign in the latter.

Problem 2	Key	Display	Answer
Course to Make Good 265°		c 0.	Course to Steer
Speed to Make Good	265	c 265.	276°32'.0
15 knots	⊙	d 0.	Speed through Water
Set (toward) 185°	15	d 15.	14.8 knots
Drift *1 3 knots	⊙	c 0.	
	185	c 185.	
	⊙	d 0.	
	3 [+/-]	d -3.	
	⊙	c 276.320	
	⊙	d 14.8	
	⊙	Repeat c and d	

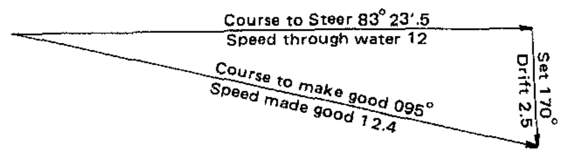


*1 Always reverse the sign of "drift" input in solving the [CU2] problem.

3. Finding the Course to steer at a given speed to make good a given course through a current

[CU3] Current 3 mode computes the course to steer and speed made good when the course to make good and speed through water are given, and set and drift are known.

Problem 3	Key	Display	Answer
Course to Make Good 095°	[F] [CU3]	c 0.	Course to Steer 83°23'.5
Speed through Water 12 knots	95	c 95.	Speed Made Good
Set (toward) 170°	⊙	d 0.	12.4 knots
Drift 2.5 knots	12	d 12.	
	⊙	c 0.	
	170	c 170.	
	⊙	d 0.	
	2.5	d 2.5	
	⊙	c 83.235	
	⊙	d 12.4	
	⊙	Repeat c and d	

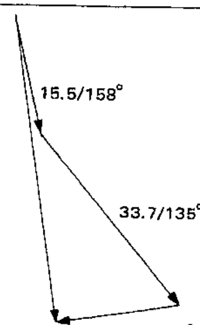


Note: The desired course (course to make good) cannot be made when ship's speed is not sufficient to overcome the drift. In such a case the output becomes *E*

4. Traverse Sailing

[CU1] Current 1 mode is also used for the solution of Traverse Sailing. A traverse is a series of courses, or a track consisting of a number of course lines, as might result from a sailing vessel beating into the wind. Traverse Sailing is the finding of a single equivalent course and distance.

Problem 4		Key	Display	Answer
Course	Distance	[CU1]	c 0.	Single Equivalent Course and Distance
		158	c 158.	
158°	15.5	[⊙]	d 0.	161°29'.7
135°	33.7	15.5	d 15.5	43.5n.m.
259°	16.1	[⊙]	c 0.	
		135	c 135.	
		[⊙]	d 0.	
		33.7	d 33.7	
		[⊙]	c 142.118	
		[⊙]	d 48.3	
		[M1]	d 48.3	
		[⊙]	c 142.118	
		[CU1]	c 142.118	
		[⊙]	d 0.	
		[F] [RM1]	d 48.3	
		[⊙]	c 0.	
		259	c 259.	
		[⊙]	d 0.	
		16.1	d 16.1	
		[⊙]	c 161.297	
		[⊙]	d 43.5	
		Repeat *c* and *d*		



More courses may be added by repeating the same process.

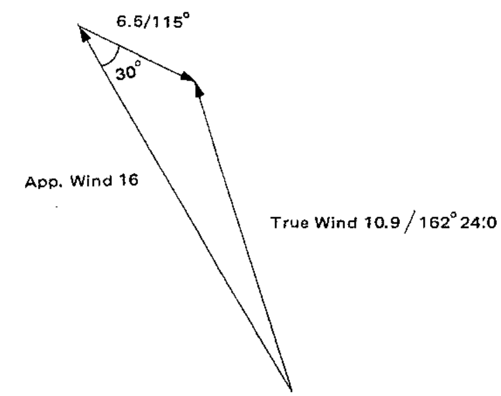
5. Finding the Direction and Speed of True Wind

[WDS] Wind Direction and Speed mode computes the True Wind Direction and True Wind Speed when a ship is taking a certain course at a certain speed.

Problem 5	Key	Display	Answer
Ship Course 115°	[F] [WDS]	c 0.	True Wind Direction
Ship Speed 6.5 knots	115	c 115.	162° 24'.0
Apparent Wind Direction	[⊙]	d 0.	True Wind Speed
30° starboard	6.5	d 6.5	10.9 knots
Apparent Wind Speed	[⊙]	c 0.	
16 knots	115[+]30[=]	c 145.000 *1	
	[⊙]	d 0.	
	16	d 16.	
	[⊙]	c 162.240	
	[⊙]	d 10.9	
	[⊙]	Repeat *c* and *d*	

*1 Ship course ± Apparent Wind Direction should be entered here. Use (+) when the apparent wind is blowing from starboard and (−) for port.

Note: NC-77 solves the current and wind problems by plane Sailing.



CHAPTER III

Tide and Stream (Tidal Current)

1. Finding the Height of Tide

[TIDE] Tide mode computes the height of tide at any selected time.

Problem 1	Key	Display	Answer
Time of Low Tide 01^h45^m	[TIDE]	h 0.	Height of Tide at 07^h35^m 10.8ft.
Height of Low Tide 0.6ft.	1.45	h 1.45	
Time of High Tide 09^h06^m	◎	d 0.	
Height of High Tide 11.9ft.	0.6	d 0.6	
Selected Time 07^h35^m	◎	h 0.	
	9.06	h 9.06	
(Seattle, Wash. Dec. 1, 1977)	◎	d 0.	
	11.9	d 11.9	
	◎	h' 0.	
	7.35	h' 7.35	Make sure the side selector switch is set on "ft".
	◎	d' 10.8	
	◎	h' 0.	
		Continue	

2. Finding the Velocity of Stream (Tidal Current)

[STRM] Stream Mode computes the velocity of stream (tidal current) at any selected time.

Problem 2	Key	Display	Answer
Time of Slack 01^h42^m	[F] [STRM]	h 0.	Velocity at 03^h30^m 3.7 knots toward 245°T
Time of Max. 04^h43^m	1.42	h 1.42	
Velocity at Max. 4.6 knots 245°T	◎	h 0.	
	4.43	h 4.43	
Selected Time 03^h30^m *1	◎	d 0.	
	4.6	d 4.6	
(San Francisco Bay Entrance	◎	h' 0.	
Aug. 16, 1977)	3.30	h' 3.30	
	◎	d' 3.7	
	◎	h' 0.	
		Continue	

*1 If the selected time is between the Max. and Slack time, for example Max. 5^h00^m, Slack 10^h00^m and the selected time 8^h00^m, input 10^h00^m first, and then 5^h00^m and its velocity. Then enter 8^h00^m to obtain the corresponding stream.

Note: The local information on TIDE and STREAM is given in TIDE TABLES and TIDAL CURRENT TABLES by the U.S. Department of Commerce or the equivalent authorities of the other countries.

Caution

1. Height of Tide at any intermediate time between high and

low tides is computed on the assumption that the rise and fall conform to simple cosine curves. (See the formulas below). Therefore the heights obtained will be approximate. The roughness of approximation will vary as the tide curve differs from a cosine curve.

TIDE TABLES By U.S. Department of Commerce includes "TABLE 3. – HEIGHT OF TIDE AT ANY TIME" to derive the intermediate height based on the same cosine curve. For European waters the ADMIRALTY TIDE TABLES VOL 1 by the Hydrographer of the British Navy gives the tidal curves for the areas where the curves are seriously distorted. In such areas the tidal curve for the particular port contained in the Admiralty Tide Tables should always be used.

2. The velocity of current at any intermediate time between the slack and maximum currents is also computed on the assumption that it changes in accordance with simple cosine curves. (See the formulas below).

Height of Tide

$$H = \frac{H_1 - H_2}{2} \cdot \cos\left(180 \cdot \frac{T - T_1}{T_2 - T_1}\right) + \frac{H_1 + H_2}{2}$$

Where
- H : Height at selected time
- H_1 : Height of high tide
- H_2 : Height of low tide
- T : Selected time
- T_1 : Time of High
- T_2 : Time of Low

It is essential to check if the tidal curve in the areas you plan to sail would conform to the standard theoretical movement.

Verocity of Tidal Current

$$V = Vm \cdot \sin\left(90 \cdot \frac{T - T_0}{Tm - T_0}\right)$$

Where
- V : Velocity at selected time
- Vm : Velocity at maximum
- T : Selected time
- T_0 : Time of slack
- Tm : Time of maximum

CHAPTER IV

Speed, Time, Distance

Speed, Time and Distance are computed by the following key sequence, selecting [N] mode in the beginning.

Speed (Knots)	: d [÷] t [·h.hh] [=]
Time (h.ms)	: d [÷] s [=] [F] [·h.ms]
distance (n.m.)	: s [×] t [·h.hh] [=]

Problem 1. A ship travels 35.2 nautical miles in 1 hour and 35 minutes.
What is the ship speed?
35.2 [÷] 1.35 [·h.hh] [=] **Answer:** 22.2 knots

Problem 2. How long will it take to travel 125 nautical miles at ship speed of 21.5 knots?
125 [÷] 21.5 [=] [F] [·h.ms] **Answer:** $5^h48^m50^s$

Problem 3. A Ship travels at a speed of 18.3 knots for 5 hours and 45 minutes.
What is the distance traveled?
18.3 [×] 5.45 [·h.hh] [=] **Answer:** 105.2 n.m.

CHAPTER V

Time and Arc

TIME and ARC Computations

Time mode makes hours, minutes, seconds computation; ARC mode makes degrees, minutes, and 1/10 minute computation. TAMAYA NC-77 follows the customary navigation rule of expressing seconds in terms of 1/10 of a minute in arc mode.

Problem 1	Key	Display
$(14^h59^m23^s + 15^h01^m59^s)$ $\div 2 = 15^h00^m41^s$	[C] [F] [·TIME]	h 0.0000
	14.5923	h 14.5923
	[+]	h 14.5923
	15.0159	h 15.0159
	[÷]	h 30.0122
	2	h 2.
	[=]	h 15.0041

Problem 2	Key	Display
$(38°29'.8 + 39°48'.8)$ $\div 2 = 39°09'.3$	[C] [·ARC]	d 0.000
	38.298	d 38.298
	[+]	d 38.298
	39.488	d 39.488
	[÷]	d 78.186
	2	d 2.
	[=]	d 39.093

ARC ⇄ TIME Conversion

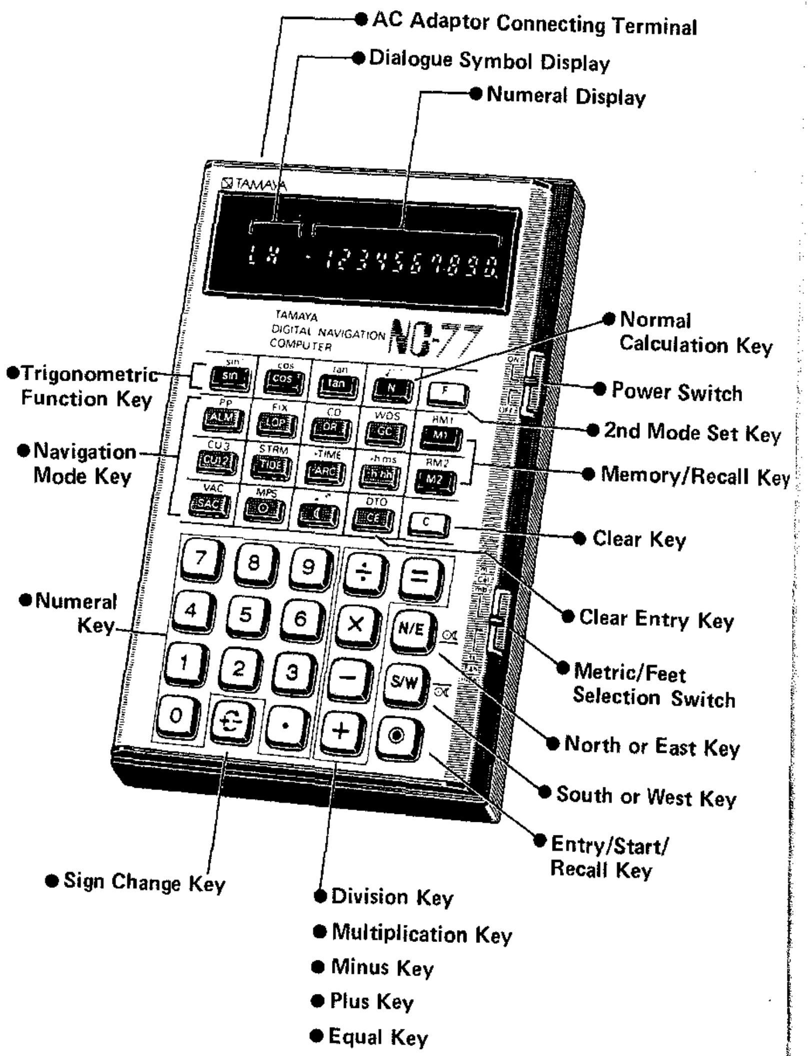
[·ARC] mode converts hours, minutes, and seconds into degrees, minutes and 1/10 minute.
[·TIME] mode converts degrees, minutes, and 1/10 minute into hours, minutes and seconds.

Problem 3	Key	Display
Arc 35°41'.8 ↓	35.418	35.418
$2^h22^m47^s$	[F] [·TIME]	h 2.2247

Problem 3 (b)	Key	Display
Time $3^h51^m03^s$ ↓	3.5103	3.5103
57°45'.7	[·ARC]	d 57.457

APPENDIX:
EXPLANATION OF NC-77 DIGITAL NAVIGATION COMPUTER

EXTERNAL FEATURES



MODE SELECTORS AND KEYS

NORMAL CALCULATION MODE KEY

[N] key clears the programmed navigation mode and sets the normal calculation mode.

DUAL FUNCTION KEY

[F] key pressed before each dual function mode key sets the 2nd mode i.e. $\sin^{-1}$, $\cos^{-1}$, $\tan^{-1}$, P.P., FIX, CD, RM1, RM2, etc.

SCIENTIFIC FUNCTION KEYS

[sin] [cos] [tan] Trigonometric function keys

[$\sin^{-1}$] [$\cos^{-1}$] [$\tan^{-1}$] Inverse trigonometric function keys

[$\sqrt{\ }$] Square root computation key

NAVIGATION MODE KEYS

[ALM] mode key computes the GHA ARIES, DEC SUN, GHA SUN and Equation of Time at any moment through the year 1999.

[P.P.] mode key makes the computation of proportional parts. It is applied in pin-pointing the GHA and DEC of the Moon and planets without using the INCREMENTS AND CORRECTIONS table of Nautical Almanac.

[LOP] mode key computes the Altitude and the true Azimuth of the Sun, Moon, planets and the navigational stars to obtain a Line of Position in celestial navigation.

[FIX] mode key computes the latitude and longitude of fix by two Lines of Position.

[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. The program continues to compute Latitude and Longitude of the Vertex, and the Latitude at any selected Longitude on the Great Circle track.

[WDS] mode key computes the True Wind Direction and True Wind Speed.

[CU1] mode key computes the Course and Speed Made Good through a current. This key is also used for the solution of Traverse Sailing.

[CU2] mode key computes the Course to Steer and the Speed to Use to make good a given course and speed through a current.

[CU3] mode key computes the Course to Steer at a given speed to make good a given course through a current.

[TIDE] mode key computes the Height of Tide at any selected time.

[STRM] mode key computes the Velocity of Stream (Tidal Current) at any selected time.

[SAC] mode computes the True Altitude by the standard sextant altitude corrections at 10°C, 1013.25mb (50°F, 29.92 in.).

[VAC] mode computes the True Altitude at variable temperature and atmospheric pressure. Both [SAC] and [VAC] compute the True Altitude for the Sun, Moon, planets and the stars.

[☉] [☾] [♀♂] These keys are used in connection with [SAC] and [VAC] to specify the celestial body, the Sun, Moon, Venus or Mars in making the sextant altitude correction.

☉☾ ☉☾ In [SAC] and [VAC] mode ☉☾ means the sighting of the lower limb and ☉☾ means the sighting of the upper limb of the Sun or Moon.

[MPS] mode key computes the Latitude and Longitude by noon sight (Sun's meridian passage).

[DTO] mode key computes the Distance to an Object by the vertically measured angle.

[▸ARC] key sets the computation in degrees, minutes and 1/10 minute.
This key also converts hours, minutes, seconds into degrees, minutes and 1/10 minute.

[▸TIME] key sets the computation in hours, minutes and seconds.

This key also converts degrees, minutes, 1/10 minute into hours, minutes and seconds.
(ARC to TIME or TIME to ARC conversion is made by the above two keys.)

[▸h.hh] key converts hours, minutes and seconds into hours, 1/10 hour and 1/100 hour.

[▸h.ms] key converts hours, 1/10 hour, 1/100 hour into hours, minutes and seconds.
The above two keys are used in Speed, Time and Distance computations.

[N/E] key designates North in latitude and East in longitude.

[S/W] key designates South in latitude and West in longitude.

MEMORY KEYS

[M1] [M2] Memory keys

[RM1] [RM2] Recall memory keys

OTHER KEYS

[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 a displayed number.

[◉] Enters a number, starts the programmed computation or recalls the programmed memory.

POWER SWITCH

on / off

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 SWITCH

m. / Cel. / mb. — ft. / Fah. / inch

In [SAC] and [VAC] mode the switch selects the input by meters, Celsius (temperature) and millibars (pressure), or feet, Fahrenheit and inches of mercury. In [DTO] mode it selects the input by meters or feet.

DIALOGUE SYMBOLS AND THE MEANING

Dialogue system makes the operation very easy by telling you at each step what data to feed in. The answers are also accompanied by the symbols which specify the meaning.

– sign after L indicates South latitude
– sign after // indicates West longitude
E: overflow error symbol
–: minus symbol

NC-77 DIALOGUE SYMBOLS

CD. DR. GC.

L	Lat.
//	Long.
c	Course
d	Distance
Lu	Vertex Lat.
//u	Vertex Long.
//'	Selected Long.
L'	Corres. Lat.

P.P.

h	Time (1)
d	Corres. Arc
h	Time (2)
d	Corres. Arc
h'	Selected Time
d'	Corres. Arc

LOP

LH	LHA
d	Dec.
L	Lat.
R	Computed Alt.
Ξ	Azimuth

ALM

y	Year. Month Day
h	Time of Observ.
Ho	GHA
d	Dec.
H	GHA
Eo	Eqn. of Time

MPS

h	Time of Mer. Pass.
Ro	True Alt.
d	Dec.
Eo	Eqn. of Time
L	Lat.
//	Long.

FIX

L	Lat.
//	Long.
d	Intercept
Ξ	Azmuth

SAC VAC

R,	Sextant Alt.
hE	Height of Eye
Rr	Dip Corrected Alt.
E	Temperature
P	Pressure
Rn	Refract. Corrected Alt.
5d	Semidiameter
hP	Horizontal Parallax
Ro	True Alt.

TIDE

h	Time of Low
d	Ht. of Low Tide
h	Time of High
d	Ht. of High Tide
h'	Selected Time
d'	Corres. Ht.

STRM

h	(1) Time of Slack
h	(2) Time of Max.
d	Vel. at Max.
h'	Selected Time
d'	Corres. Vel.

CU1

c	Course steered
d	Speed Thru Water
c	Set (Toward)
d	Drift
c	Course Made Good
d	Speed Made Good

CU2

c	Course to Make Good
d	Speed to Make Good
c	Set (Toward)
d	Drift ⊡
c	Course to Steer
d	Speed Thru Water

CU3

c	Course to Make Good
d	Speed Thru Water
c	Set (Toward)
d	Drift
c	Course to Steer
d	Speed Made Good

WDS

c	Ship Course
d	Ship Speed
c	Ship Co. ± Appar. W.D. (From)*
d	Appar. Wind Speed
c	True Wind Direction
d	True Wind Speed

*+ Starboard
– Port

DTO

R,	Sextant Alt.
hE	(1) Height of Eye
hE	(2) Height of Object
d	Dist. to Object

►TIME►ARC►h.ms

h'	Hour. Minute Second
d	Degree. Minute 1/10 Minute

Speed (Knot): d [÷] t [h.ms] [=]
Time (h.ms): d [÷] s [=] [h.ms]
Distance (n.m.): s [×] t [h.ms] [=]

MEMORY CAPABILITIES

NC-77 has two user-accessible memories, M1 M2 and RM1 RM2, to greatly increase the flexibility of computations. Use of the memory keys does not affect the displayed number or computation in progress, so they can be used at any point in a computation. They can save you keystrokes by storing long numbers that are to be used several times.

Key	Display
5 [F] [√]	2.236067977
[M1]	2.236067977
[+] 10 [F] [√] [=]	5.398345637
[F] [RM1]	2.236067977
[×] 4 [=]	8.944271908
[C]	0
[F] [RM1]	2.236067977

Besides M1, M2 and RM1, RM2 two extra memories are provided internally for the output of ALM, FIX, LOP, CD, DR, WDS, CU1, 2, 3, and MPS, where there are two answers to be recalled alternatively.

NOTE ON DECIMAL POINT

In NC-77 TIME is always expressed as Hours, Minutes, Seconds, and ARC as Degrees, Minutes, 1/10 minute to follow conventional navigation practice. The decimal point should be entered as follows. The same rule applies to the reading of the displayed outputs.

TIME	12^h	15^m	33^s	Enter	12.1533
		15	33		.1533
		5	33		.0533
			33		.0033
			3		.0003

ARC	180°25′.5	Enter	180.255
	25′.5		.255
	5′.5		.055
	0′.5		.005

Input/output of trigonometric and inverse trigonometric computation follows the same rule as ARC.

0.8 [F] [sin⁻¹] → 53.078 is read as 53°07′.8

In ALM (Almanac) mode the year, month and day are entered as follows.

ALM	January 2nd, 1978	Enter	78.0102
	12^h 06^m 08^s		12.0608

Precision Marine Sextants Since 1925
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