TAMAYA
ASTRO-NAVIGATION
CALCULATOR

NC-2

INSTRUCTION MANUAL

TAMAYA & COMPANY LIMITED

5-8, 3-chome, Ginza
Chuo-ku, Tokyo 104 Japan

TAMAYA

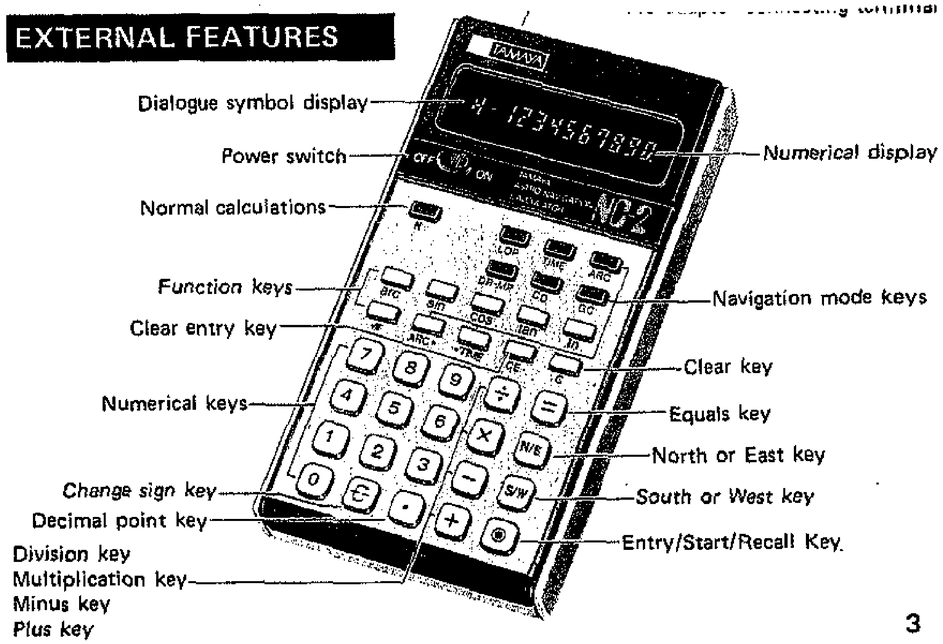
July '76 Printed in Japan

CONTENTS

INTRODUCTION

TAMAYA NC-2 ASTRO-NAVIGATION CALCULATOR can perform navigational calculations quickly and economically. It eliminates painstaking tabulation from conventional tables, and is not only faster but more accurate. Included in the navigation programs are Dead Reckoning, Course and Distance by Mercator and Mid-latitude Sailing, Course and Distance by Great Circle Sailing, Altitude and Azimuth of a body for Celestial Navigation, Most Probable Position, Time and Arc calculation, and TIME⇄ARC conversion. In addition, NC-2 features with four scientific function keys and the normal arithmetic calculation capabilities.

EXTERNAL FEATURES



EXPLANATION OF MODE SELECTORS AND KEYS

NAVIGATION MODE KEYS

[LOP] mode key calculates the Altitude and Azimuth of the sun, moon, planets and the stars to obtain a Line of Position in celestial navigation.

[DR-MP] mode key calculates the Dead Reckoning and Most Probable Position.

[CD] mode key calculates the Course and Distance by Mercator Sailing and Mid-latitude Sailing.

[GC] mode key calculates the Initial Course and Distance by Great-circle Sailing.

[TIME] mode key makes the hours, minutes, seconds calculation.

[ARC] mode key makes the degree, minutes and 1/10 minutes calculation.

[ARC→TIME] mode key converts the hours, minutes and seconds into degrees, minutes and 1/10 minutes.

[→TIME] mode key converts the degrees, minutes and 1/10 minutes into hours, minutes and seconds.

FUNCTIONS KEYS

arc: Key for converting sin, cos and tan to $\sin^{-1}$, $\cos^{-1}$ and $\tan^{-1}$ functions.

sin cos tan: Trigonometric function keys

ln: Natural logarithmic function key

√‾: Square root calculation key

OTHER KEYS

[C] Clears all the calculation registers, error etc. Resumes the begining of the program in CD, DR-MP, LOP, GC, TIME, ARC.

[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 function.

[+/−] Inverses the sign of a displayed number.

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

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

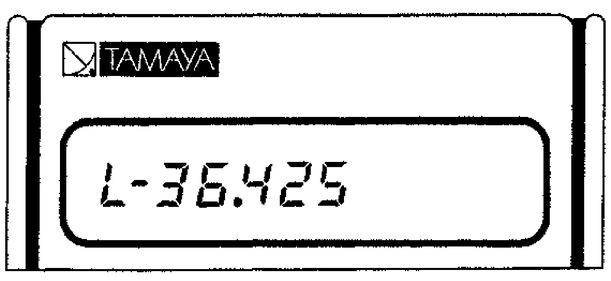
[◉] Enters a number, starts the programmed calculation and recalls the memory.

off [ ] on
POWER SWITCH When the power switch is slid to "ON" position the calculator is powered, automatically cleared and ready for operation by normal calculation mode.

[N] Clears the navigation modes and sets the normal calculation mode.

EXPLANATION OF DIALOGUE SYMBOLS AND INDICATORS

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.



Ex. Latitude 36° 42'.5S

NC-2 ASTRO-NAVIGATION CALCULATOR

INPUT/OUTPUT DIALOGUE

LOP ▼	DR.MP CD GC ▼	TIME ▼	ARC ▼	MODE / MEANING
H				Local Hour Angle
d				declination
A				Calculated Altitude
Z				Azimuth
L	L			Latitude
	ll			longitude
	c			course (Azimuth)
	d			distance (Intercept)
		h		hour
			d	degree

– sign after L indicates South latitude
– sign after ll indicates West longitude
E : Overflow error symbol
– : minus symbol

NORMAL CALCULATION (N-MODE)

1 four rules of arithmetic calculation

Problem 1	Key		Display	Note
123 – 45.6 + 789 =	[N]	123 [−]	123.	
		45.6 [+]	77.4	123 – 45.6
		789 [=]	866.4	answer
365 x (–1.15) ÷ 0.5 =	[N]	365 [×]	365.	
		1.15 [+/−] [÷]	– 419.75	365 x (– 1.15)
		.5 [=]	– 839.5	answer

To enter negative number, depress the [+/−] key after the number

2 constant calculation

Problem 2		Key	Display	Note
constant addition	5 + 3 =	[N] 5 [+] 3 [=]	8.	
	10 + 3 =	10 [=]	13.	10 + 3
	15 + 3 =	15 [=]	18.	15 + 3
constant subraction	5 − 3 =	[N] 5 [−] 3 [=]	2.	
	10 − 3 =	10 [=]	7.	10 − 3
	15 − 3 =	15 [=]	12.	15 − 3
constant multiplication	295 × 8 =	[N] 295 [×] 8 [=]	2360.	
	295 × 6 =	6 [=]	1770.	295 × 6
	295 × (−12) =	12 [+/−] [=]	−3540.	295 × (−12)
constant division	32 ÷ 2 =	[N] 32 [÷] 2 [=]	16.	
(divisors will be constant)	24 ÷ 2 =	24 [=]	12.	24 ÷ 2
	(−16) ÷ 2 =	16 [+/−] [=]	−8.	(−16) ÷ 2

3 chain multiplication and division

Problem 3	Key	Display	Note
5 × 3 ÷ 9 =	[N] 5 [×]	5.	
	3 [÷]	15.	5 × 3
	9 [=]	1.666666666	answer

4 square and power calculation

Problem 4	Key	Display	Note
$((2^3)^2)^2 = 2^{12} =$	[N] 2 [×] [=]	4.	2^2
	[=]	8.	2^3
	[×] [=]	64.	$(2^3)^2 = 2^6$
	[×] [=]	4096.	$(2^6)^2 = 2^{12}$

5 reciprocal calculation

Problem 5	Key	Display	Note
$\frac{1}{5} =$	[N] 5 [÷]	5.	
	[=]	1.	
	[=]	0.2	$\frac{1}{5}$

6 mixed calculation

Problem 6	Key	Display	Note
$\left\lvert\frac{(5+12)\times 18\div 3-16}{4}\right\rvert^2=$	N 5 + 12 ×	17.	5 + 2
	18 ÷ 3 −	102.	(5 + 12) × 18 ÷ 3
	16 ÷ 4 ×	21.5	$\frac{(5+12)\times 18\div 3-16}{4}$
	=	462.25	answer

7 function calculation

a) trigonometric function Problem 7	Key	Display	Note
sin 63° =	N 63 sin	0.891006524	answer
tan 23°45′.5 =	23.455 tan	0.440184145	answer

b) inverse trigonometric function Problem 8	Key	Display	Note
$\cos^{-1}$ 0.5 =	N .5 arc cos	60.000	answer 60°00′.0
$\sin^{-1}$ 0.2 =	.2 arc sin	11.322	answer 11°32′.2

The input/output of trigonometric and inverse trigonometric function calculations is given as follows.

11 ⟶ degree 32 ⟶ minute 2 ⟶ 1/10 minute

c) logarithmic function Problem 9	Key	Display	Note
ln 7 =	N 7 ln	1.945910148	answer

d) square root calculation Problem 10	Key	Display	Note
$\sqrt{5}+\sqrt{3}=$	N 5 √ +	2.236067977	$\sqrt{5}$
	3 √ =	3.968118784	answer

e) mixed calculation Problem 11	Key	Display	Note
sin 30° + $\sqrt{5}$ − cos 25°45′. 5 =	N 30 sin +	0.5	sin 30°
	5 √	2.236067977	$\sqrt{5}$
	−	2.736067977	sin 30° + $\sqrt{5}$
	25.455 cos	0.900635042	cos 25° 45′ .5
	=	1.835432935	answer

NAVIGATION CALCULATIONS

I. Dead reckoning and piloting

1. Dead Reckoning

(DR) Dead Reckoning mode calculates the latitude and longitude of the point of arrival.

Problem 1		Key	Display	Answer
Departure Poing Lat.	32°30'.6N	(DR-MAP)	L 0.	D.R. Lat. 30°34'.2N
Departure Point Long.	118°36'.2W	32.306 (M/E)	L 32.306	D.R. Long. 123°36'.0W
Course	245°30'	(◎)	II 0.	
Distance	280.8 miles	118.362 (%W)	II−118.362	
		(◎)	c 0.	
		245.3	c 245.3	
		(◎)	d 0.	
		280.8	d 280.8	
		(◎)	L 30.342	
		(◎)	II−123.360	
		(◎) REPEAT	L and II	

2. Course and Distance

(CD) Course and Distance mode calculates the course and distance from the departure point to the arrival point.

Problem 2		Key	Display	Answer
Departure Point Lat.	35°22'.4N	(CD)	L 0.	Course made good 203°32'.8
Departure Point Long.	125°08'.2W	35.224 (M/E)	L 35.224	distance 3477.1 miles
Arrival Point Lat.	17°45.2S	(◎)	II 0.	
Arrival Point Long.	149°30'.0W	125.082 (%W)	II−125.082	
		(◎)	L 0.	
		17.452 (%W)	L−17.452	
		(◎)	II 0.	
		149.30 (%W)	II−149.30	
		(◎)	c 203.328	
		(◎)	d 3477.1	
		(◎) REPEAT	c and d	

Principle

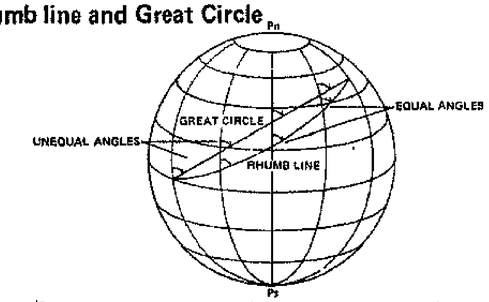
The principle of DR and CD calculation is Mercator Sailing. Accuracy is lost when the course approaches near 090° and 270°, so the program automatically switches to Mid-latitude Sailing, thus assuring accurate program for all circumstances. The course obtained by Mercator Sailing is a rhumbline. Appearing as a straight line on the Mercator chart it makes the same angle with all meridians it crosses. The main advantage of a rhumbline is that it maintains constant true direction. A ship following rhumbline between two points will not change a certain course. With the exception of very high latitudes (over 89°59'. 5), NC-2 is virtually good for all course and distance calculation.

3. Great Circle Sailing

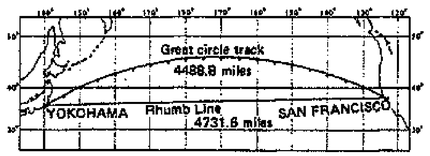
[GC] Great Circle Sailing mode calculates the great circle distance between two points and also the initial course from the departure point.

Problem 3		Key	Display	Answer
Departure Point Lat.	37°50'.8N	[GC]	L 0.	Great circle distance
Departure Point Long.	122°25'.5W	37.508 [%]	L 37.508	4488.8 miles
	(San Francisco)	◎	II 0.	
Arrival Point Lat.	34°52. 0N	122.255 [%]	II−122.255	Initial great circle course
Arrival Point Long.	139°42. 0E	◎	L 0.	302°37'.9
	(Yokohama)	34.520 [%]	L 34.520	
		◎	II 0.	
		139.420 [%]	II 139.420	
		◎	d 4488.8	
		◎	c 302.379	
		◎ REPEAT	d and c	

Comparison Rhumb line and Great Circle



Great Circle and Rhumb Line on the Earth's Surface



Great Circle and Rhumb Line on the Mercator Chart

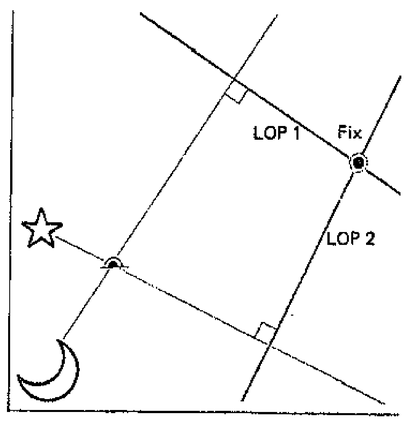
II. Celetial Navitation

1. Line of Position

[LOP] Line of Position mode calculates the altitude and azimuth of a celestial body. The NC-2 makes calculation extremely simple. Only three factors are needed; local hour angle, declination. and latitude.

Problem	Key	Display	Answer
Local Hour Angle of the sun 345°23'.9	[LOP]	H 0.	Calculated Altitude of the sun (Hc) 40°29'.3
	345.239	H 345.239	
Declination of the sun 17°10'.1S	[◎]	d 0.	Azimuth of the sun (Zn) 161°32'.2 from North easterly
	17.101 [+/-W]	d−17.101	
DR Latitude of the ship 30°18'.3N	[◎]	L 0.	
	30.183 [N/E]	L 30.183	
	[◎]	A 40.293	
	[◎]	Z 161.322	
	[◎] REPEAT	A and Z	

In the theory of celestial navigation a ship's position can be determined only after at least two LOP's are obtained. The intersection of the two or more LOP's called "fix" is the ship's position.



How to Use Nautical Almanac

In order to obtain a Line of Position you need a sextant, watch and the Nautical Almanac (WASHINGTON : United States Naval Observatory or LONDON : Her Majesty's Stationary Office) besides TAMAYA NC-2 ASTRO-NAVIGATION CALCULATOR.

Note (1) Sextant Altitude Corrections. (See the following Tables in the Nautical Almanac) A_2 and A_3 Altidude correction Tables for Sun, Stars and Planets (The first yellow pages) Altitude Correction Tables – Moon (The last yellow pages) A_4 Altitude Correction Tables – Additional Corrections.
The Nautical Almanac gives a clear explanation of how to use these altitude correction tables with examples on page 259 (1976 version).
(2) GHA (Greenwich Hour Angle) and (3) DECLINATION These data to be fed into NC-2 are found in the Nautical Almanac. Similarly, on page 256 The Nautical Almanac illustrates the examples for obtaining GHA and DEC. of the Sun, Moon, Planets and Stars.

LINE OF POSITION BY TAMAYA NC-2 ASTRO-NAVIGATION CALCULATOR

Example : The Dead Reckoning Position of a vessel is 30°22'. 8N, 69°35'. 5W at GMT 15h 23m 46s on May 5th, 1976. Compute the Altitude and Azimuth of the Sun. The Hs is 68°23'. 5. Waht is the altitude intercept?

Date & Time	DR. LAT.	DR. LONG
May 5, 1976 WWV 15h 23m	30°22'.8N	69°35'.5W

SEXTANT

NC-2 ARC		
	Body	◎
	Hs (Sextant Altitude)	68°23'.5
	Corrections (1)	+ 12'.5
	Ho (Observed Altitude)	68° 36'.0

TIME

TIME		
	GMT (Watch)	15h 23m48s
	Correction	− 2
	GMT	15 23 46

(1) (2) (3) See page 23

LOCAL HOUR ANGLE (From Nautical Almanac) (2)

NC-2 ARC		
	GHA hours	45° 50'.4
	GHA min. sec.	5° 56'.5
	V correction (for Moon & Planets)	
	SHA (for Stars)	
	Total GHA	51° 46'.9
	DR. LONG.	69° 35'.5 W
	LHA = (GHA ± E/W DR.LONG.)	− 17° 48'.6
	Application of ± 360° not requisite when LHA<0° or LHA>360°.	

DECLINATION (From Nautical Almanac) (3)

LOP ◎		
	DEC hours	16° 24'.3N
	"d" correction Omit for Stars	d=0.9 +.3
	Total DEC.	16° 24'.6 N

DR. LAT. ◎ — TAMAYA NC-2

CALCULATED ALTITUDE

R	68° 33'.2	(Hc)

AZIMUTH

Z	126° 38'.0	(Zn)

Always from North easterly

LINE OF POSITION	
DR. LAT.	30° 22'.8 N
DR. LONG.	69° 35'.5 W
Zn	126° 38'.0
I = (Ho-Hc)	2'.8 towards

Hc>Ho LOP is away from body.

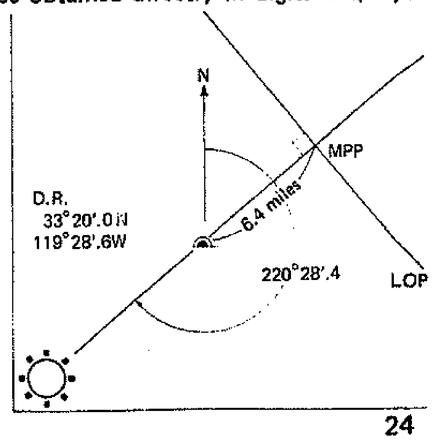
Ho>Hc Lop is towards body

Some Hints for Quicker Operation

1. Use ARC mode for the sextant altitude correction, LHA and DEC calculations. It saves a lot of pencil and paper work.
2. At the end of LHA column you may change the mode into LOP, leaving the displayed LHA, -17°48'.6 in the example. Then touch start key to proceed to the declination column. You may also add or subtract "d" correction in the LOP mode (-17.486 [LOP] [◎] 16.243 [N/E] + 0.003 [=] [◎] 30.228 [N/E] [◎])
3. Do not forget to make the decimal point when entering the figures in TIME or ARC mode. For instance 35 minutes 20 seconds must be keyed as .3520. Similarly 1'.9 in arc must be keyed as .019.
4. If you find it easier to do so, you may also touch the decimal point key between minutes and seconds in TIME mode and minutes and 1/10 minutes in ARC mode. It makes no difference.
5. When you have learned the operation thoroughly you may omit entirely the use of N/E key. It is not connected to the circuit but left on the panel to make the step by step learning easy.

2. Most Probable Position

[MP] Most Probable Position mode calculates the intersection of LOP and intercept. Instead of plotting a line of position, a calculated most probable position can be obtained directly in digital display.



Problem 2		Key		Display	Answer
DR Lat	33°20'.0N	[DR·VP]		L 0.	Most probable position
DR Long	119°28'.6W	33.200	[1/t]	L 33.200	33°25'.9N
Azimuth of the sun (Z)		[◎]			119°25'.7 W
	202°28'.4	119.286	[sin/w]	II–119.286	
Intercept :	6.4 miles away	[◎]		c 0.	
		202.284		c 202.284	
		[◎]		d 0.	
		6.4	[+/-]	d –6.4 (Change sign when Intercept is "away". Do not change if it is "towards".)	
		[◎]		L 33.259	
		[◎]		II–119.257	
		[◎] Repeats		L and II	

Most probable position helps improve the reliability of DR position but should be differentiated from the "fix" obtained by two or more LOP's.

III. Other convenient calculations in navigation

1. ARC TIME Conversion

[ARC←] mode converts the hous, minutes, and seconds into degrees, minutes and 1/10 minutes.

[→TIME] mode converts the degrees, minutes, and 1/10 minute, into hours, minutes and seconds

Problem 1(b)	Key	Display
Arc 35°41'.8	[ARC]	d 0.
	35.418	d 35.418
↓	[→TIME]	h 2.2247
2h22m47s		

Problem 1(a)	Key	Display
Time 3h 51m 03s	[TIME]	h 0.
	3.5103	h 3.5103
↓	[ARC←]	d 57.457
57°45'.7		

2. TIME and ARC calculations

Time mode makes the hours, minutes, seconds calculation, ARC mode makes the degree, minutes, and 1/10 minutes calculation. TAMAYA NC-2 follows the customary rule of expressing seconds in terms of 1/10 of a minute in arc mode.

Problem 2(a)	Key	Display
(14h59m23s	[TIME]	h 0.
+15h01m59s)	14.5923	h 14.5923
÷ 2 = 15h00m41s	[+]	h 14.5923
	15.0159	h 15.0159
	[÷]	h 30.0122
	2	h 2
	[=]	h 15.0041

Problem 2(b)	Key	Display
(38°29′.8	[ARC]	d 0.
+ 39°48′.8)	38.298	d 38.298
÷2 = 39°09′.3	[+]	d 38.298
	39.488	d 39.488
	[÷]	d 78.186
	2	d 2
	[=]	d 39.093

All +–x÷ calculations can be performed by TIME and ARC mode.

CORRECTION OF MISTAKES

When false number is entered during calculation, depress the [CE] Key, Then, only the false number is cleared.

Key	Display	Note
123 [+] 455	455.	False number 455
[CE]	0.	is cleared
456 [=]	579.	Answer 123 + 456

If the arithmetic calculation keys ([×][÷][+][−]) are operated by mistake, depress the correct key sucessively. Then, correct instruction replaces the preceding instruction.

Key	Display	Note
7 [×]	7.	False instruction
[÷]	7.	correction of the instruction
8 [=]	0.875	Answer 7 ÷ 8

OVERFLOW ERROR

An overflow error will occur in the following cases. When an overflow error is detected, all keys elctronically are inter-locked except the [C] and [CE] key. overflow error is cleared by pressing the [C] or [CE] key.

1. When the integer portion of sum, dirrerence, product or quotient exceeds 10 digits.
2. When a number is divided by zero.
3. When x value in the function calculation is in the following cases :

   $\sqrt{x}$ ..... $x<0$ tanx ..... $x=90^\circ\pm n-180^\circ(n=0,1,2..)$

   $\ln x$ ..... $x\leqq 0$ $\sin^{-1}x$, $\cos^{-1}x$ ..... $|x|>1$
4. In TIME mode; when an entered number, sum, difference, product or quotient exceeds 8 digits.
5. In ARC⇌TIME conversion mode ; when the integer portion of TIME exceeds 8 digits.
6. In LOP, DR—MP, CD, GC mode; when any one of the conditions stated in above 1,2,3 occurs.

(Note) In all the cases 1 to 6, the memory retains the contents before the overflow error is detected

HOW TO INSERT AND REPLACE BATTERIES

1. Turn off the power switch and slightly push the battery compartment cover in the arrow mark direction to remove it (fig. 1)
2. Insert four type SUM-3E batteries or Ni-Cd battery pack (EA-19B) (fig. 1, fig. 2). At this time set them to the spring side ("—" side) first while taking care of their polarities.
3. Slide the battery compartment cover into the main body after setting the pawls on the right and left sides of the former to the grooves in the latter.
4. When display becomes fading, it means that batteries are exhausted. Therefore, replace the batteries with new ones (in the case of Ni- Cd battery rechrge it).

- When replacing the batteries with new ones, replace all of four batteries at the same time.
- To insert or pull the plug of AC adaptor into or from calculator, be sure to turn off the power switch of calculator.

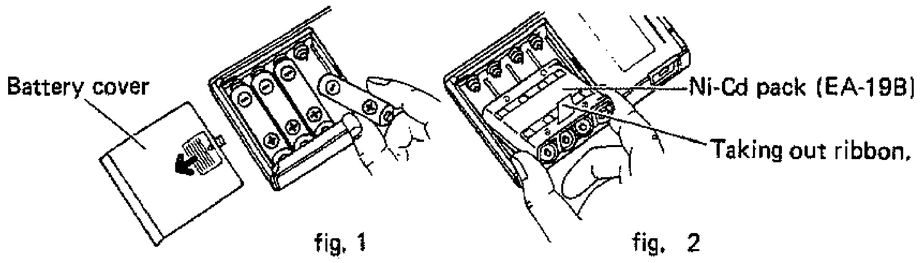


fig. 1

fig. 2

SPECIFICATIONS

Power Source :	AC: with Adaptor/Charger Sharp EA-14a (Option) for 100, 117, 220, 240V 50/60 Hz DC: 6V 1.5 V x 4 Sharp SUM 3E (Standard) 10 hours Rechargeable Ni-Cd battery EA-19B (Option) (6.5 hours – charge 15 hours)
Display :	Fluorescent (Itron) display with zero suppression
Capacity :	Input/output : 10 digits (max.) Dialogue symbol and minus sign : 2 digits
Decimal Point :	Fully floating decinal point
Sign & dialoque symbols :	Minus sign, error, Local Hour Angle, declination, course, distance, latitude, longitude, hour, degree, Calculated Altitude, Azimuth
Calculations :	four arithmetic calculations, constant calculations, chain multiplication & division, square and power calculation, reciprocal calculation, mixed calculation
Scientific functions :	sinx, cosx, tanx, $\sin^{-1}x$, $\cos^{-1}x$, $\tan^{-1}x$, lnx, $\sqrt{\ }$

Programmed Navigation Functions :	Dead Reckoning, Course and Distance by Mercator and Mid-latitude Sailing, Course and Distance by Great-circle Sailing, Altitude and Azimuth of a celestial body for Line of Position, Most Probable Position by celestial navigation. Hour minute second calculation, degree, minute, 1/10 minute ⇄ hour, minute second conversion
Memory :	2 memories for the output of DR-MP,CD, GC and LOP mode
Components :	LS1, etc.
Operating temperature :	0 – 40° C (32 – 104° F)
Power Consumption :	DC: 0.6W
Dimentions :	82(W) x27(H) x150(D)mm 3-1/4"(W) x 1-1/8"(H) x 5-1/2"(D)
Weight :	250 grams (0.55 lbs.)

CAUTION

It is highly recommended that coventional tables and tools be taken on cruises along with the NC-2 Calculator as insurance against Calculator failure or battery discharge.

Keep NC-2 away from water moisture or extreme low temperature and heat. Use the storage case as protection against vibration and shock.