HANDBOOK OF
OPERATING INSTRUCTIONS
FOR

POLHEMUS

CELESTIAL COMPUTER — AIR NAVIGATION

TYPE CPU-41/P

With Arithmetic and Vector Solutions for Aircraft Speeds of 90 to 2000 Knots

With Consideration of Errors Due to Aircraft Acceleration

With Dead Reckoning Capability of a Plotting Board

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NOTE: The reader is cautioned that the problem selected for use as an illustration in this handbook is taken as typical of a standard celestial precomputation and cannot be directly related to tabular information contained in HO249, Vol. I. For example, the tabulated altitudes (Ha) and Azimuths of Pollux, Antares, and Dubhe are fictitious.

SECTION I
INTRODUCTION

The Polhemus Celestial Navigation Computer was designed to meet the needs of navigators of high speed jet aircraft by giving them a device which, with practice in its use, will permit them to accommodate observations for last minute changes in ground speed, to space fixes more closely, and to take a final fix at a point closer to intended destination.

The slide rule portion of the computer presents information accurate to a tenth of a minute of arc, allows the navigator to consider simultaneously all the bodies he intends to shoot, and obviates the necessity of erasing and re-annotating information for each change of speed, track, or celestial body.

The plotter side of the computer supplies the navigator with the means to translate the arithmetic values of the observation to geographic coordinates more easily than is true of older systems and with greater accuracy. It offers him the means to develop a simple vector solution in minimum time in the event speed is more important than precision, and it permits him to determine course being made good, wind, and heading to steer to destination with more facility than is obtainable in standard chart work.

BIBLIOGRAPHY

The following texts were used to verify the methods outlined in the accompanying handbook:

USAF Manual 51-40, Vol. II

U.S. H.O. publication 211

U.S. Naval Observatory letter "Position of Polaris and Q of Polaris for 1965", R. Haupt

SLIDE RULE SIDE OF COMPUTER WITH SCALES IDENTIFIED

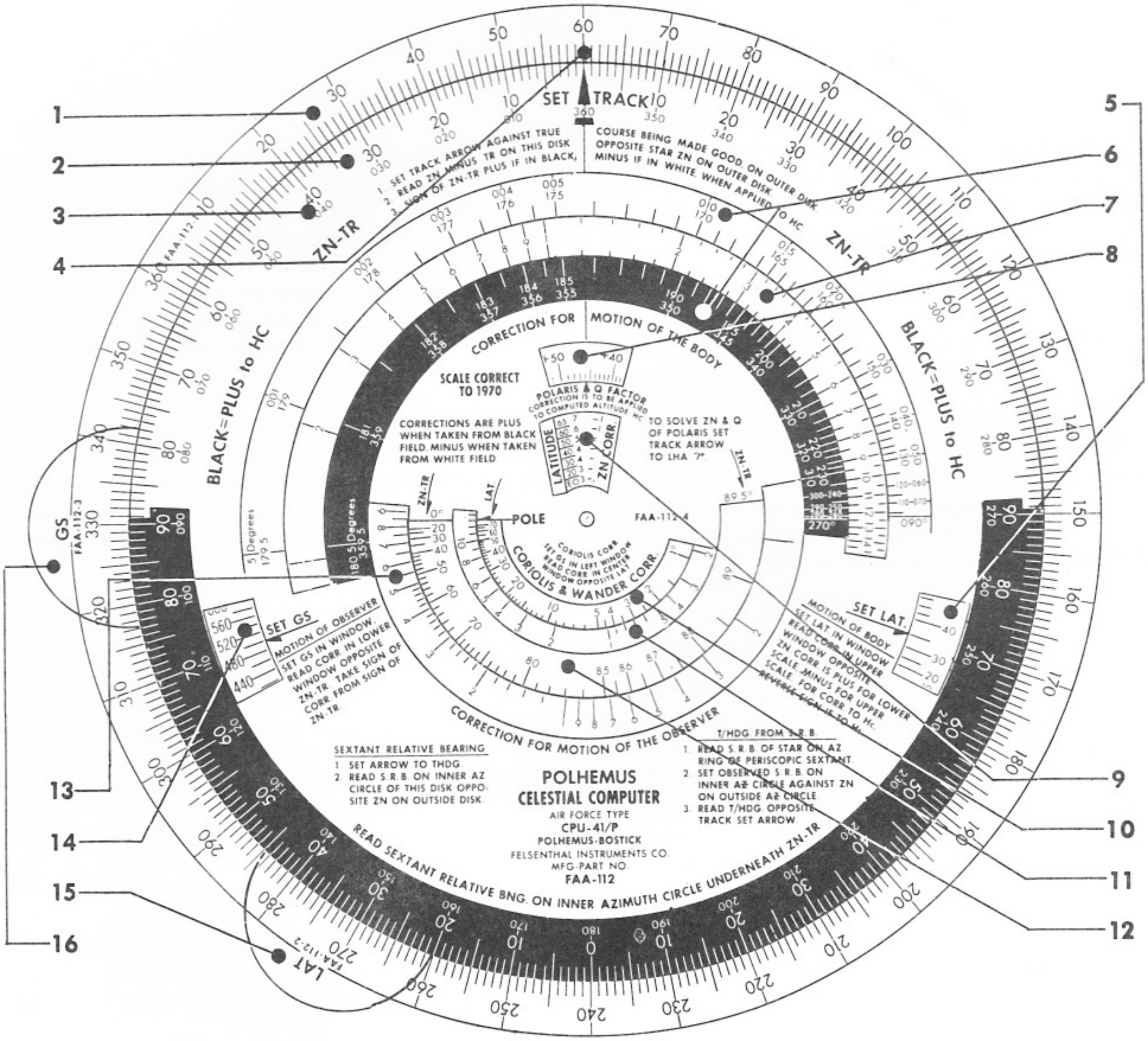


FIGURE 1

SECTION II

IDENTIFICATION OF SLIDE RULE SCALES

Using figure 1 identify the scales and indexes as follows:

1 . . . TRUE AZIMUTH scale. . .the outermost scale annotated each 10° commencing with North and increasing clockwise through 360°. Scale is used for locating star ZN, aircraft track, heading, LHA Aries, and Grid direction.

2 . . . RELATIVE BEARING scale (ZN-TR). . .the scale on upper disk adjacent to the True Azimuth scale, annotated with four, zero to 90 degree scales, two of which are black and two white.

3 . . . SEXTANT RELATIVE BEARING scale (SRB). . . .the scale next in from the Relative Bearing Scale annotated in small characters starting at the Index at the top of the disk and increasing in a counter clockwise direction through 360°.

4 . . . SET TRACK index. . .the black arrow at the top of the Relative Bearing scale used to orient the top disk with the True Azimuth scale.

5 . . . LATITUDE SCALE and index. . .the numbers appearing in the window on the right side of the computer at the 4 o'clock position commencing with the Equator and increasing counter clockwise to the Pole.

6 . . . STAR AZIMUTH (ZN) scale. . .the two scales surrounding the window in the upper hemisphere of the computer, the white scale starting at 0.5° and increasing clockwise to 090° then decreasing back counter clockwise to 179.5°; the lower black scale commencing with 180.5° increasing clockwise through 270° then back counter clockwise to 359.5°.

7 . . . MOTION OF THE BODY scale and window. . .the scale which appears in the window between the black and white Star Azimuth scales, commencing at zero and increasing to 15 in a clockwise direction.

8 . . . POLARIS Q FACTOR and index. . .the scale in the small window immediately below the 12 o'clock position of the Star Azimuth scale in the upper hemisphere. Note the algebraic sign is opposite from values taken from the Air Almanac.

9 . . . POLARIS AZIMUTH correction scale. . .the small scale appearing in the window next below the Q Factor window. On the left is a table of latitude ranging from Equator to 65°N.

10 . . . AIRCRAFT LATITUDE scale. . .the sine scale immediately beneath the computer pivo point commencing at the 9 o'clock position with POLE and decreasing counte clockwise through 1°. Scale also used for locating ZN-TR in Wander Erro calculations. Scale entitled Coriolis & Wander Corr.

11 . . . CORIOLIS CORRECTION scale. . .also Wander Error correction scale. . .appears i the window adjacent to the Aircraft Latitude scale and ranges in value from less-than-0.1 at the counter clockwise extreme, for ground speed 90 knots, t 55 minutes of correction for a speed in excess of 2000 knots.

12 . . . STAR RELATIVE BEARING (ZN-TR) scale. . .also GS change correction. . .the cosine scale immediately below the coriolis error window commencing at the 9 o'clock position with 0° and increasing counter clockwise through 89.5°. At the 9 o'clock position appears the annotation ZN-TR.

13 . . . MOTION OF THE OBSERVER correction scale. . .appearing in the window immediately below Star Relative Bearing scale. It begins at the counter clockwise extreme with a value of less-than-0.1 and increases clockwise to a maximum value of 35 minutes of arc.

14 . . . GROUND SPEED scale and index. . .the numbers appearing in the window at the 8 o'clock position on the left side of the computer ranging in value from 90 clockwise through 2000 knots.

15 . . . SET LATITUDE tab. . .the protruding plastic stub labelled LAT used to rotate the Motion of the Body scale so that the correct value of aircraft latitude appears in the SET LAT window.

16 . . . SET GROUND SPEED tab. . .the protruding plastic stub labelled GS used to rotate the Motion of the Observer and Coriolis correction scales so that the correct value of aircraft ground speed appears in the SET GS window.

SECTION III

DESCRIPTION OF SLIDE RULE OPERATION

Operation of the computer is best illustrated by taking a sample problem and following it through each step of the solution using the accompanying illustrations.

GIVEN: Aircraft track 060°, ground speed 500 knots, DR position 36° North latitude, 97° West longitude, LHA Aries 55°, three stars, Pollux, Antares, And Dubhe. Additional information is presented in the table below.

Star	POLLUX	ANTARES	DUBHE
Time of actual observation	0955Z	0958Z	1001Z
Fix time	-	-	1000Z
Time diff. between actual shot and fix	:05	:02	-:01
Tabulated altitude (Ha)	37°20'	20°15'	40°15'
Tabulated Azimuth	290°	170°	040°
Wander error experienced during observation	1.2°L	.7°R	zero
Ground Speed change	zero	-2 kt.	-4 kt.

FIND: All the corrections necessary to resolve the observations to a fix time of 1000Z.

3.1 GENERAL
3.2 MOTION OF THE BODY
3.3 ZN-TR
3.4 MOTION OF THE OBSERVER
3.5 COMBINED CORRECTIONS
3.6 CORIOLIS EFFECT - TWO METHODS
3.7 SEXTANT RELATIVE BEARING
3.8 DETERMINATION OF TRUE HEADING
3.9 WANDER ERROR CORRECTION
3.10 GROUND SPEED CHANGE ACCELERATION ERROR
3.11 Q FACTOR OF POLARIS
3.12 AZIMUTH CORRECTION FOR POLARIS

3.1 GENERAL

The slide rule must first be oriented for aircraft track, DR latitude, and best known ground speed. With the computer properly set-up it is possible to determine Motion of the Body, Motion of the Observer, Coriolis Effect, Wander Error Correction, and Sextant Relative Bearing for any number of bodies desired. THE MOTION CORRECTIONS ARE FOR ONE MINUTE OF TIME. The corrections for acceleration errors are for two minute observation periods to agree with the integration period of most averaging sextants.

MOTION OF THE BODY

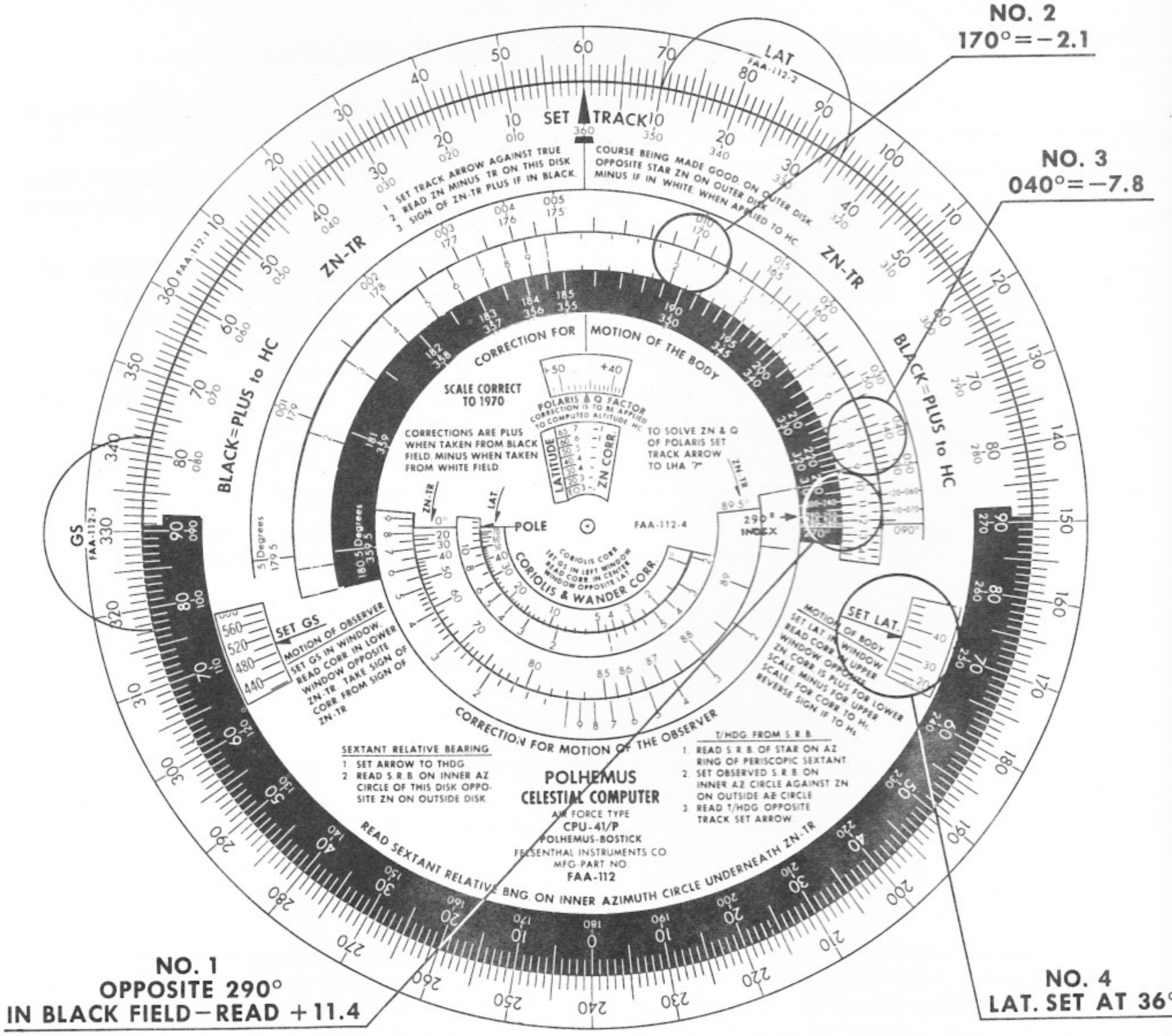


FIGURE 2

3.2 MOTION OF THE BODY

Rotate the LAT tab so as to bring the DR latitude of the aircraft into alignment with the SET LAT index (4, figure 2). The correction for MOTION OF THE BODY is then read in the window in the upper half of the computer. Pollux, ZN 290°, is found in the black field (1, figure 2). Antares is found in the white field above the window opposite 170° (2, figure 2). Dubhe is found in the white field at an azimuth of 040° (3, figure 2).

Star	POLLUX	ANTARES	DUBHE
ZN	290°	170°	040°
Motion of the Body correction (1 minute)	+11.4	-2.1	-7.8

NOTE: When observations are to be adjusted for considerable periods of time (as with a Landfall procedure), greater accuracy of the motion correction will be achieved by entering the star azimuth scales, above and below the window in the upper half of the computer, with the true azimuth of the body derived from the H.O. Pub 249 opposite mean LHA for the period.

3.3 ZN-TR

Find Star Relative Bearing, or ZN-TR, by rotating the top disk of the computer so as to bring the SET TRACK index (1, figure 3) into alignment with the outermost azimuth scale at the number equivalent to TRACK being made good, in this case, 060°.

On the True Azimuth scale locate the azimuth values of each of the stars, then read-in to the relative bearing scale, either black or white, and note the star relative bearing, ZN-TR. SIGN OF CORRECTION POSITIVE IF BEARING IS IN BLACK FIELD, SIGN IS NEGATIVE IF BEARING IS IN WHITE FIELD, assuming that the corrections are to be applied to Hc. Opposite 290° read 50° in the black field (2, figure 3). Opposite 170° (3, figure 3) read 70°. Opposite 040° (4, figure 3) read 20°. The Pollux and Antares bearings are considered positive, the Dubhe bearing is considered negative insofar as Motion of the Observer is considered.

Use the algebraic signs as given above when the corrections are to be applied to Computed Altitude, Hc, for the purpose of advancing the observations to the time of the fix. If the observation is late the sign of the correction must be reversed. An alternative would be to keep the sign as taken from the computer and apply it to Observed Altitude, Ho, for shots made later than fix time.

ZN-TR

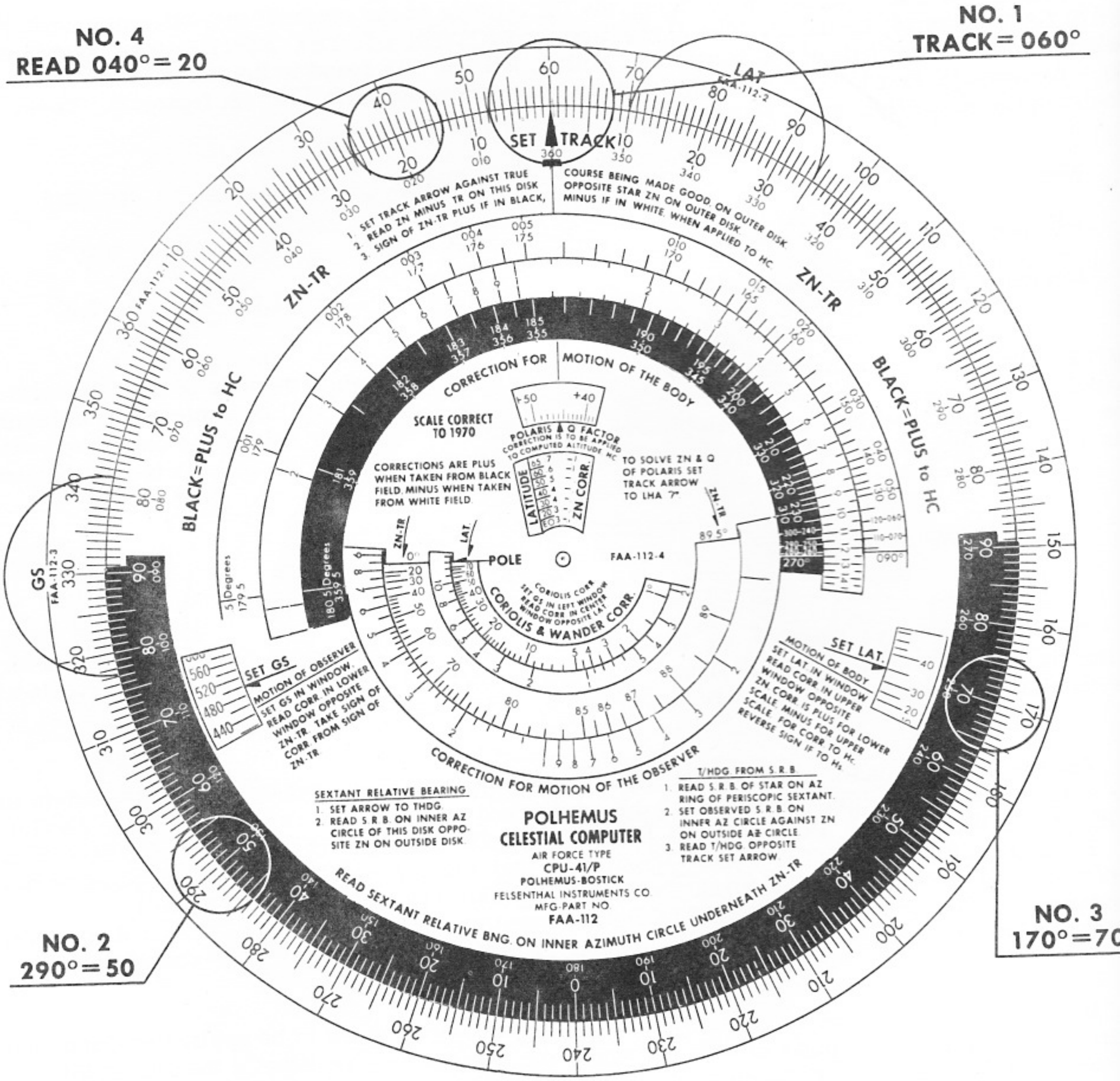


FIGURE 3

3.4 MOTION OF THE OBSERVER

Set aircraft ground speed in the window at the 8 o'clock position of the slide rule (1, figure 4). Locate the three ZN-TR values determined in paragraph 3.3 on the ZN-TR scale adjacent to the bottom window of the computer. Figure 4 illustrates the orientation.

Star	POLLUX	ANTARES	DUBHE
ZN-TR.	50°	70°	-20°
Motion of the Observer correction (1 minute)	+5.4	+2.8	-7.8

3.5 COMBINED CORRECTIONS

The two corrections, Motion of the Body and Motion of the Observer, are combined to obtain the total Motion Corrections to apply to tabulated altitude.

Star	POLLUX	ANTARES	DUBHE
Motion of the Body	+11.4	-2.1	-7.8
Motion of the Observer	+ 5.4	+2.8	-7.8
Total Adjustment for 1 minute of time . . .	+16.8	+ .7	-15.6
Multiply by planned interval between shots	x 8	4	0
Total Adjustment	+134.4 (2°14.4')	+2.8	- - - -

If the observations are not made on schedule (which is the case in the example given at the beginning of Section III), the 1 minute total adjustments are multiplied by the actual time difference. Using the differences given in one of the opening paragraphs of Section III, find the Total Adjustment required.

Star	POLLUX	ANTARES	DUBHE
Total Adjustment for 1 minute of time .	+16.8	+ .7	-15.6
Multiply by actual interval between shots	x 5	2	(-1)
Total Adjustment	+84.0	+1.4	+15.6

Note that the Dubhe observation, made later than fix time, now picks up a change in algebraic sign.

MOTION OF THE OBSERVER

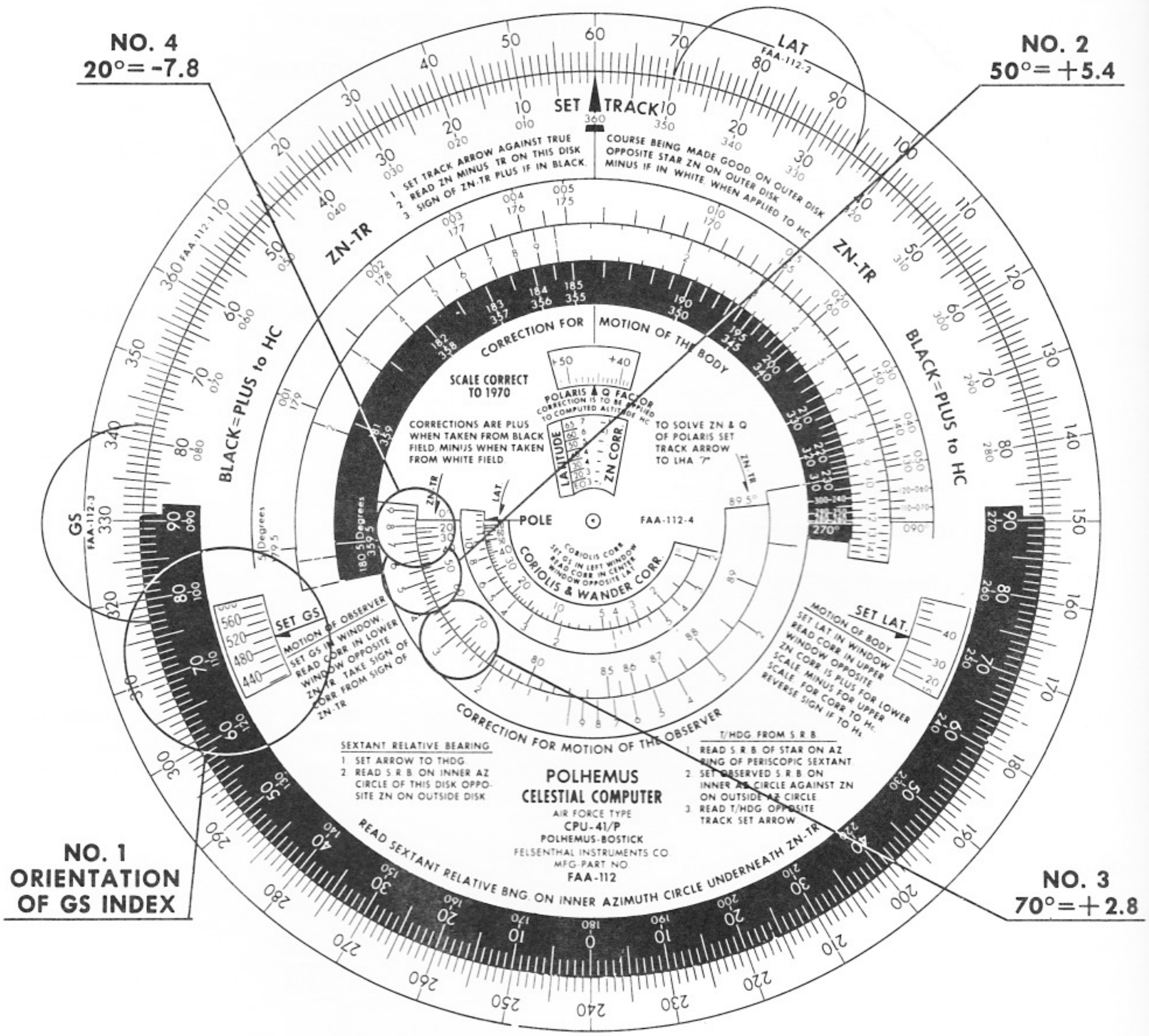


FIGURE 4

CORIOLIS EFFECT

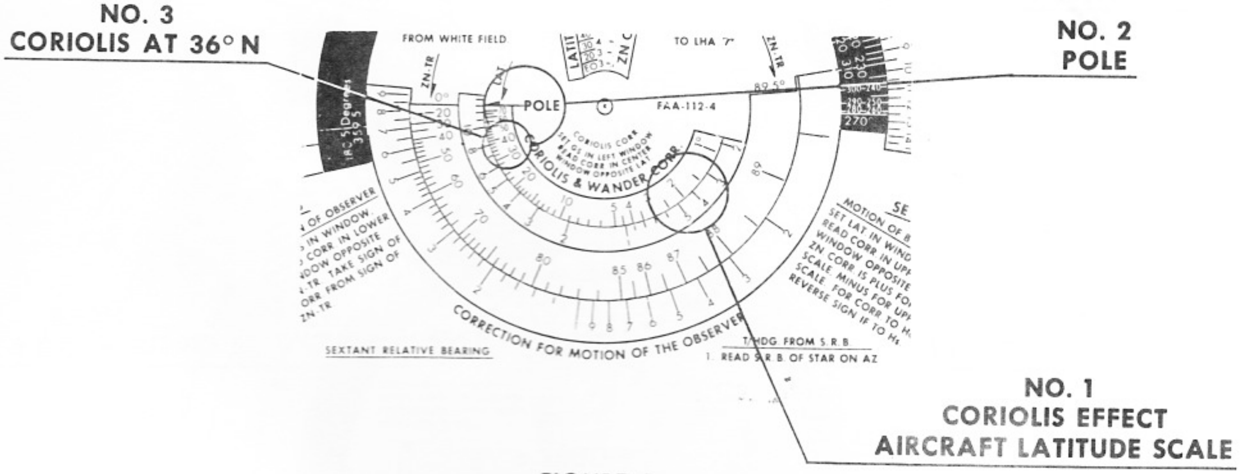


FIGURE 5

3.6 CORIOLIS EFFECT

The correction for CORIOLIS EFFECT is taken from the window immediately below the computer pivot on the lower face of the computer. Once aircraft Ground Speed has been set in the window (1, figure 4) entering argument for determining the correction is aircraft latitude. The scale (1, figure 5) originates at the POLE and swings in a counter clockwise arc through 1° of latitude. The correction may be read from the window to an accuracy of 2/10th minutes of arc.

Given a ground speed of 500 knots and an aircraft position of 36°N latitude determine the magnitude of the coriolis correction. Locate the latitude value of 36° on the Coriolis scale (3, figure 5) and read a correction of 7.6 minutes of arc or nautical miles.

Current practice is to plot the Coriolis correction as a vector applied to either the Assumed Position or to the plotted celestial fix. It is possible, however, to include consideration of coriolis effect in the regular calculation of Hc and/or Ho. It is recommended that the correction be applied to each shot in the same manner as are the Motion corrections. This procedure will prove most useful where extreme accuracy of work is desired or where an MPP is to be constructed from one line of position.

READJUSTED CORIOLIS SCALE

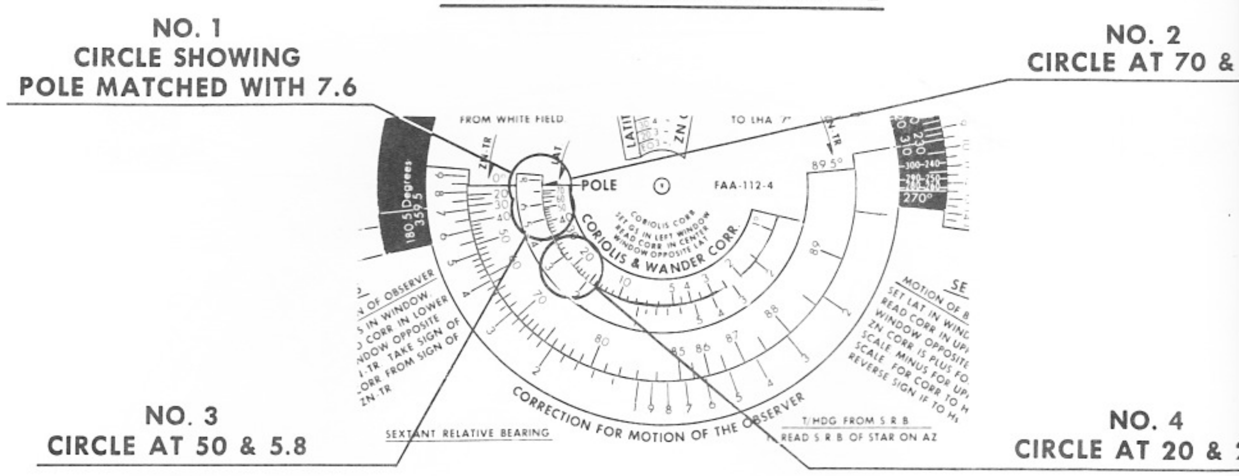


FIGURE 6

Reset the POLE index on the Latitude scale to the value of coriolis correction determi above, 7.6 nm (1, figure 6). Still using the same latitude scale locate the values for ZN-TR each star and note the coriolis correction adjacent to these values (2, 3, 4, figure 6). remove the effect of coriolis error by adjustment of Hc use the following rule: STAR TO T RIGHT, SIGN IS MINUS. STAR TO THE LEFT, SIGN IS PLUS.

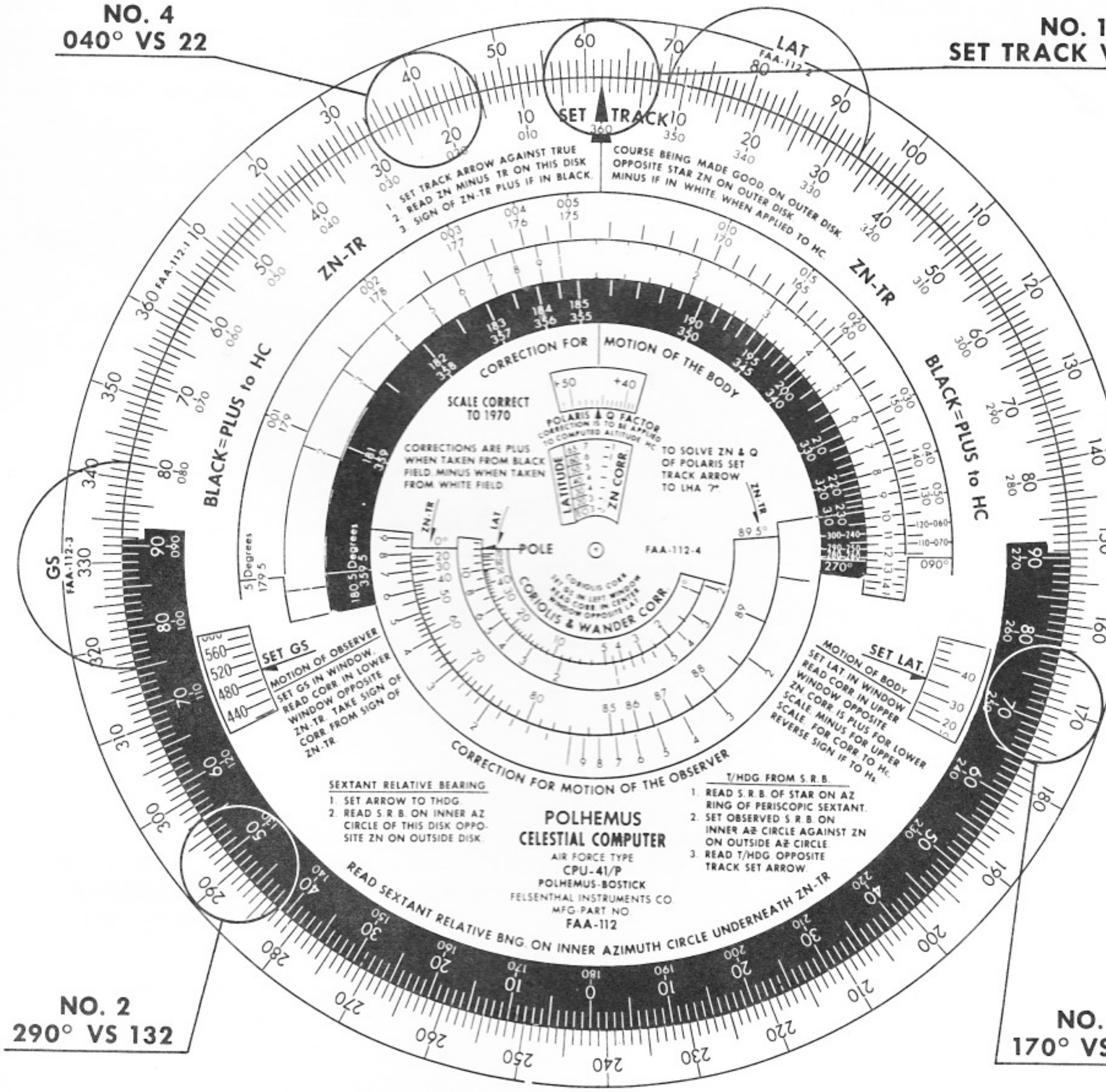
Star	POLLUX	ANTARES	DUBHE
Relative position of body	Left	Right	Left
Previous Adjustment for Motion Correction	+84.0	+1.4	+15.6
Individual CORIOLIS CORRECTIONS	+ 5.8	-7.0	+ 2.6
New Adjustment Factors	+89.8	-5.6	+18.2

NOTE THAT THE CORIOLIS ADJUSTMENT MUST BE ADDED AFTER CALCULATION THE TOTAL MOTION CORRECTIONS.

SEXTANT RELATIVE BEARING

NO. 4
040° VS 22

NO. 1
SET TRACK VS 062°



NO. 2
290° VS 132

NO. 3
170° VS 252

FIGURE 7

TRUE HEADING

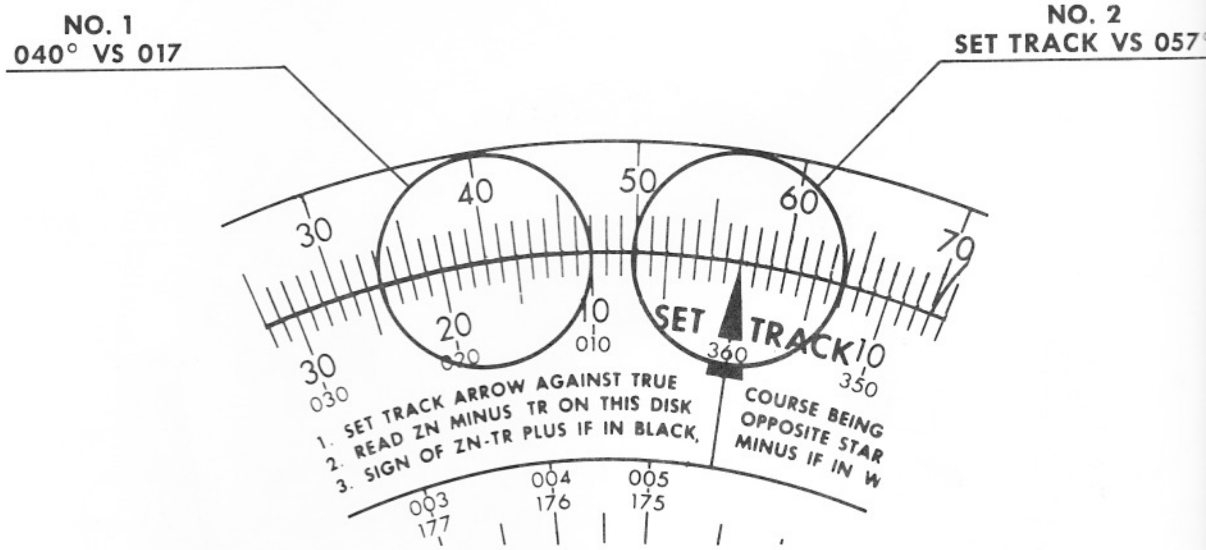


FIGURE 8

3.7 SEXTANT RELATIVE BEARING

It is common practice to use pre-computed values of Hc and Azimuth in setting up a periscopic sextant. It is possible to reduce the interval between observations by eliminating the readjustment of the azimuth counter of the sextant for each shot. This is done by utilizing SRB's to locate the celestial bodies in the optical field of view rather than turning the sextant until True Heading comes into view.

To find SRB orient SET TRACK index to True Heading of aircraft (1, figure 7). Locate star ZN on outermost azimuth scale as in 3.3 and read-in to azimuth scale just inside the ZN-TR scale. Read SRB opposite ZN.

Given a True Heading of 062° find SRB for the three stars used in the basic problem (2, 3, 4, figure 7).

Star.	POLLUX	ANTARES	DUBHE
Star true azimuth (ZN)	290°	170°	040°
Sextant Relative Bearing (SRB)	132°	252°	022°

The periscopic sextant is rotated on its base to bring these azimuth values into coincidence with the lubber line of the optical chamber.

3.8 TRUE HEADING

To obtain a True Heading check using the Sextant Relative Bearing procedure, read SRB in the optical field of view (FOR THE EXACT TIME OF THE COMPUTATION) then rotate the Relative Bearing disk of the computer so as to bring the SRB value into alignment with star true azimuth.

For example, assume that at 1000Z the SRB of Dubhe was found to be 017°. What would be the aircraft True Heading?

Locate 017° on the SRB scale (1, figure 8) and rotate the upper disk of the computer so as to place 017° in line with 040°, Dubhe's ZN. Opposite the SET TRACK index read a True Heading of 057° (2, figure 8).

WANDER ERROR

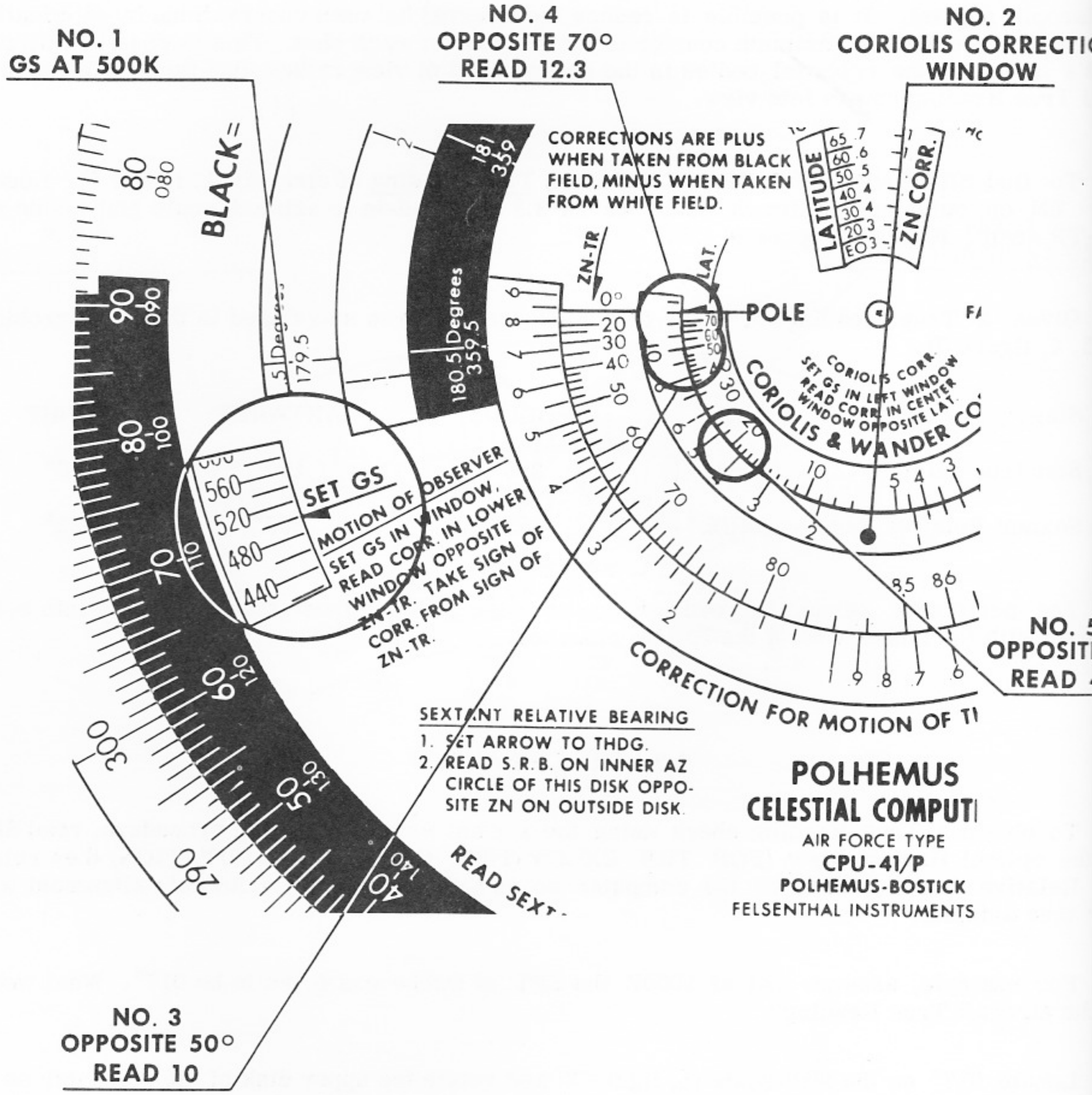


FIGURE 9

3.9 WANDER ERROR

There will be cases wherein the navigator experiences an acceleration effect on the bubble of his sextant caused by a change of aircraft heading during the period of observation. A correction for this effect may be determined from the computer by aligning best known ground speed with the GS index (1, figure 4), then reading the magnitude of the correction in the Coriolis correction window opposite ZN-TR (2, figure 9).

THE CORRECTION TAKEN FROM THE COMPUTER IS FOR A WANDER IN HEADING OF 1° DURING THE TWO MINUTE PERIOD OF OBSERVATION. The correction must be doubled for a 1 minute observation. The algebraic sign of this correction is determined by the rule: SIGN IS PLUS IF TURN IS TOWARD THE BODY...SIGN IS MINUS IF TURN IS AWAY FROM THE BODY. . .when applied to computed altitude (Hc).

Using the values given in the Table of Information at the beginning of Section III, determine the magnitude and algebraic sign of the correction to be applied to each observation for two cases; a, 1° of wander; b, the number of degrees actually experienced (3, 4, 5, figure 9).

Star	POLLUX	ANTARES	DUBHE
Relative position of body	Left	Right	Left
Correction factor for 1° heading change	10	12.3	4.4
Direction of turn.	Left	Right	No turn
Magnitude of heading change and sign of correction	x + 1.2	x + .7	x - -
Correction	+12	+ 8.6	- -

NOTE: Sign of correction may be determined by referring to the guide at the top of the Acceleration Error section of the Celestial Precomputation Form, figure 11A. A similar guide is shown below. In the table above Pollux is to the left of the aircraft and turn is to the left; therefore the sign is +.

HEADING CORRECTION SIGN GUIDE

BODY	HEADING CHANGE	
	Left	Right
Left	+	–
Right	–	+

For cases where the change in heading has been more or less than one whole degree t fractional part, or whole part plus fraction, may be determined without need for the multip cation demonstrated before. Set the Ground Speed Index to the value which represents GS HDG CHGE.

For example to solve for the correction necessary to Pollux, for a wander of 1.2 degree set GS Index to 500 x 1.2, or 600, then read the correction necessary opposite 050° on t coriolis latitude scale. Answer is 12 miles or minutes of arc as shown above. Since turn right and star is left of aircraft heading, sign is positive.

To solve for 0.7 degrees of wander during the ANTARES observation set GS Index to 5 x .7 =350 knots, and read the correction necessary opposite 70°. The answer is +8.5 miles minutes, as before. Since turn is right and star is right of heading, sign is positive.

GROUND SPEED CHANGE ACCELERATION ERROR

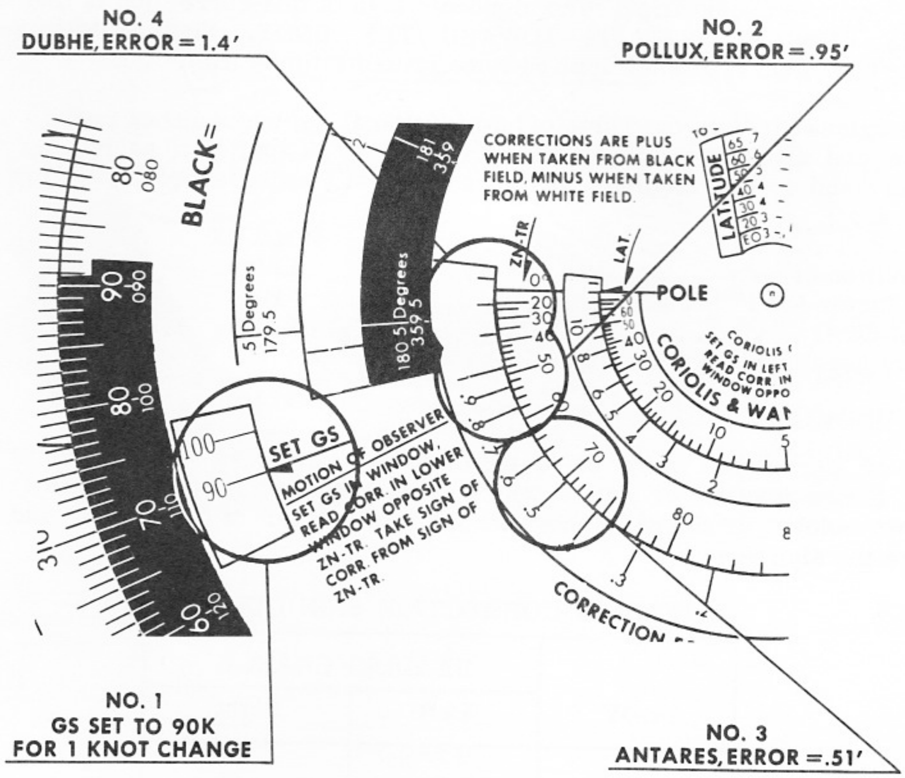


FIGURE 10

3.10 GROUND SPEED CHANGE ACCELERATION ERROR

There will be cases wherein the navigator is aware of a change in aircraft velocity either due to a gust of wind (seen on doppler) or to a change of true airspeed... which is itself caused by a change in aircraft trim, IAS, or Outside Air Temperature. Regardless of cause he may correct his observation for the error by using a correction taken from the computer.

The Ground Speed scale is re-oriented to 90 knots. The correction factor for a change in velocity of 1 knot is taken from the Motion of the Observer correction scale (figure 10). ZN-TR is the entering argument. The sign of the correction is taken from the rule SIGN IS MINUS IF VELOCITY CHANGE IS AWAY FROM BODY, SIGN IS PLUS IF VELOCITY CHANGE IS TOWARD BODY. These signs are as given above when correction is made to Hc.

Velocity change away is intended to mean that the vector of the acceleration is away from the azimuth of the body whereas toward is a vector in the direction of the star. An aircraft which increases speed during the period the navigator is observing a body in front of the vehicle is said to be increasing toward the body. Had the star been aft of the aircraft the velocity would have been considered as having the direction 'away'.

To accommodate for a change greater than 1 knot multiply 90 x the actual GS change and reset the GS Index to the new value. For example let the change in velocity be 2.5 knots, then the GS Index will be set to 2.5 x 90 =225 knots.

Using the ground speed changes listed for Antares and Dubhe in the beginning of Section III set the GS Index to 2 x 90, or 180, for Antares, and to 4 x 90, or 360, for Dubhe. The corrections will be:

Star.	POLLUX	ANTARES	DUBHE
ZN-TR.	50°	70°	-20°
Ground Speed Change	zero	2 kts.	4 kts.
times 90		180	360
GS Change Correction		+1	-5.6

These corrections are added algebraically to computed altitude, Hc.

NOTE: Sign of correction may be determined by referring to the guide at the top of the Acceleration Error section of the Celestial Precomputation Form, figure 11A. A similar guide is shown below. In the table above Dubhe is ahead of the aircraft and the velocity change is away from the body (decrease); therefore the sign is –.

VELOCITY (GS) CORRECTION SIGN GUIDE

BODY	VELOCITY (GS) CHANGE Increase	VELOCITY (GS) CHANGE Decrease
Ahead	+	–
Behind	–	+

3.11 Q FACTOR OF POLARIS

Use of the star Polaris is facilitated by use of the computer. Rotate the top disk to the SET TRACK index into alignment with the value representing LHA ARIES (1, figur Read Q Factor in the window opposite Index, upper hemisphere of computer (2, figur Algebraic sign is reversed from that which appears in the Air Almanac to permit the Fa application to Hc of Polaris, the DR Latitude for the time of the fix.

Q FACTOR OF POLARIS

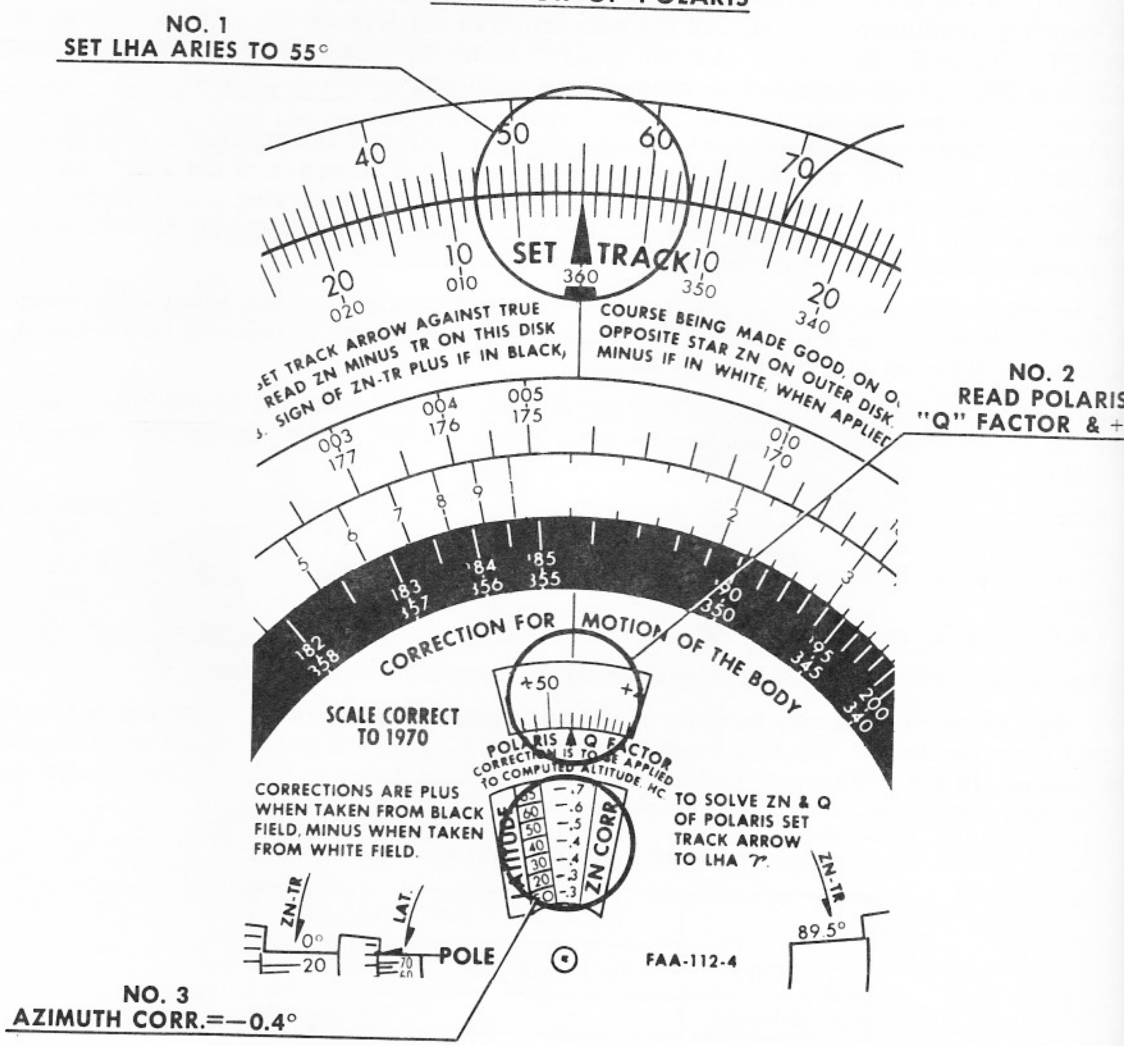


FIGURE 11

In the event the observation is made earlier or later than fix time a correction for Motion of the Observer must be applied to the shot.

Given an LHA ARIES of 55° and a DR position for time of fix of 35°42'N Latitude find Q Factor and adjusted latitude.

Orient the SET TRACK index to 55° on the outermost scale (1, figure 11) and read a Q Factor of +48.1 minutes above the index (2, figure 11). Then 35°42' plus (+48.1') =36°30.1' for an Hc of Polaris. (The computer is correct for the year 1965.)

''Attention is invited to the fact that under some circumstances where extreme precision is required the navigator may wish to consider Motion of the Body for Polaris. For example given an LHA γ of 310°, at Lat 36° N, the Azimuth correction for Polaris is found to be 001° and as a consequence Motion of the Body will be .2 minutes of arc/minute of time. Thus if Polaris were to be used as a line of position under these circumstances such that it was observed 8 minutes before fix time a Motion of Body correction of — 1.6 minutes of arc would be required.

3.111 POLARIS INTERCEPT USED WITH ASSUMED POSITION

''In the event the navigator wishes to treat Polaris in the same manner as the other bodies operating on the celestial fix, that is as an intercept vector plotted from Assumed Position, the DR latitude is replaced with Latitude of Assumed Position (item 4 on fig. 11A). In the sample problem the DR latitude of 35°50' is replaced with 36° to which is added the quantities 'Q Factor' and 'Total Adjust' in the conventional manner. For example add (Lat 36°00' plus Q Fac (+48.1') plus Tot Adj (+22.7') to arrive at a new Hc of 37°10.8'. Compare this value with Observed Altitude of 37°02.8' to arrive at Intercept of 8' Away from Assumed Position along Polaris Azimuth line.''

3.12 AZIMUTH OF POLARIS

Since Polaris does not have its Zenith at a point directly over the Pole it is necessary to correct the azimuth value by a small amount when using this body for heading checks.

The Azimuth correction is taken from the window immediately below the Q Factor window described in 3.11 above. The entering argument is Aircraft Latitude with the SET TRACK index oriented to LHA ARIES.

Given an LHA ARIES of 55° and an aircraft latitude of approximately 36° determine the azimuth correction to apply to 360 when sighting Polaris.

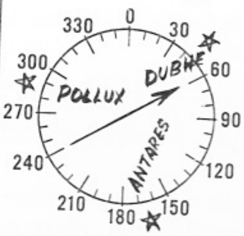
Locate the approximate position of 36°N on the latitude scale (3, figure 11) and read minus 0.4° alongside. Azimuth of Polaris is corrected to 360° -0.4° =359.6°. To convert this value to an SRB reset the TRUE INDEX to True Heading, find 359.6° on the outermost scale, and read the SRB on the interior azimuth scale.

For example, with a True Heading of 060° find SRB to be 060.4°.

CELESTIAL PRECOMPUTATION

NAVIGATOR	DATE	FIX TIME	
		1000Z	2

STAR SELECTION BY AZIMUTH



DEVIATION CHK			
BODY	DUBHE		
SRB	017°		
ZN	040°		
T/G HDG	057°		
VAR		-14°	
MAG HDG		043°	
	BNS	N-1	STBY
DEV CORR	-1	-2	+3
COMPASS HDG	056	041	046

DR				
LATITUDE 35 50N	TR 060°	TH 062	ALT 34000	1
LONGITUDE 96 30W	GS 500	TAS 480		

	BODY	POL	ANT	DU	POLARIS
4					360°
			AZIMUTH CORR.		-0.4
4	ZN	290	170	040	359.6
	± CONV.				
	GRID ZN				
6	ZN-TR	050	070	020	060.4
5	MOTION OF BODY	+11.4	-2.1	-7.8	
7	MOTION OF OBSERVER	+5.4	+2.8	-7.8	-3.8
8	1 MIN ADJ.	+16.8	+.7	-15.6	-3.8
	X△ TIME	5	2	(-1)	-4
19	TOTAL MOT. COR.	+84.0	+1.4	+15.6	+15.2
9	CORIOLIS	+5.8	-7.0	+2.6	+6.5
20	WANDER	+12.0	+8.6	—	—
21	GS CHGE	—	+1.0	-5.6	—
14	MISCEL	+1.0	+1.0	+2.0	+1.0
22	TOTAL ADJ.	+102.8	+5.0	+14.6	+22.7

ACCELERATION ERROR · CORR TO HC

		HEADING CHGE LEFT ±	HEADING CHGE RIGHT ∓	AHEAD BEHIND	GS CHGE INCREASE ± / DECREASE ∓
	BODY LEFT RIGHT				
15	HDG START	060.5	062.3	061.0	060.0
16	HDG END	061.7	061.6	061.0	060.0
	CHG L/R	1.2L	.7R	—	—
10	X FAC FOR 1°	10L	12.3R	4.4L	11.4
20	WANDER CORR	+12	+8.6	—	—
15	GS START	—	499	503	—
16	GS END	—	497	499	—
	CHG INC/DEC	—	DEC 2	DEC 4	—
11	X FAC FOR 1 KT	.95	.51	1.4	.75
21	GS CHG	—	+1.0	-5.6	—
	SIGN REVERSED FROM TABLE				
12	REFRAC	—	—	+1	—
	SIGN REVERSED FROM CORR. CURVE				
13	DOME PERSONAL	+1	+1	+1	+1
14	TOTAL	+6	+1	+2	+1

BODY	POLLUX	ANTARES	DUBHE	POLARIS	
GHA BODY					
GHA ♈			152		2
+ CORR					
SHA			—		
PLUS 360 IF NECESSARY			—		
GHA ✳/♈			152		2
± E/W LONG			-97		
LHA ✳/♈			55		3
ASSUMED LAT.			36		
DEC.			—		

Hs TIME	0955	0958	1001	1004	17
Q FACTOR				+48.1	
Ha HO249	37° 20′	20° 15′	40° 15	DR LAT 35° 50′	4
TOTAL ADJUST	+1° 42.8	+5	+14.6	+22.7	23
CORR A					
CORR DEC					
Hc	39° 02.8	20° 20′	40° 29.6	37° 00.8	24
Ho	38° 47.3	20° 34.4	40° 43.0	37° 02.8	18
INT TO		14.6T	13.4T	PLOT FROM DR LATITUDE 2.0T	
INT AW'Y	15.5A				25
ZN	290	170	040	000.4	4
± CONV					
GRID ZN					
SRB	132°	252°	022°	062.4	6

CORIOLIS & RHUMB LINE 7.6 NM TC + 90° 150° 9

TABLE IV PRECESSION & NUTATION CORR.

______ NM ______ DIRECTION 4

	LATITUDE	LONGTITUDE	
FIX	35 50N	96 36W	27
BNS	35 40N	96 19W	26
COUNTER ADJ.	10′N	17′W	28

FIGURE 11A

SECTION IV

EXPLANATION OF CELESTIAL PRECOMPUTATION FORM

An example of the use of the Celestial Precomputation Form is shown in figure 11A. The steps involved in completing this form are explained below, numbered in order of performance. Corresponding numbers along the margins of the form facilitate location of the entry.

1 . . . On the basis of navigator's knowledge of aircraft position and progress, complete the two lines at top-right of form.

2 . . . For the time of programmed fix extract and record GHA γ from the Air Almanac.

3 . . . Calculate LHA γ to use as entering argument to H.O. Pub. 249 or other sight reduction tables.

4 . . . Extract and record name, Ha, and ZN of celestial bodies to be observed, and procession & nutation correction. List planned observation times.

NOTE: Use computer as required in performing the following steps.

5 . . . Determine MOTION OF BODY, paragraph 3.2.

6 . . . Determine the relative bearings of the bodies (ZN-TR), paragraph 3.3, and sextant relative bearing (SRB), paragraph 3.7.

7 . . . Determine MOTION OF THE OBSERVER, paragraph 3.4.

8 . . . Determine combined motion for one minute of time, paragraph 3.5.

9 . . . Determine individual and total coriolis correction, paragraph 3.6.

10 . . . Determine factor for wander error, paragraph 3.9.

11 . . . Determine Ground Speed change factor, paragraph 3.10.

12 . . . From Air Almanac extract correction for refraction being careful to reverse its sign.

13 . . . List corrections for personal or sextant error, with signs reversed.

14 . . . Combine corrections from 12 and 13 and carry to MISCEL block at middle of left side of form.

15 . . . At start of each observation note heading and ground speed (if doppler equipped) o
airspeed.

16 . . . At completion of observation record heading, ground speed (if doppler equippe
true airspeed.

17 . . . Record mid-time of observation.

18 . . . Record sextant measured altitude of body, Ho.

19 . . . Determine time difference between observation time and fix time, record this
multiply by 1 minute adjustment factor (8), and record product as total r
correction.

20 . . . Determine magnitude of heading change and calculate required wander corre
paragraph 3.9.

21 . . . Determine magnitude of ground speed change and calculate required correction,
graph 3.10.

22 . . . Combine corrections obtained from 19, 9, 20, 21, 14, at middle of form and trans
right side of form below recorded Ha from H.O. 249, (23).

23 . . . Recorded value of total adjustments.

24 . . . Combine Ha, Total Adjustment (23), correction for declination and d if using th
and record as Hc.

25 . . . Compare Ho with Hc in conventional manner to determine magnitude and sign of
cept.

26 . . . Record DR position displayed by navigation system at time of fix.

27 . . . When fix has been resolved on plotting surface or on chart record its coordinates

28 . . . Determine correction to make to navigation system latitude and longitude count
comparing 26 with 27.

PLOTTER BASE PLATE

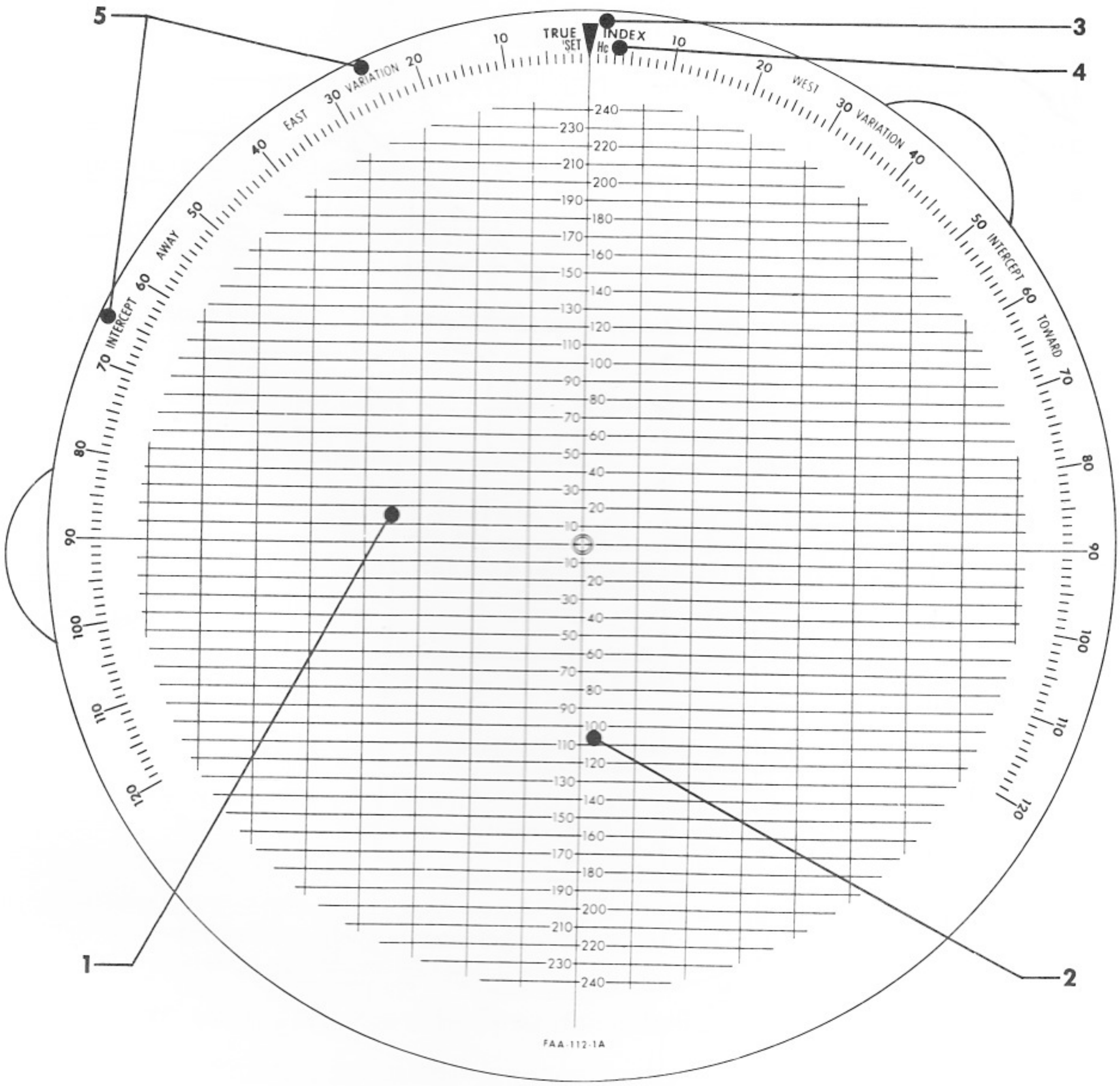


FIGURE 12

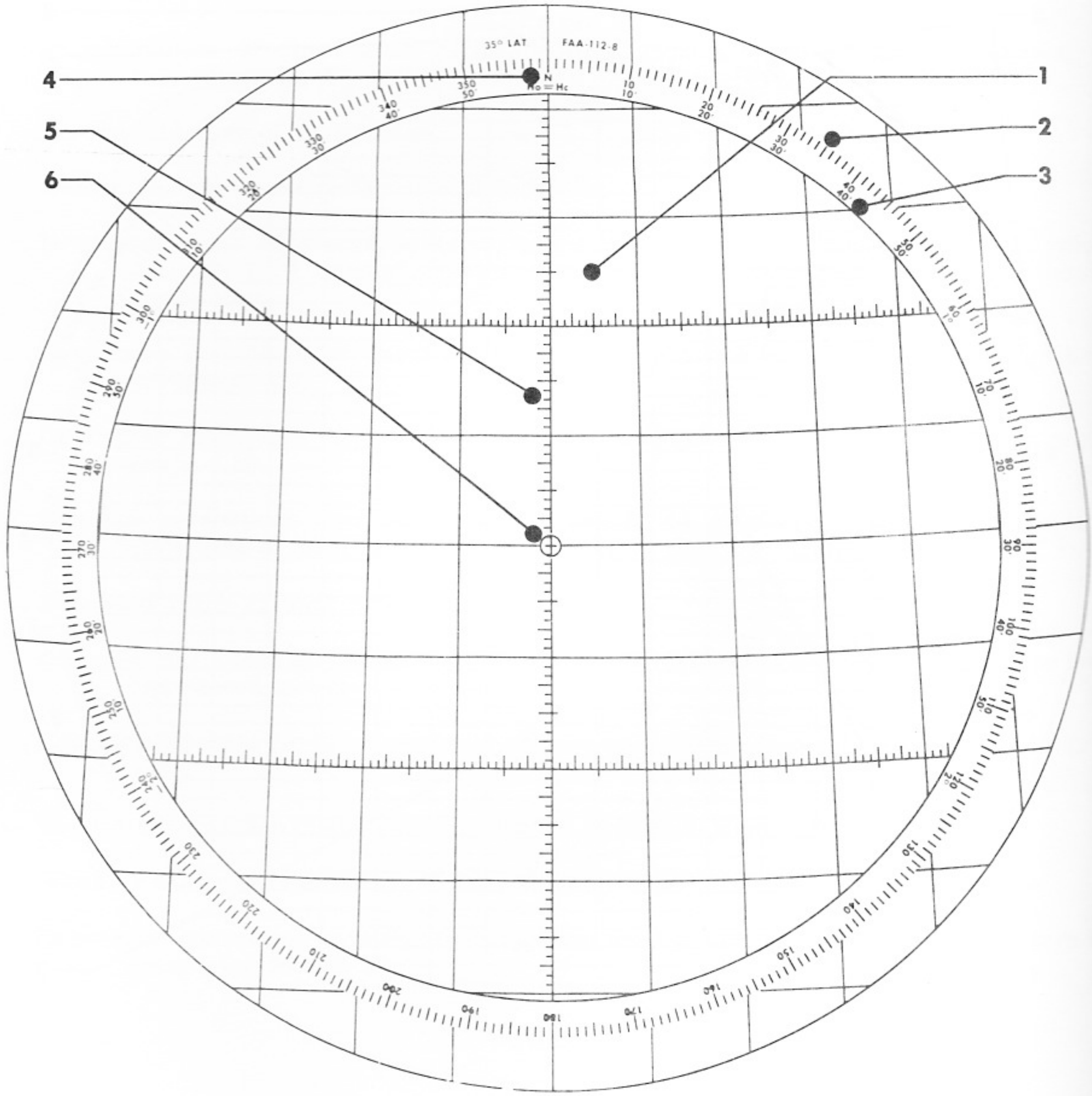


FIGURE 13

SECTION V
IDENTIFICATION OF PLOTTER SCALES

Using figure 12 identify the scales, indexes, and templates as follows:

1 . . . BASE PLATE AND RECTALINEAR GRID. . .the primary disk of the plotter before the chart projection templates are fastened on.

2 . . . DISTANCE SCALE. . .the numbered parallels on the base plate commencing with -240 and extending up to +240.

3 . . . TRUE INDEX. . .the heavy black arrow at the top of the disk.

4 . . . SET Hc INDEX. . .the annotation adjacent to the True Index.

5 . . . VARIATION & INTERCEPT DISTANCE scale. . .the scale commencing at 8 o'clock position of the disk with the number 120 and decreasing in a clockwise direction to zero at the True Index then increasing in value clockwise to 120 at the 4 o'clock position.

Using figure 13 identify the scales and indexes as follows:

1 . . . TEMPLATE. . .the series of secondary disks used as overlays for plotting purposes.

2 . . . PERIPHERAL AZIMUTH SCALE. . .the scale commencing at 12 o'clock with North and increasing clockwise through 360° and used for establishing direction on the plotting disks.

3 . . . SUBTRACTION SCALE. . .the minor scale immediately adjacent to the peripheral azimuth scale commencing with -2° at the 240 position and increasing clockwise to +2° at the 120 position.

4 . . . HO = HC index. . .the zero point of the subtraction scale.

5 . . . THE GRATICULE. . .the family of parallels and meridians used for establishing geographic position. Note the latitude index just above and to the left of North.

6 . . . GROMMET. . .the pivot point or attachment point for the templates.

ORIENTATION OF PLOTTER FOR CALCULATION OF INTERCEPT DIST.

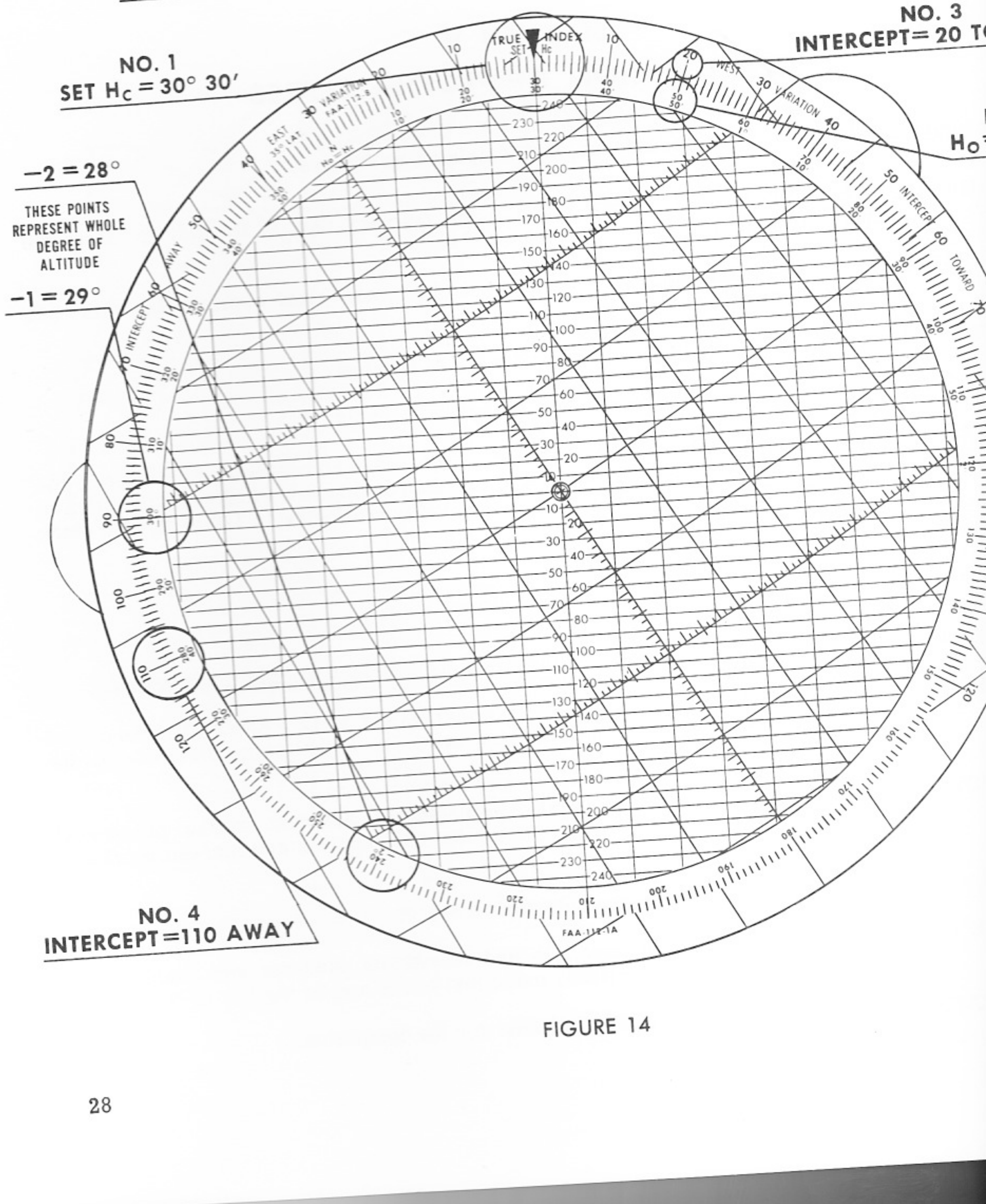


FIGURE 14

SECTION VI

FUNCTION OF PLOTTER SCALES

The base plate (1, figure 12) is constructed with a family of mutually perpendicular lines spaced 10 units apart in a North/South direction and 30 units apart in an East/West direction. The scale approximates the length of a minute of arc at 35° latitude on a GNC 1:5,000,000 scale navigation chart. By utilizing the full range of values presented on the base plate it is possible to describe a distance of 480 nautical miles (2, figure 12).

The TRUE INDEX and SET Hc indexes are the reference points against which the plotting templates are oriented to establish direction and/or to make subtractions (3, 4, figure 12).

When the VARIATION & INTERCEPT DISTANCE scale is used as a magnetic reference it becomes a 'read-in' point to the matching peripheral azimuth scale of the plotting template. When it is used as an Intercept Distance scale it is a 'read-out' point coming from the minor subtraction scale adjacent to the peripheral azimuth scale of the plotting template (5, figure 12).

Six of the templates (1, figure 13) are constructed at a scale of approximately 1:5,000,000. The template for 35° North being equivalent to the GNC chart of that latitude. The remaining templates take the length in inches of a minute of latitude from the 35° template and have their meridians converge at a cosine rate with reference to that length. Read-out of geographic position is accurate to less than 2 miles.

One of the six GNC scale templates has mutually perpendicular lines for plotting in polar latitudes using grid reference or for use at equatorial latitudes.

The seventh template is constructed at a scale of 1:2,000,000 inches, approximately equal to the JN chart projection at the Equator, making the template satisfactory for polar navigation legs, equatorial latitudes, and for developing a fix as a range and bearing from the grommet as is the practice with older computers. In this latter case the base plate grid is taken as being 1 mile increments rather than 10.

The peripheral Azimuth scale (2, figure 13) allows the navigator to align the plotting surface with the True Index of the base plate. When 360° is aligned with the True Index the surface becomes a conventionally oriented chart. With convergence angle, or local longitude properly considered, the chart can be used for polar navigation.

With Star Azimuth set against the Index it is possible to plot the intercept value (difference between Ho & Hc) as a range and bearing from either the grommet or from an arbitrary point selected on the plotting surface.

The plotting template has a minor subtraction scale adjacent to the peripheral azimuth scale for use in calculating Intercept Distance. It is annotated with values, commencing at 8 o'clock position of the template, ranging from minus 2° (which is 28° of Hc in this problem) to plus 2° (which is 32° of Hc in this problem) see 3, figure 13. Preparatory to making a celestial observation the navigator aligns the plotting disk against the True Index in such a manner that the minutes of Hc appear under the SET Hc point of the base plate. This orientation places the 360° position of the True Azimuth ring (4, figure 13) counter clockwise to the index and represents the Hc of the body in whole degrees. . .30° in this problem.

For example, let the computed altitude of the body be 30°30'. . .then an observed altitude which is also 30°30' should yield a zero value of intercept. With the 30'' portion of the scale set against the True Index, a measured value of 30°30' will be read into the subtraction scale at this same point resulting in a zero intercept.

Assume that Ho is found to be 30°50', then noting figure 14 we find at '1' the value 30 set against the SET Hc index, Ho =Hc just to the left of the index, and at '2' the number 50. Reading out from this number to the scale on the base plate we find the number 20 (3, figure 14) and taking the instruction of the base plate 'Intercept Toward' we plot towards the sub-point of the body from the assumed position used in the sight reduction.

The advantage of this scale does not become apparent until large intercepts are considered. Assume the Ho had been 28°40' now find the intercept distance. Since Ho =Hc occurs at even degrees, in this case 30°, minus 1° on the template must be a value of 29°, and minus 2° must be equivalent to 28°. Then with the template oriented as above note the Intercept that has been asked for is 110 miles AWAY (4, figure 14).

SECTION VII

DESCRIPTION OF PLOTTER SCALES

7.1 PLOTTING THE FIX FROM GEOGRAPHIC COORDINATES OF ASSUMED POSITION.

7.2 PLOTTING THE FIX AS A RANGE AND BEARING FROM THE GROMMET.

7.3 COMPLETE SIGHT REDUCTION AS A VECTOR SOLUTION.

7.4 EVALUATING AN MPP.

7.5 LANDFALL PROCEDURE FOR CONTROL TIME PROBLEMS OR CELESTIAL BOMBING.

7.6 DEAD RECKONING PROBLEMS.

7.1 PLOTTING THE FIX FROM GEOGRAPHIC COORDINATES

The advantage of using this method for plotting the celestial fix is that the position obtained does not need to be transferred to a chart to have significance thus the speed of the hand-held computer solution is retained without loss of the advantage of evaluating the fix on a chart. The Present Position being carried by the Automatic DR computer may be more easily updated.

Prepare the plotting template prior to fix time by assigning values of latitude and longitude to the graticule (figure 15). It is suggested that the preflight DR track be drawn on the template during mission planning.

At the time the celestial precomps are calculated annotate the template with the assumed position used in the sight reduction utilizing the latitude and longitude prepared earlier. In the following illustration (4, figure 15), assumed position is 36°N latitude and 97°W longitude. Track is 060°. Assumed position is plotted as near the 'entry' edge of the template as is convenient to allow for a second fix later on or a turning point, etc.

To plot the fix the navigator rotates the plotting disk so as to align the Star ZN with the True Index (1, figure 16) then plots the Line of Position parallel to the horizontal lines of the base plate at a distance from the assumed position (2, figure 17) equal in magnitude to the Intercept Distance. When Intercept is TOWARD, the horizontal line, or LOP, is drawn above the assumed position, when the Intercept is AWAY the LOP is drawn below the assumed position (3, figure 16).

PLOTTING ASSUMED POSITION, LAYOUT OF TRACK AND GRATICULE

NO. 1
NORTH ORIENTED

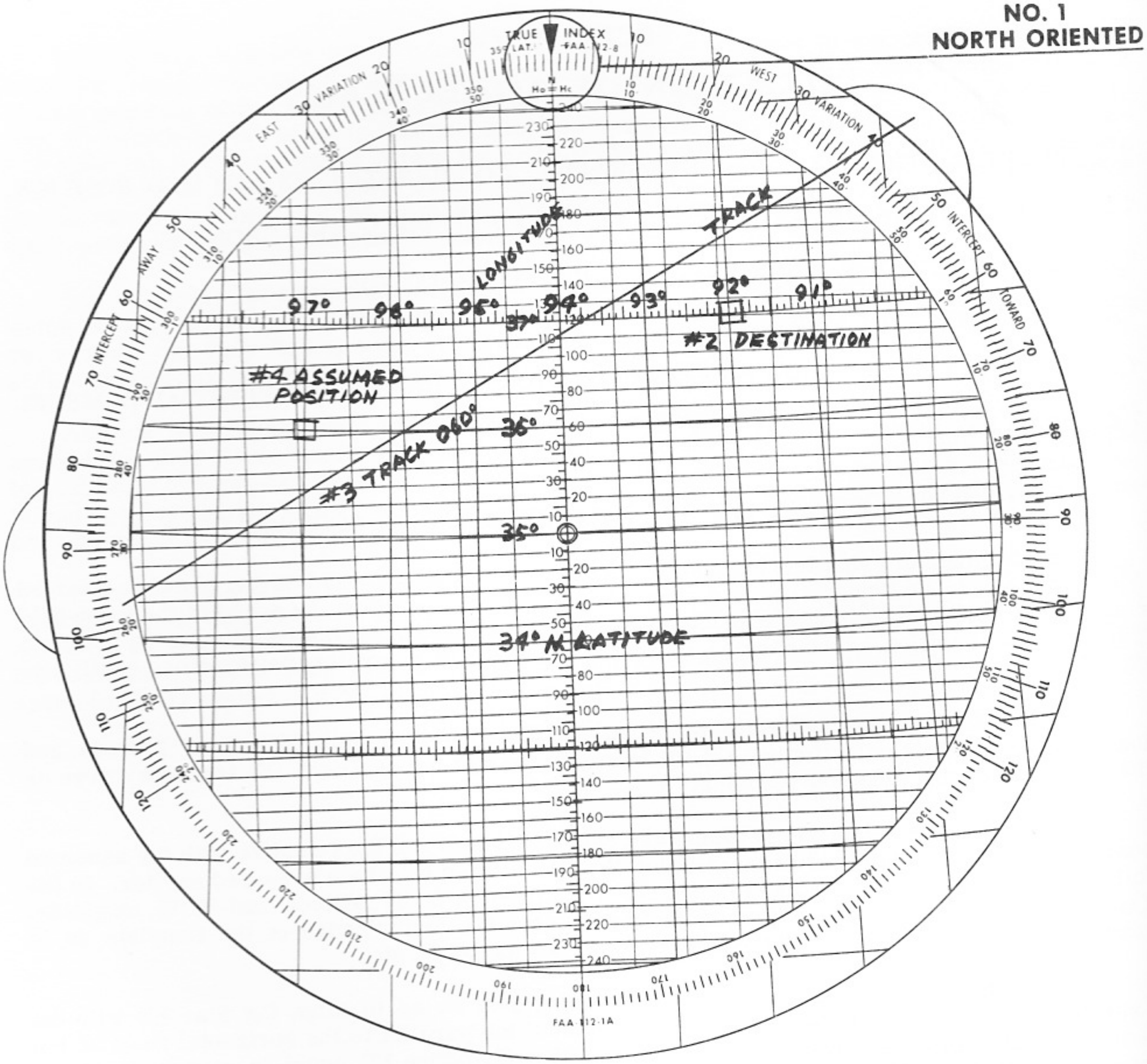


FIGURE 15

PLOTTING THE LINE OF POSITION

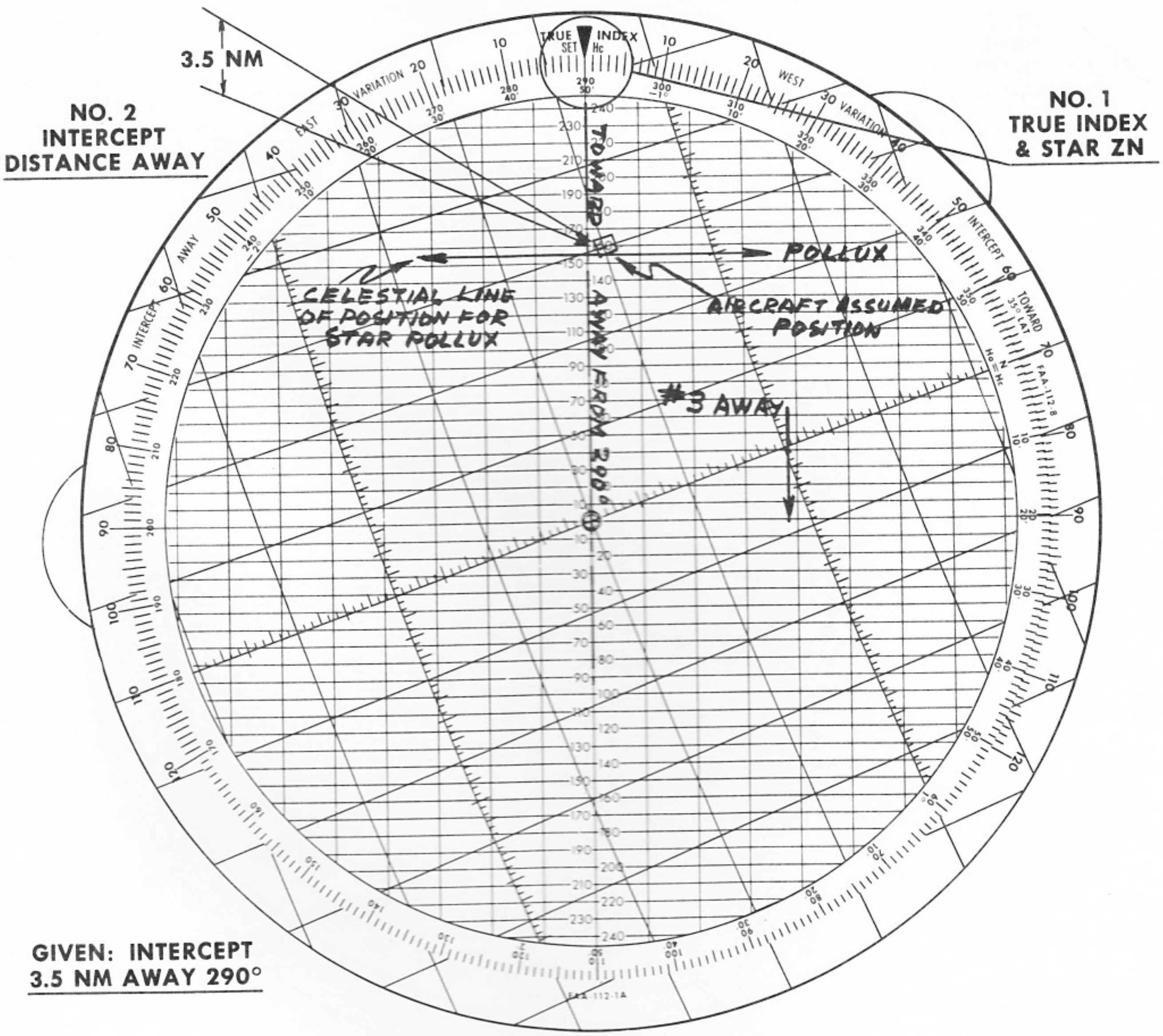


FIGURE 16

PLOTTING A 3-STAR FIX

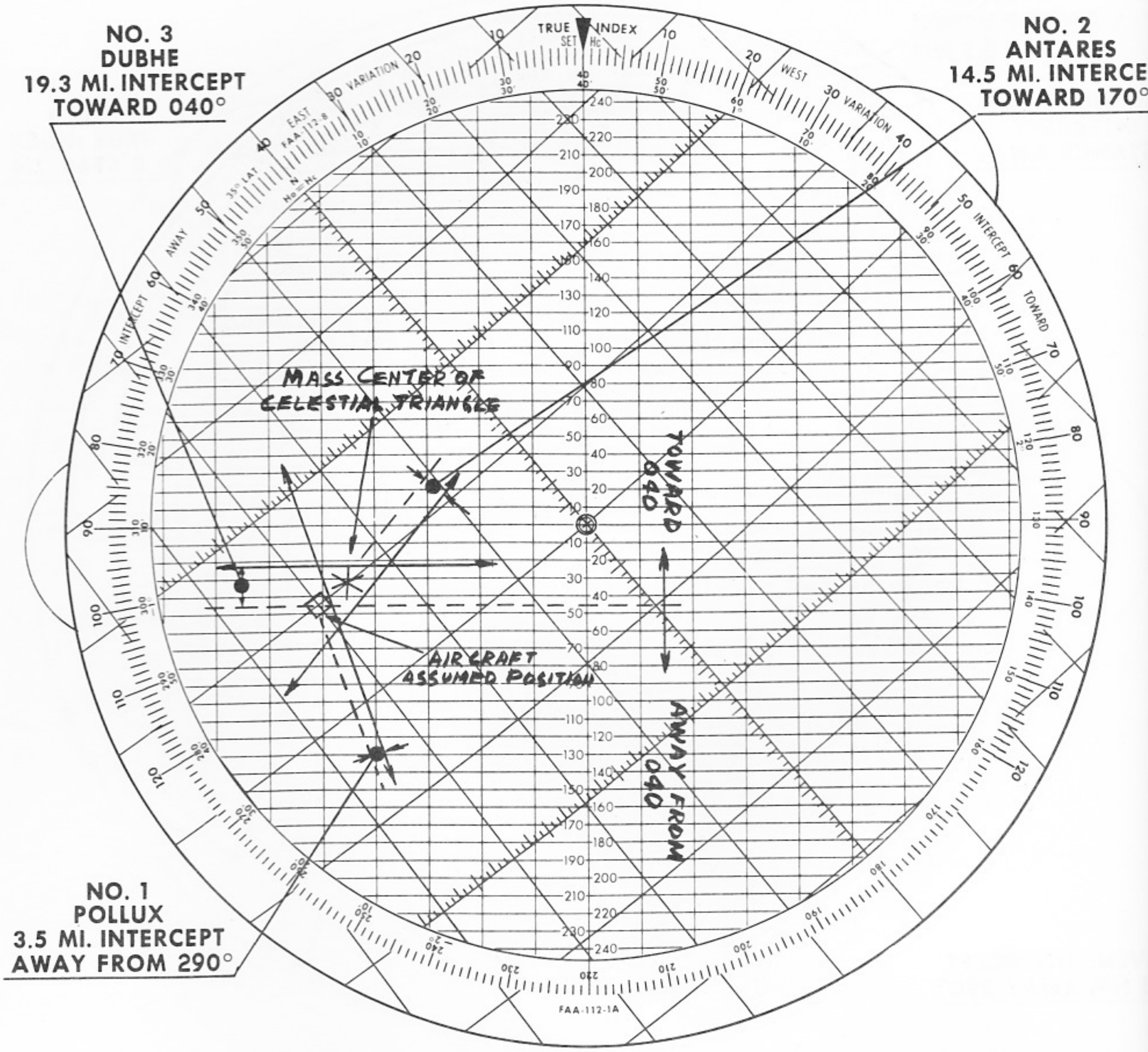


FIGURE 17

PLOTTING CORIOLIS CORRECTION

NO. 1
SET INDEX AT
90°+TRACK
(90°+060°=150°)

NO. 2
MASS CENTER OF
TRIANGLE MOVED 7½ MI.
TOWARD 150°

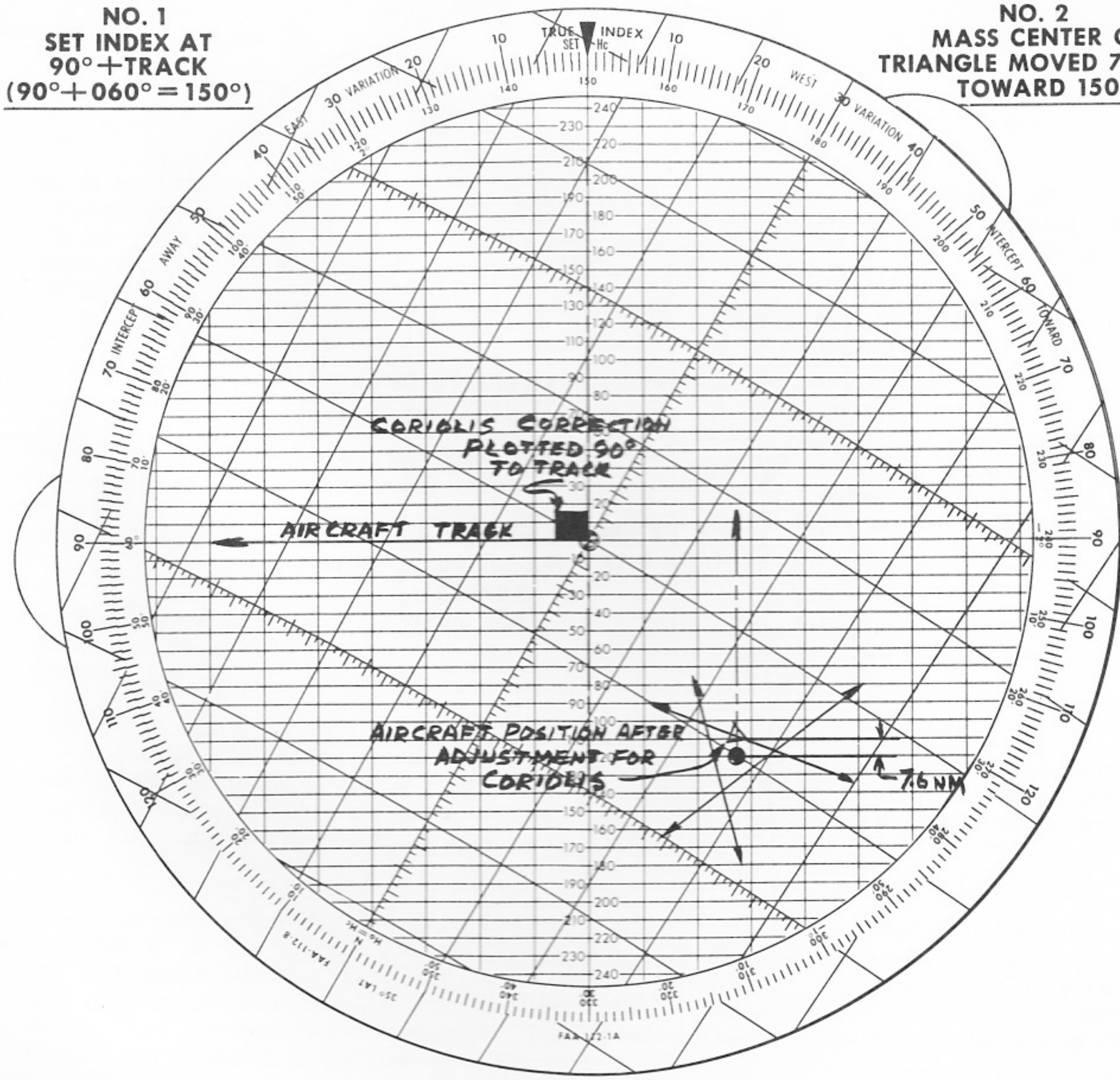


FIGURE 18

EXTRACTING LATITUDE & LONGITUDE DIFFERENCES FOR CORRECTING AUTOMATIC DR COMPUTERS

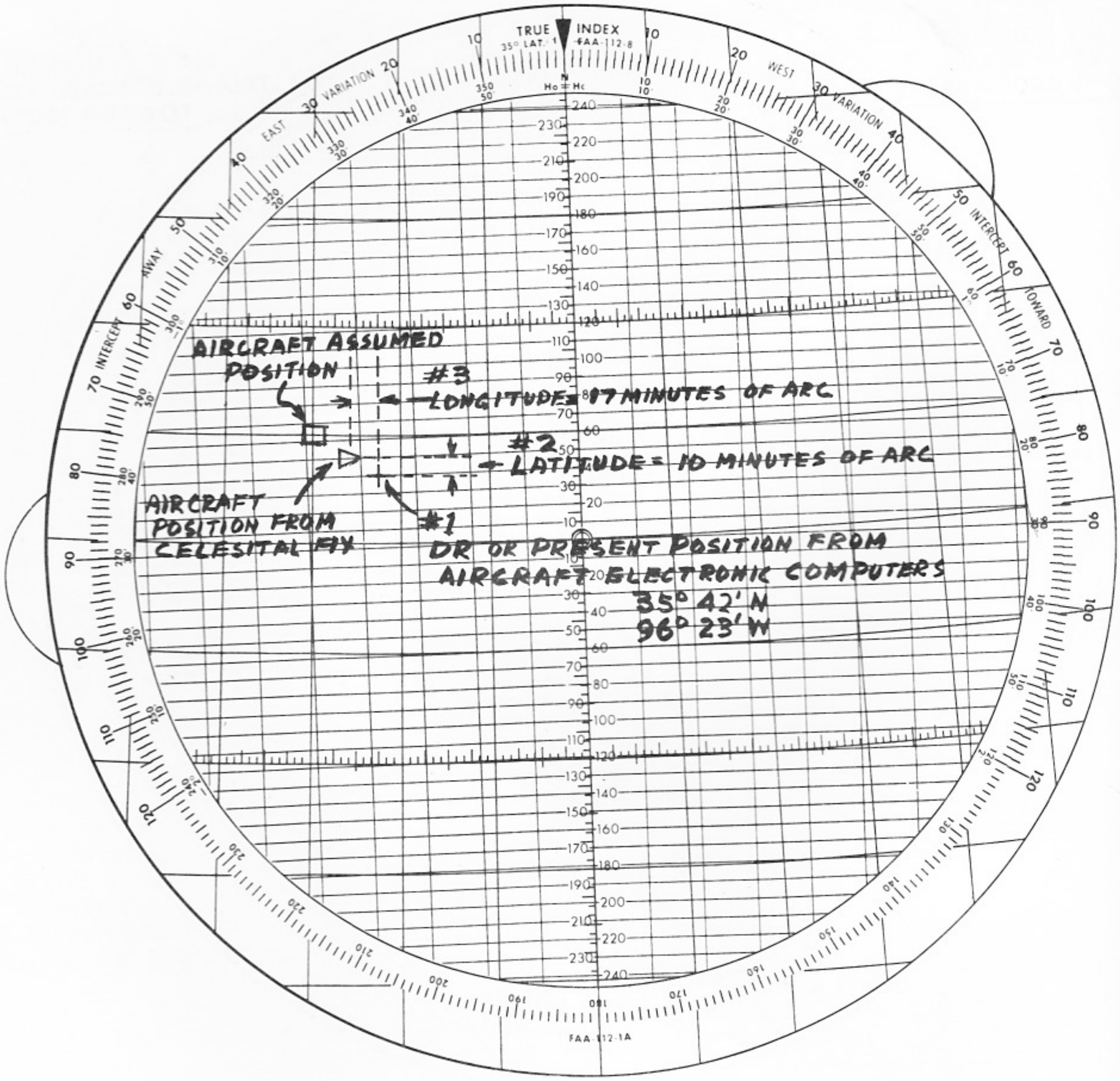


FIGURE 19

Each body is treated in the same manner. First the ZN is aligned with the True Index then the LOP is plotted as line normal to the azimuth of the star either Toward or Away from the Assumed Position as necessary. The following values of Intercept distance were chosen arbitrarily and do not relate to the slide rule computations of the previous discussion.

STAR	POLLUX	ANTARES	DUBHE
Intercept	3.5 Away	14.5 Toward	19.3 Toward
ZN	290°	170°	040°

Given an Assumed Position of 36°N and 97°W, plotted as shown in figure 16, the intercept and azimuth data given above, plot the LOP's and determine the coordinates of the celestial fix. Figure 17 pictures a completed problem. To read the coordinates of the fix return the template to North orientation by placing 360° in line with the True Index. The fix falls at 35°59.5'N, 96°40'W.

The celestial fix must now be adjusted for coriolis effect if the correction was not taken care of in the calculation as suggested in paragraph 3.6, Section III. There are two methods which may be employed. . .the assumed position may be moved prior to plotting the fix, or the fix itself may be moved for the amount necessary. In either case the technique is the same. The template is rotated to bring the value (Track +90°) into alignment with the True Index. The fix, or assumed position, is then moved Toward the top of the plotter by an amount equal to the necessary correction (figure 18).

To compensate for precession and nutation effects, the plotting template is rotated to bring the desired azimuth value into alignment with the index and the correction applied Towards the top of the plotter.

The evaluation of the fix is completed by returning the template to North orientation and plotting the DR position of the aircraft for the time of the fix (1, figure 19). The DR position may be the result of the navigator's chart work or it may be the position carried by the automatic DR computer (e.g. the D-2 nav unit in B-47 aircraft).

If the navigator desires to update his chart work the fix is transferred in its proper coordinates to the chart. If the automatic DR computer is to be corrected the DR position and the completed celestial fix are evaluated for a difference in latitude and a difference in longitude values in minutes of arc (2, 3, figure 19). The differences are used to correct the North/South and East/West read-outs. This procedure allows the navigator the option of setting the correction in at his convenience.

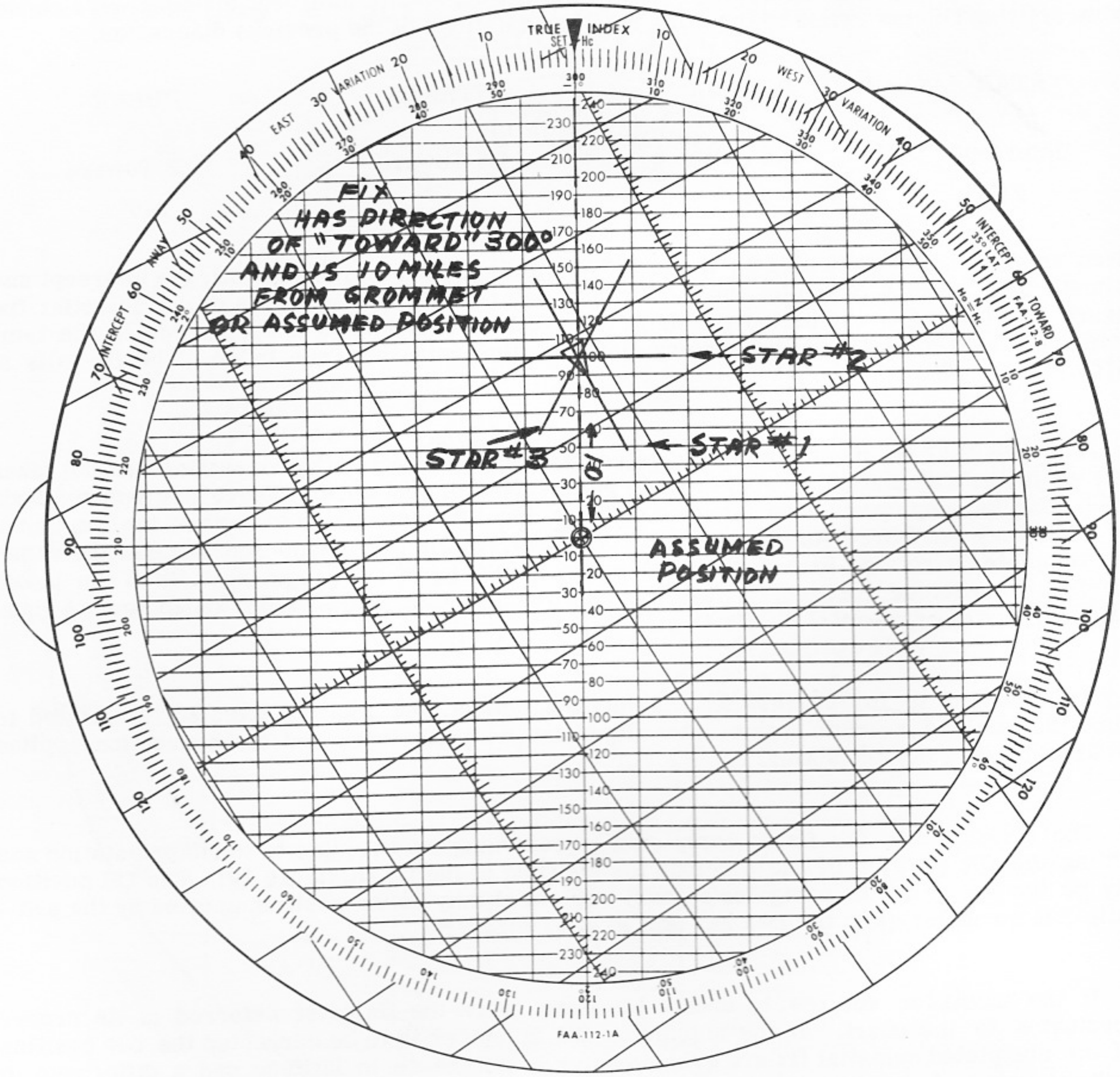

FIX
HAS DIRECTION
OF "TOWARD" 300°
AND IS 10 MILES
FROM GROMMET
OR ASSUMED POSITION
STAR #2
STAR #3
STAR #1
ASSUMED
POSITION
TRUE INDEX
FAA-112-1A

FIGURE 20

7.2 PLOTTING THE FIX AS A RANGE AND BEARING

The range and bearing fix may be useful when extreme precision of plotting accuracy is desired and the intercepts are not too long. It further lends itself to an evaluation of automatic astro tracker output values in that a number of Lines of Position or Fixes may be plotted to ascertain the tendency of the navigation system's DR computer to drift. The procedure is analagous to rating gyro drift or precession in polar navigation.

The grommet or pivot point of the plotter (6, figure 13) is taken to be the aircraft assumed position. Plotting of Line of Position information is exactly as described in 7.1 of Section VII. Intercepts TOWARD are plotted up from the grommet Toward the top of the plotter while intercepts AWAY are plotted down from the grommet. It is important to remember that the completed fix must be transferred to a chart as a range and bearing from the assumed position before the fix has significance. (Figure 20 shows a completed range and bearing fix.)

The introduction of astro trackers has caused a change in the technique of celestial fixing in that motion corrections and acceleration errors may be disregarded. However, the output of the tracker and computer, displayed as an Intercept as well as an Ho, tends to oscillate through a modified sinusoidal wave shape depending on the type of platform on which it is mounted, electrical noise in the circuitry, and stability of the aircraft auto-pilot system. The combination of effects makes it desirable to withhold corrections to the automatic DR computer until such time as it has been definitely established that a true navigation error exists in the system.

The most simple means for performing this evaluation is to plot a number of range and bearing fixes on the plotter, using the grommet as assumed position, determine the magnitude and bearing of the mean error, and establish with respect to time the tendency of the system to drift in a particular direction. If the system is drifting, then the most recent fix may be used to update the DR computer. In addition the rate of drift can be used to establish a measure of distance off course for any point in time. This knowledge can be used to set a false wind in the system or to move the destination counters in a direction opposite to the direction of drift.

7.3 COMPLETE SIGHT REDUCTION AND FIXING AS A VECTOR SOLUTION

It is possible to completely resolve the celestial fix on the plotter side of the computer thus bypassing the slide rule (with minor exceptions). This facility provides the navigator with the means to speed the determination of fix information although it does not provide a fix having as high degree of accuracy as the arithmetically computed fix. The loss of accuracy should not exceed 5 miles at a maximum.

MOVING ASSUMED POSITION FOR MOTION OF BODY

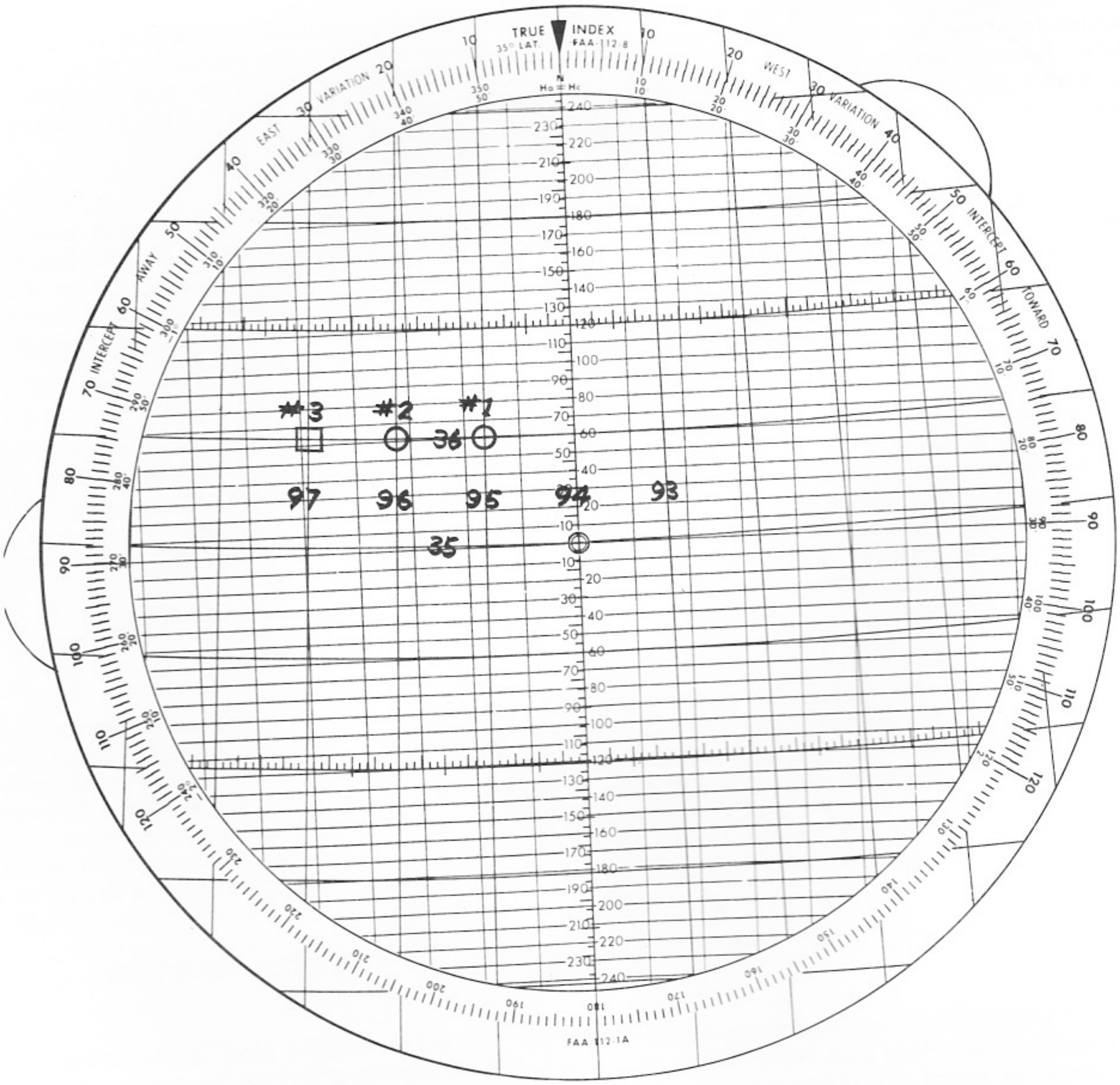


FIGURE 21

To assist in visualizing the technique described below the navigator is reminded that Motion of the Body may be thought of as a displacement of position at a rate of 15 minutes of arc per minute of time (longitude direction) rather than as a displacement in nautical miles as is used in the arithmetic solution. As a result the correction for Motion of the Body may be accounted for simply by moving the assumed position East for observations made earlier than fix time and West for observations made later than fix time.

Figure 21 illustrates the locus of points for an assumed position adjusted for observations to be made 4 minutes and 8 minutes early. The fix time in this illustration is taken as 1000Z and the assumed position for the 'on time' shot is annotated at 36°N and 97°W. Since the 1000Z observation will be last it is labelled #3.

The middle shot is to be made 4 minutes early at 0956Z, so the assumed position is moved EAST one degree along the 36th parallel (15' of longitude times 4 minutes of time=60' of long). This position is annotated #2 (2, figure 21). The first observation will be made at 0952Z so must be moved for 8 minutes of time. The assumed position is moved EAST 2 degrees to 95°W. Assuming the observations are completed on time the corrections for Motion of the Body are now complete.

To compensate for Motion of the Observer the navigator must move the Lines of Position along Track at a ground speed rate. If the GS is 420 knots he must move the LOP's forward at a rate of 7 miles per minute for observations made earlier than fix time, and he must retard them at a rate of 7 miles per minute for observations made after fix time. (The slide rule GS tab may be adjusted to best known GS and the rate/minute read on the Motion of Observer scale opposite 0°, e.g. with 420 knots set against the GS index read 7 in the Motion of Observer window opposite zero.)

To make use of this information align the plotter so as to bring Track being made good opposite True Index then advance Assumed Positions #1 and #2 towards the top of the plotter, towards 060°, on lines which are parallel to the meridians of the base plate (figure 22).

For example, with a track of 060°, a GS of 420 knots, and a shooting schedule of 8 minutes early, 4 minutes early, and On Time, position #1 would be moved 56 miles towards the top of the plotter (1, figure 22) and position #2 would be moved 28 miles in the same manner (2, figure 22).

The next step is to determine Intercept from a comparison of Ho and Hc. The intercepts are plotted from their respective assumed positions, along the azimuths of the respective stars, in the manner used for the two previous methods of plotting a fix.

Finally, the fix must be adjusted for coriolis, precession and nutation corrections as in the other fixes. With practice it should be possible to plot a three star fix within a 60 second period without suffering serious loss of accuracy.

MOVING ASSUMED POSITION FOR MOTION OF THE OBSERVER

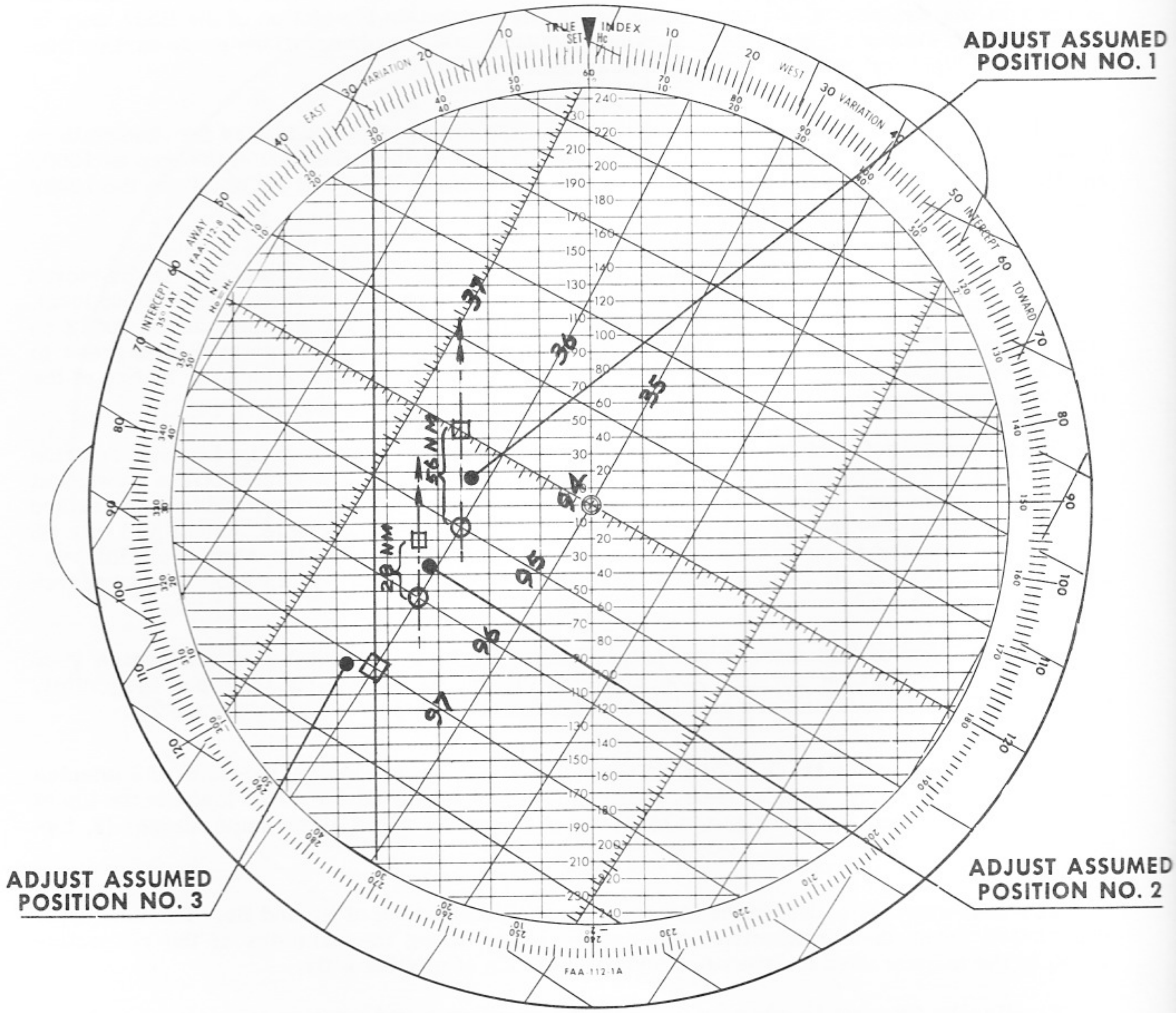
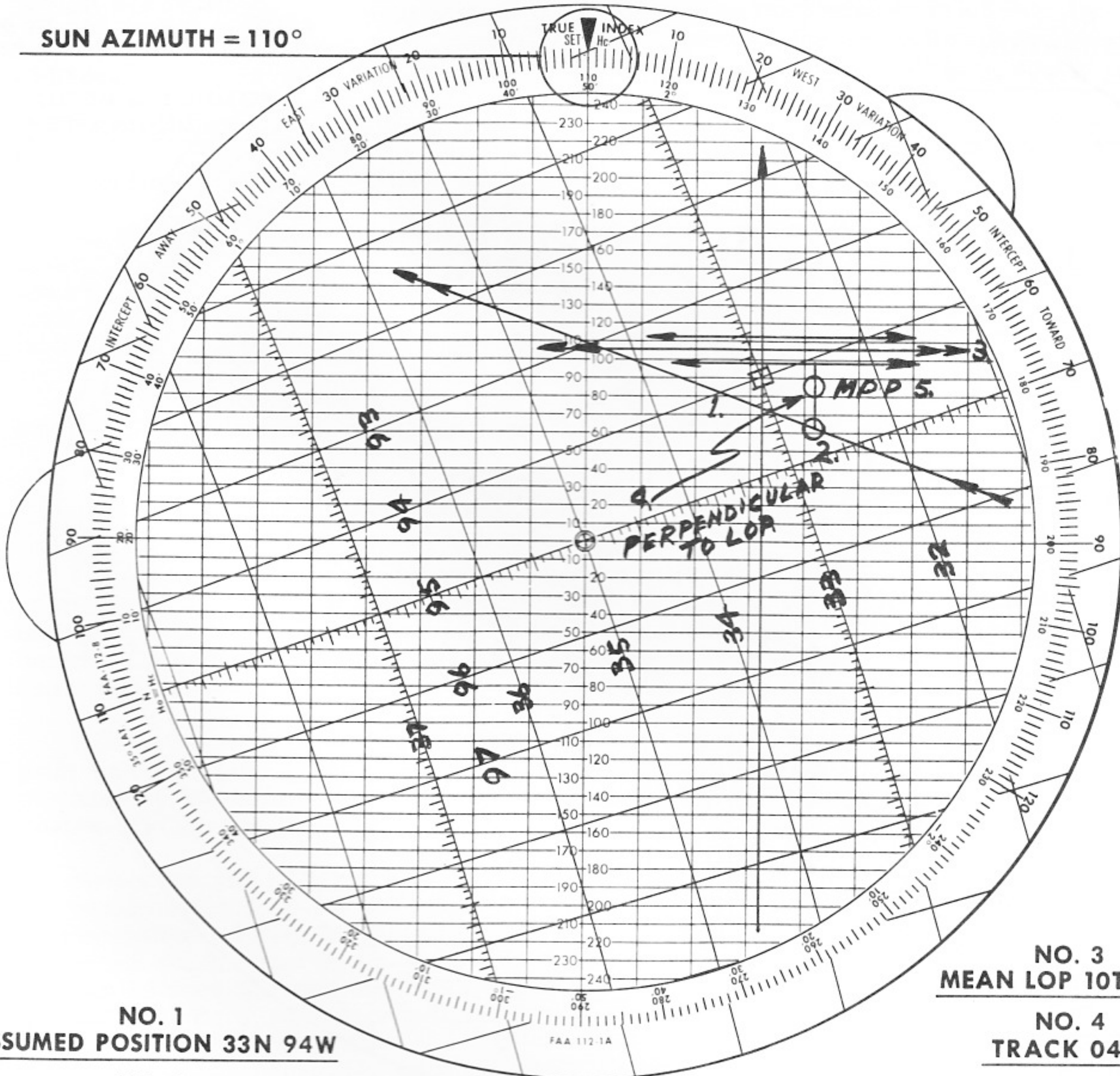


FIGURE 22

MOST PROBABLE POSITION EVALUATION

SUN AZIMUTH = 110°



NO. 1
ASSUMED POSITION 33N 94W

NO. 2
DR POSITION 3240N 9440W

NO. 3
MEAN LOP 10T, 110°

NO. 4
TRACK 040°

NO. 5
MPP 3235N 9422W

FIGURE 23

CONTROL TIME PROBLEM USING LANDFALL

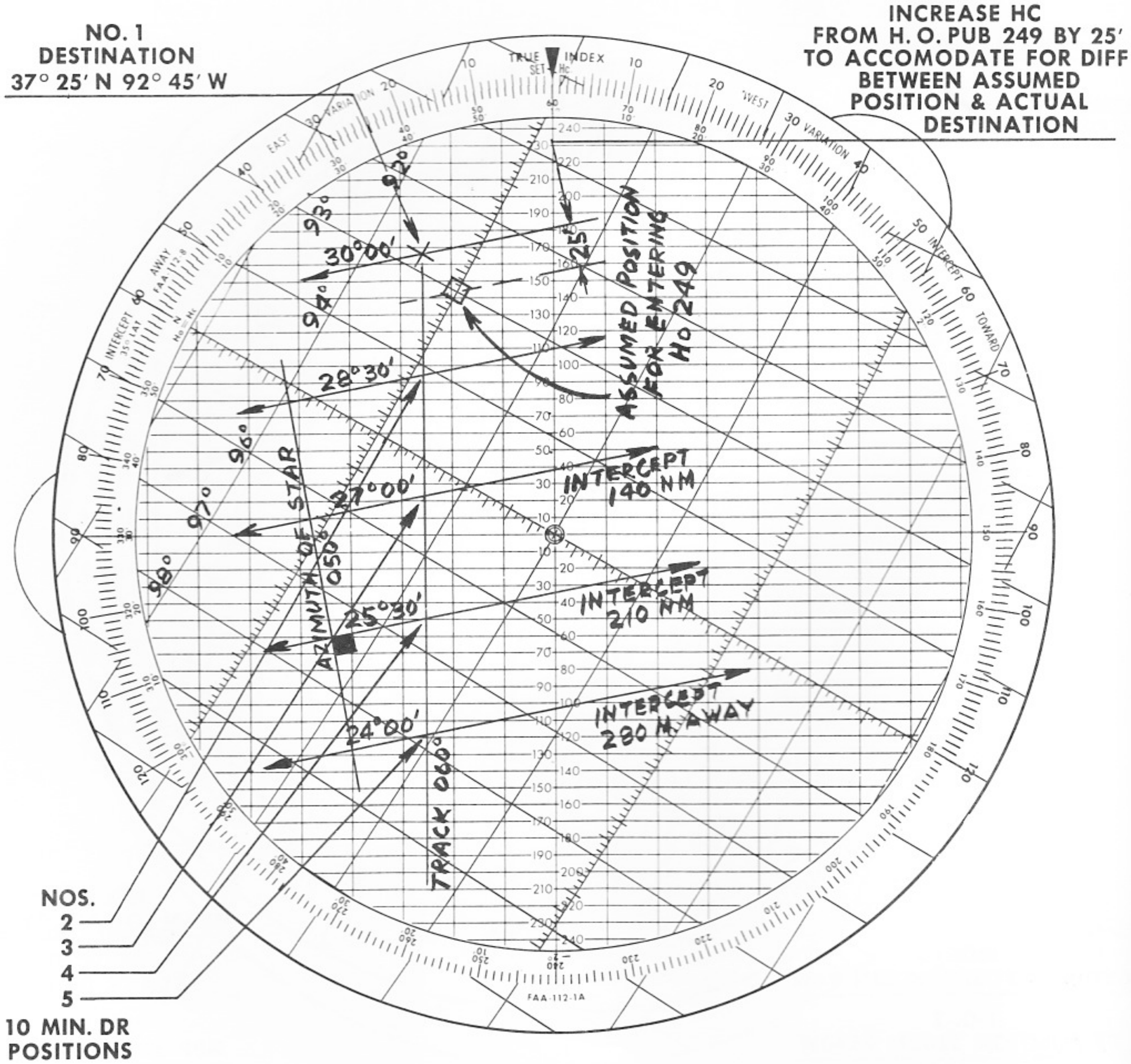


FIGURE 24

7.4 EVALUATING A 'MOST PROBABLE POSITION'

The single Line of Position is dealt with as readily on the plotter as is a 3-star fix. The assumed position is plotted as in paragraph 7.1, this section, the DR position is plotted using its true geographic coordinates, as is the Air Position if a knowledge of wind is required.

The true azimuth of the body is aligned with the True Index and an evaluation is made of the LOP by dropping a line from the DR position to the Line of Position such that it is parallel to the meridians of the base plate. . .in other words normal to the LOP (4, figure 23).

An MPP is constructed on the 'normal' based on the navigator's estimate of possible DR error. The plotter is then rotated to place the MPP below, and in line with, the Air Position, assuring that a line connecting the two (the wind arrow) is parallel to the meridians of the base plate. Wind direction is read under the True Index. Wind velocity is determined by counting the miles between the two points and relating it to time.

Finally, the navigation system DR counters are adjusted for the difference in latitude and longitude in minutes between the DR position and the MPP.

7.5 LANDFALL PROCEDURE FOR CONTROL TIME PROBLEMS OR CELESTIAL BOMBING

Occasionally there is a requirement for controlling the arrival time of an aircraft at a specific set of geographic coordinates by means of celestial information. Because of radar malfunction it may be necessary to locate the bomb release point by celestial fixing procedures. The use of a speedline landfall technique such as is described below is easily handled on the plotter.

Determine the ETA or Control Time to be made good at Destination and/or target release point and complete a computation of Hc for that point and that time. Using the template pertinent to the latitude of destination annotate the point and lay out the DR track into destination (1, figure 24).

Rotate the plotter to bring Track into alignment with True Index then strike off ten minute DR positions along the DR track (2, 3, 4, 5, figure 24), and annotate these points with the time of observation. From the slide rule side of the computer determine the Motion of the Body correction for the star to be used. Multiply Motion of the Body per minute by the number of minutes between intended observation time and control time and subtract this value from the Control Time Hc. . .for bodies in the East, and add the correction for bodies in the West.

Referring to figure 24, track is 060°, Control Time ETA is 1000Z for a destination 37°25'N 92°45'W, star has an azimuth of 050°, ground speed is 420 knots, Motion of Body is 9 miles per minute, and the times of observation will be 0920, 0930, 0940, 0950, and 1000Z. Hc for 1000Z is given as 30°00".

To find Hc for each of the times previously listed, proceed as indicated in the table:

0920	9 x 40 minutes=360' =6°,	then 30°00' minus 6° =24°00'
0930	9 x 30 minutes=270' =4°30',	then 30°00' minus 4°30' =25°30'
0940	9 x 20 minutes=180' =3°,	then 30°00' minus 3° =27°00'
0950	9 x 10 minutes= 90' =1°30',	then 30°00' minus 1°30' =28°30'

These numbers, Hc's, are noted at their respective positions on the DR track. The actual observation for each of the times is compared with the Hc values above to produce an Intercept with respect to destination. If the aircraft is at position #5 at 0920 the intercept will be 280 miles AWAY. The shot is plotted in the conventional manner.

The second observation is made on schedule and compared in the same manner. If the aircraft is on time, that is if ground speed is still 420 knots, the intercept at position #4 will be 210 miles AWAY. If the ground speed has changed, however, it will be reflected in an Intercept not coincident with position #4. The ratio of difference in intercept values to the interval between observations will result in an expression of ground speed.

If a standard DR computer is used to set up this proportion then under the value representing the last intercept will be found the new ETA to the control point.

Assume for purposes of illustration that the first intercept at position 5 was 280 miles and that the intercept for position 4 is 205 miles. The difference between these two values, 75 miles, is set over 10 (the time between observations), and ground speed of 450 knots determined over 60; new ETA under intercept of 205 miles is 27.4 minutes. ETA is therefore 0957.4Z. If the control time is to be made good then the aircraft must be slowed to 410 knots (205 miles over 30 minutes = 410 knots).

In the event that ground speed is not to be changed but the navigator wished to know the new star altitude for his ETA he could adjust the previous Hc of 1000Z by a factor of (-9 x 2.6 =23.4 minutes of arc). Then 30°00' minus 23.4 minutes =29°36.6'.

If the coordinates of a bombing target are adjusted for ATF, trail, and wind, the adjusted coordinates can be used as the object of the landfall.

To accommodate for the circumstance of control point not being in agreement with assumed position compare the two points on the plotter by aligning star ZN with True Index then measuring the miles between the two points. Correct Hc by the number of miles difference between the two points adding the value if destination is east of assumed position, and subtracting the value if destination is west of assumed position.

In this particular illustration, figure 24, the correction will be plus 25 minutes making the initial Hc at 1000Z, 25 minutes of arc greater than the value taken from H.O. Pub 249. In other words the Hc extracted from H.O. 249 would have been 29°35' to which the navigator added the 25' correction shown in the illustration and described above.

DEAD RECKONING, FIX TO FIX

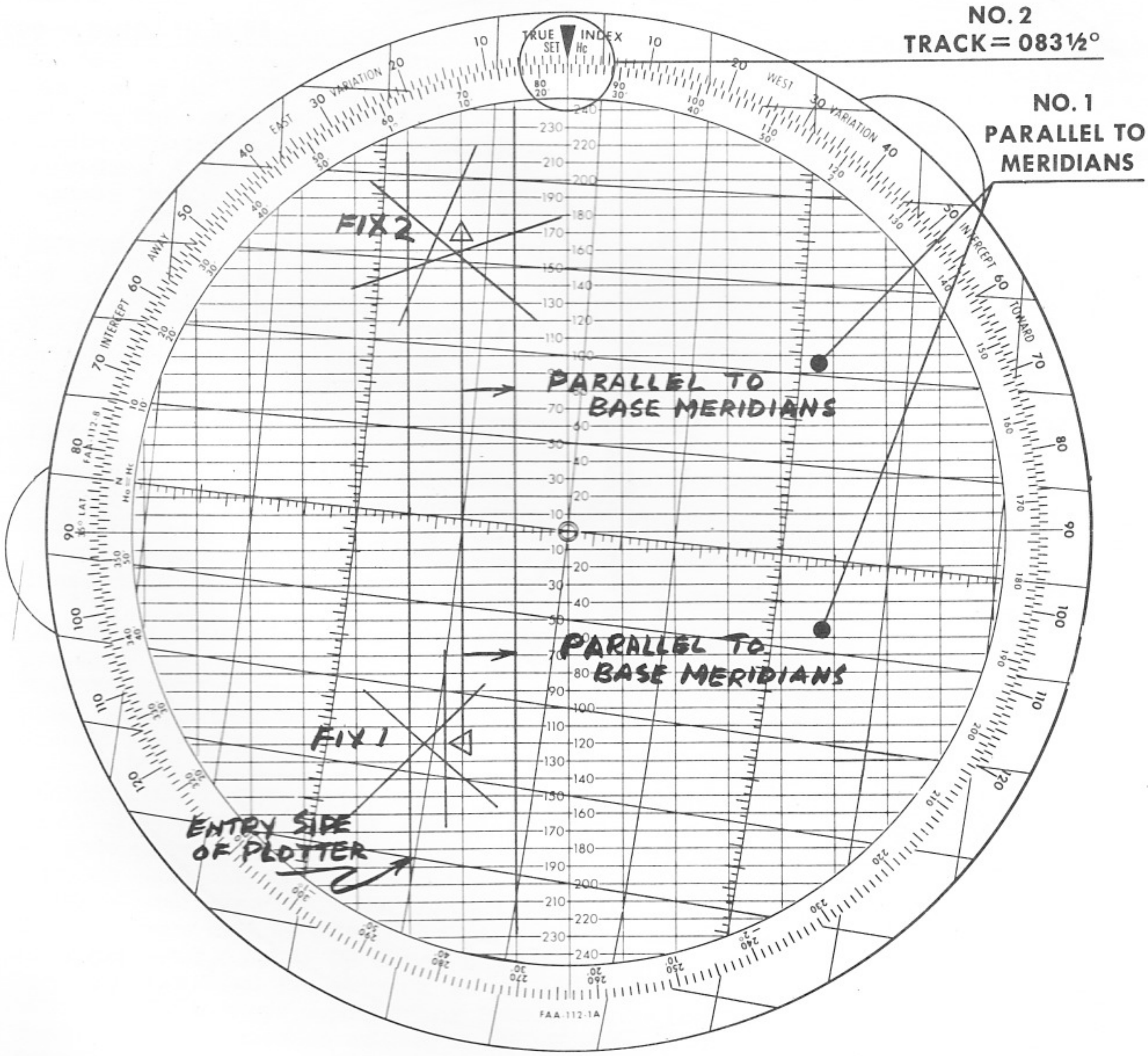


FIGURE 25

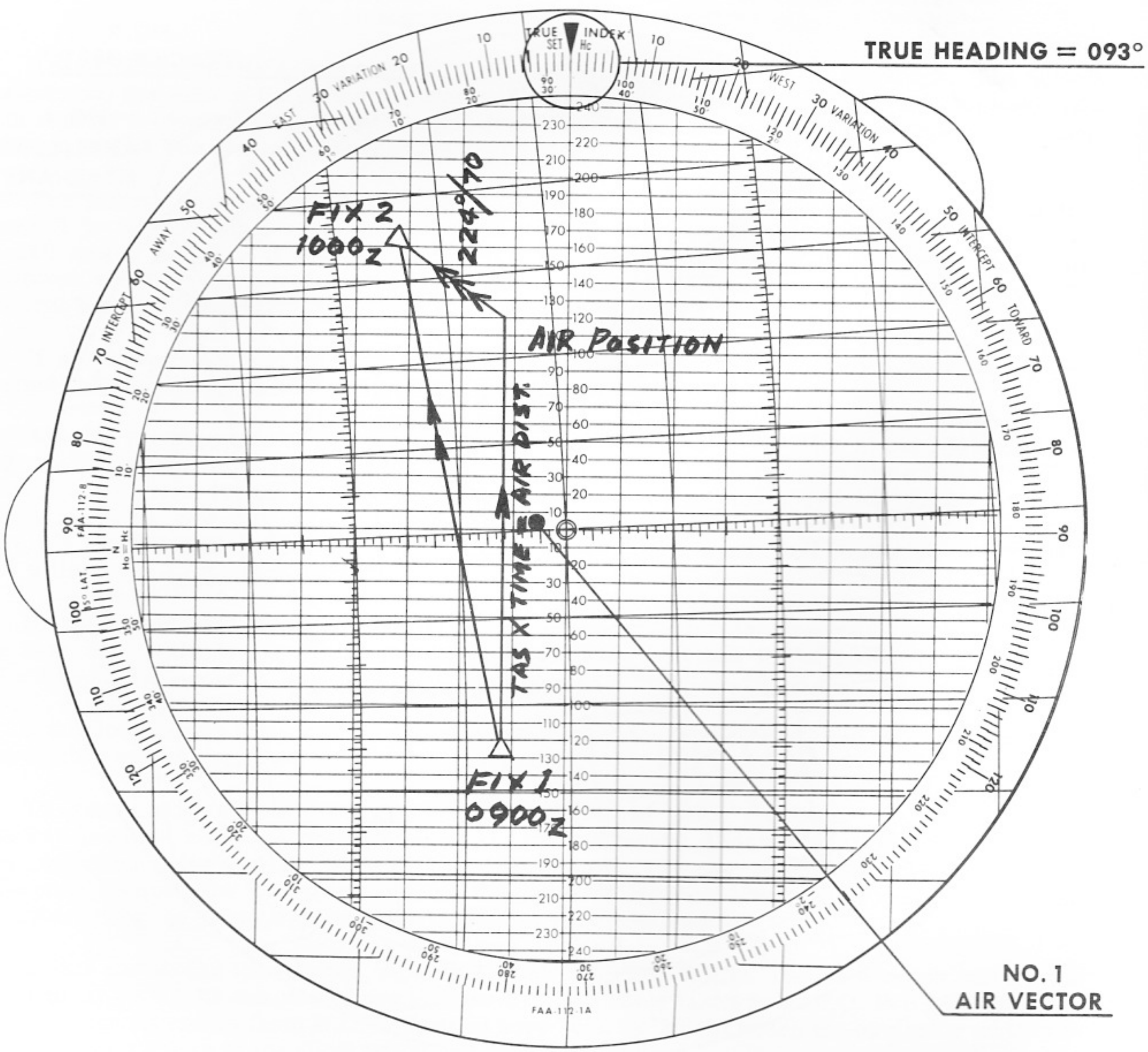

TRUE HEADING = 093°
FIX 2
1000Z
224°/70
AIR POSITION
TAS X TIME = AIR DIST.
FIX 1
0900Z
NO. 1
AIR VECTOR
TRUE INDEX
EAST VARIATION
WEST VARIATION
INTERCEPT AWAY
INTERCEPT TOWARD
FAA-112-1A

FIGURE 26

7.6 DEAD RECKONING PROBLEMS

Using the Plotting Template as a navigation chart the navigator may determine ground plot or air plot information, solve for wind, measure track made good or track to make good, and heading to steer.

TRACK MADE GOOD BETWEEN FIXES. . .the first fix of a pair should be plotted as close to the 'entry' side of the plotter as is convenient. When eastbound this places the first fix on the left side of the plotter, assuming that North is at the top. Track made good is determined by rotating the plotting template so as to place fix #2 above and directly in line with fix #1. The course or track line connecting the two points must be exactly parallel or coincide with the meridians of the base plate (1, figure 25). Track made good is read on the azimuth scale opposite True Index (2, figure 25). . .083.5° in the illustration.

DETERMINATION OF WIND. . .set aircraft average True Heading made good between fixes opposite True Index. Draw a vector up from fix #1 equal in length to TAS x t where 't' is the interval between fixes, so that it is exactly parallel to the meridians of the base plate (1, figure 26). Rotate the template so as to place fix #2 directly above Air Position on a line parallel or coincident with the meridians of the base plate. Read wind direction under True Index. Determine wind velocity by noting distance between Air Position and Fix #2. Multiply distance by time to determine velocity. In the illustration wind direction is 224° and wind velocity is 72 knots.

DETERMINATION OF ALTER COURSE. . .plot final fix as near to the 'entry' side of the template as is possible so that destination may be plotted on the same template (1, figure 27). Rotate the template so as to bring 'Destination' directly above Final Fix, the line joining them parallel or coincident with the base plate meridians, and read True Course to steer opposite True Index (2, figure 27). . .a course of 072° in the illustration.

DETERMINATION OF MAGNETIC COURSE. . .with the plotter oriented as described in the preceding paragraph locate on the VARIATION scale the value representing local variation. Note that East Variation is on the left side of the plotter and that West Variation is on the right side. Read-in from the variation scale to the azimuth scale to determine Magnetic Course to Steer (3, figure 27). Opposite 20° East read 052°.

CORRECTING COURSE FOR WIND. . .THIS IS AN AIR PLOT PROBLEM AND REQUIRES THAT THE WIND VECTOR BE DRAWN INTO destination or turning point. Rotate the template to bring wind direction into alignment with True Index. Draw a vector DOWN the template connecting with Destination or Turn Point (1, figure 28). Strike off 6 minute increments of wind along the vector commencing at Destination (1/10th of wind velocity) (2, figure 28). Estimate time enroute from Final Fix to Destination and locate the equivalent time on the wind vector. Rotate the template to place the point just annotated (air position for ETA) directly above Final Fix and on a line parallel to or coincident with the base plate meridians. Read Heading to steer opposite True Index (3, figure 28). Following the procedure for determining Magnetic direction outlined in the preceding paragraph modify True Heading to Magnetic Heading (4, figure 28).

DEAD RECKONING, MAKING GOOD DESTINATION

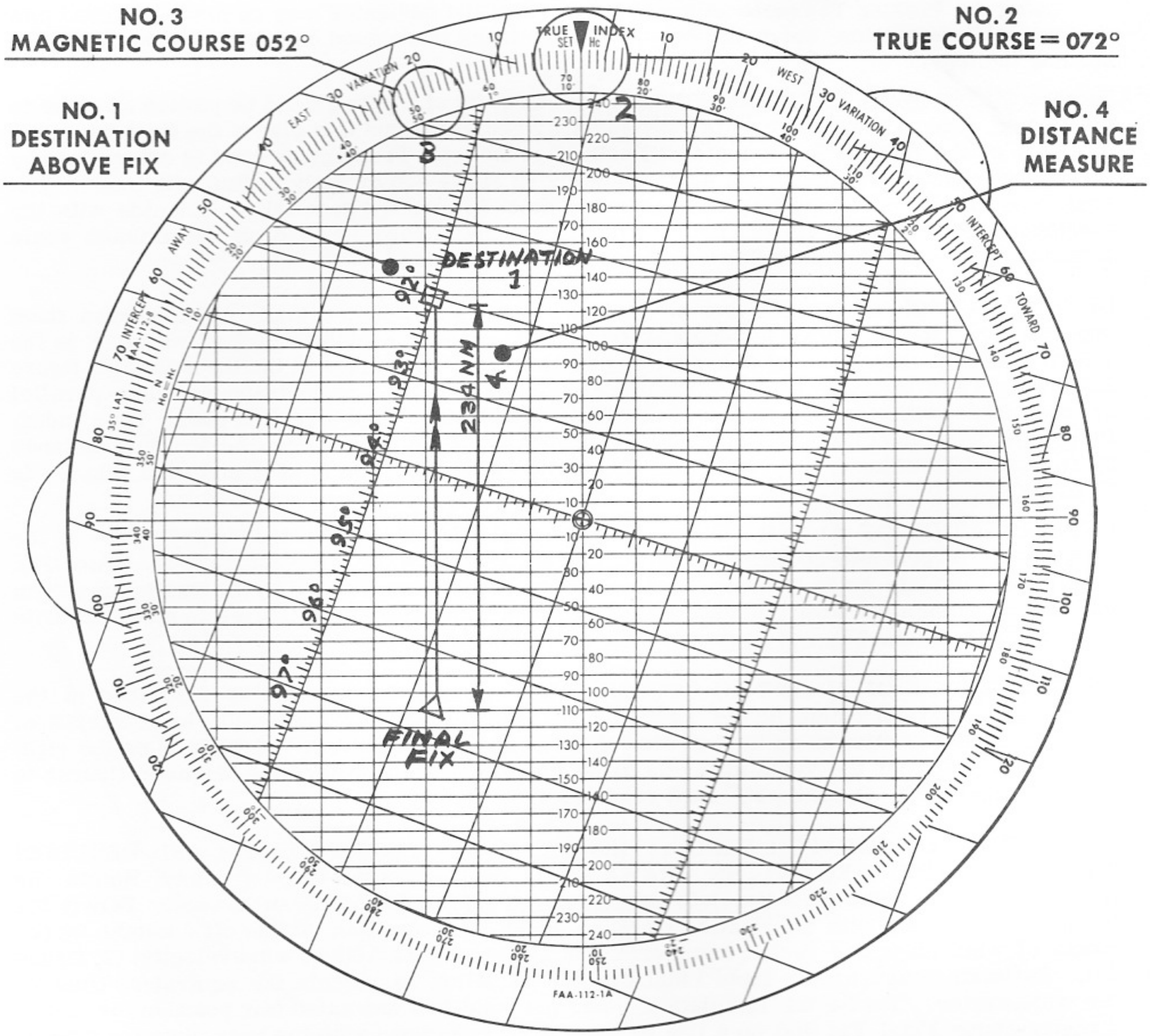


FIGURE 27

USE OF AIR PLOT WIND FOR HEADING DETERMINATION

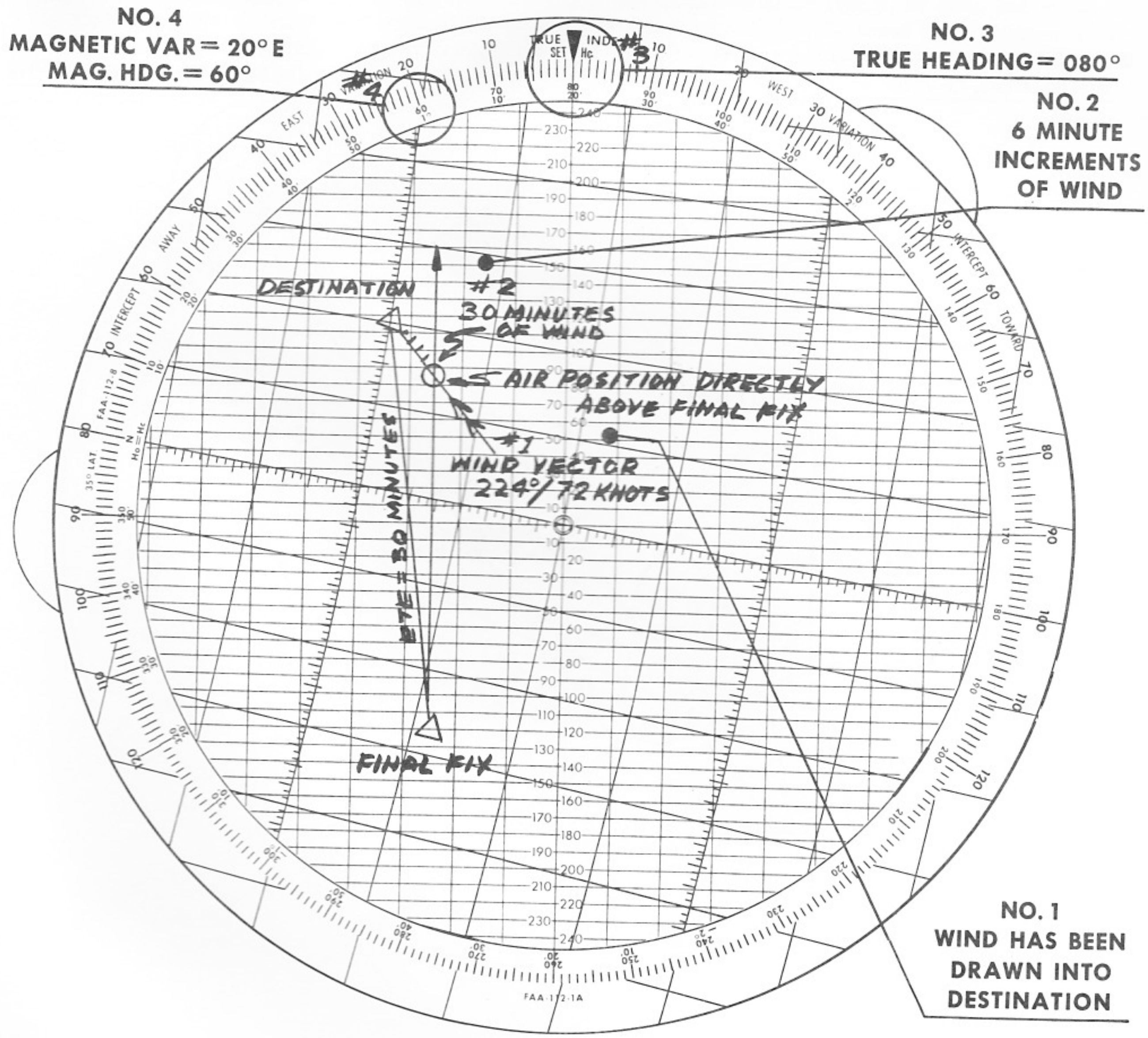


FIGURE 28

COMPLETE DR PROBLEM

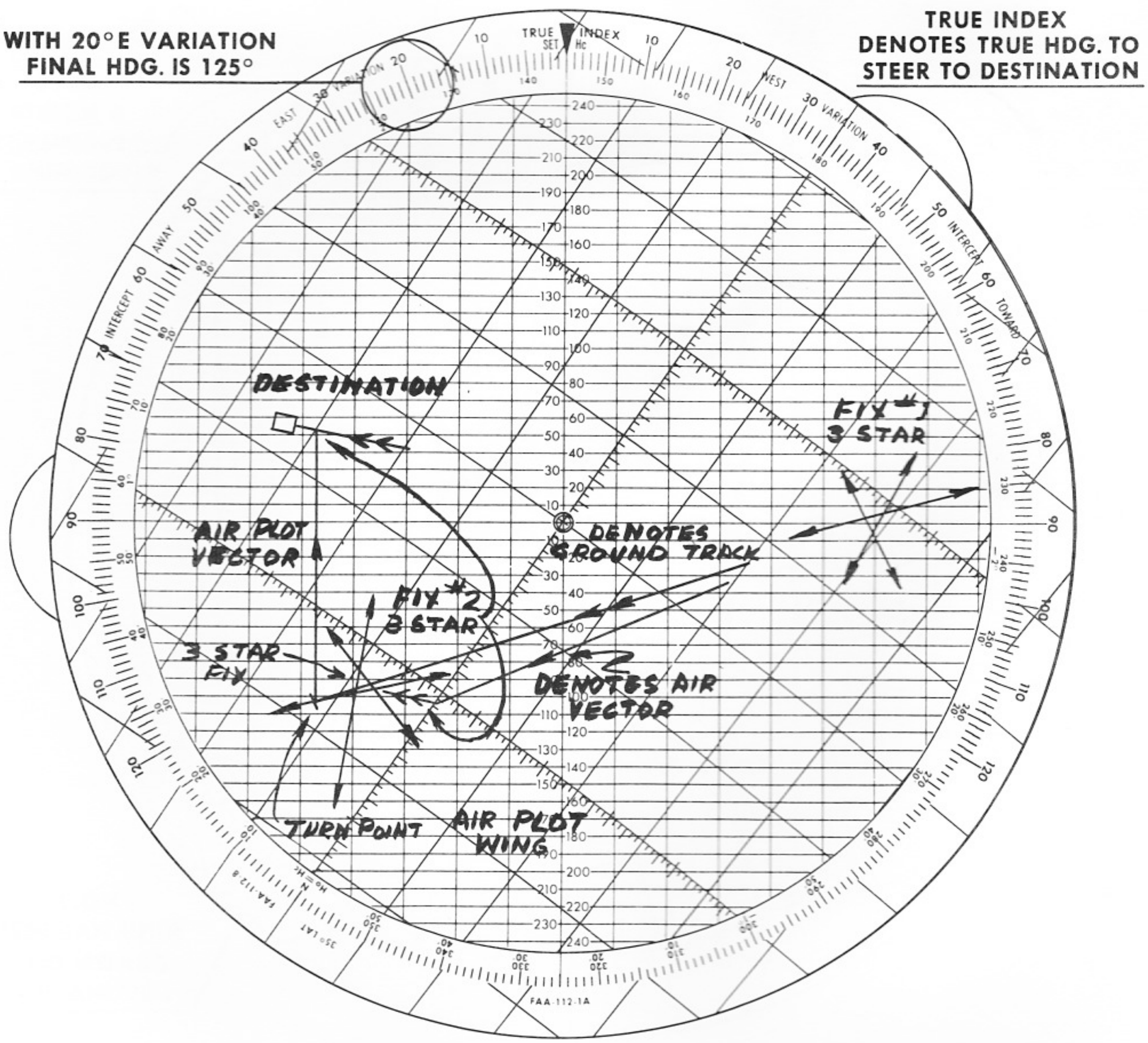


FIGURE 29

MEASURING DISTANCE TO GO...with the template oriented as in figure 27 note the value of distance scale at Final Fixpoint and the value at Destination. Combine them to determine total distance. In the illustration (4, figure 27) the two values are minus 110 and plus 124 for a total distance of 234 nautical miles. Had both points fallen on the same side of the grommet, the smaller distance would have been subtracted from the larger to find distance.

See Figure 29 for a study of a Complete DR Problem.