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PROPER PROCEDURES FOR USE AND ADJUSTMENT OF THE SURVEY SEXTANT.(U)
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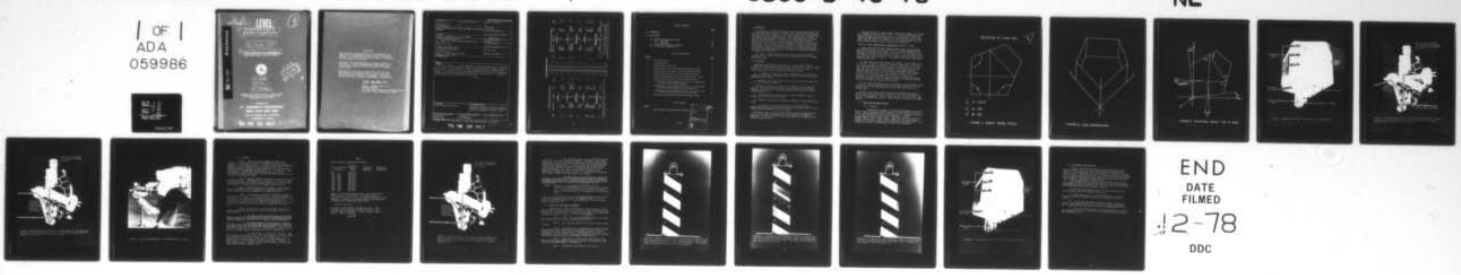

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PROPER PROCEDURES FOR USE AND ADJUSTMENT OF THE SURVEY SEXTANT

CGR/DC-14/78

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U. S. Coast Guard Research and Development Center
Avery Point, Groton, Connecticut 06340

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16. Abstract

The Survey Sextant, a sextant designed for measuring angles between terrestrial objects, has a special prism which allows the operator to measure angles beyond the normal range of the sextant's arc. Step by step procedures, including necessary graphics, are presented to guide the reader through the process of determining the alignment and making the adjustments to this special purpose prism. An alternate sighting guide for the sextant is also offered.

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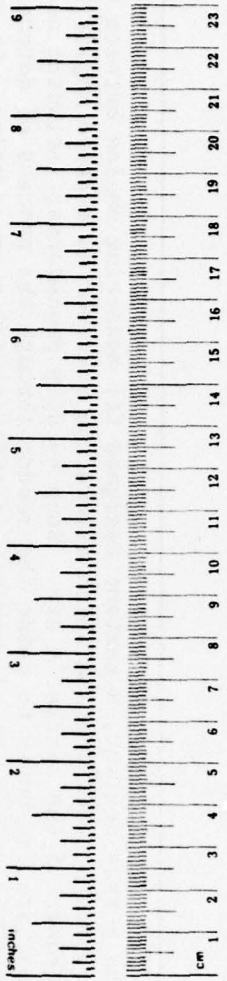
METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

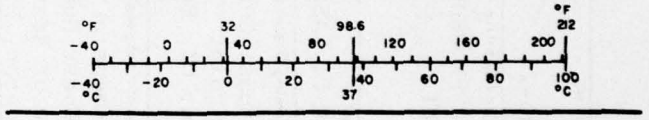
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square *miles*	2.6	square kilometers	km^2
	acres	0.4	hectares	*ha*
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35.	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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1.0 BACKGROUND

The sextant is a hand-held instrument used to measure angles and is the tool most often used to position floating aids to navigation maintained by the U.S. Coast Guard. Recently, a new type of sextant, the "Survey Sextant" was added to the Coast Guard inventory. The survey sextant is a basic marine navigation sextant, modified for use in measuring horizontal angles between terrestrial objects. As with any new and seemingly different device, there has been a reluctance by some AN servicing units to use this new sextant. This reluctance can be attributed, in part, to unfamiliarity with the entire unit; to the narrower field-of-view created by the 6 x 30 folded optics telescope; to the use of the penta prism when making large horizontal angle measurements; and to the checks and adjustments, necessary for proper use of the device.

This report presents information on the penta prism and adjustment procedures for it, and offers an alternative sighting device to the folded optics telescope.

2.0 DISCUSSION

When positioning aids to navigation, it is often useful to choose landmarks for objects which provide horizontal angles greater than the range of the arc of the marine navigation Sextant; that of -5^{0} to $+125^{0}$. These larger angles, $+125^{0}$ to $+180^{0}$, are desirable because:

A. In some cases, the limited number of targets do not provide the necessary minimum three independent lines of position (LOP's) within angles measurable by the sextant.

B. Generally, the larger obtuse angles provide relatively strong LOP's (i.e. lines with small gradients).

To expand the Coast Guard's capability to measure these large angles directly, the Coast Guard has procured over 200 Weems and Plath Survey Sextants. These sextants are the basic Weems and Plath Marine Navigation Sextant modified by:

A. The addition of a screw-in vertical handle intended to reduce fatigue when shooting horizontal angles.

B. Removal of illuminating equipment and shades to reduce unnecessary weight.

C. The addition of a penta prism which can be inserted into a bayonet-type mounting socket, located in front of the horizon glass, in the place normally occupied by the horizon shades.

The penta prism, in this last modification, permits the measurement of angles to 215^{0}. When the penta prism is not being used, alignment, adjustment, calibration and use of the survey sextant is the same as for a marine navigation sextant.

"The penta prism will neither invert or reverse the image. Its function is to deviate the line of sight by 90°. It has the valuable property of being a constant deviation prism, in that, it deviates the line of sight through the same angle (90°) regardless of its orientation to the line of sight...The penta prism is used where it is desirable to produce an exact 90° deviation, without having to orient the prism exactly."

--Warren J. Smith, Modern Optical Engineering, McGraw-Hill, 1966

Figure 1 depicts a ray trace through a penta prism. Two successive equal reflections off the two mirrored interior surfaces produce the 90° non-inverted deviation of the image. This is true for rays which strike perpendicular (normal) to the face of the prism. It is also true for rays not normal to the face, but which lie on a plane normal to the apex edge of the prism (the Z axis of Figure 2). This plane is the same as the optical plane of the sextant.

The penta prism poses three degrees of freedom of rotation about the X, Y, or Z axis. Figure 2 illustrates the penta prism and axis. Rotation of the prism around the Z axis does not disrupt the deviation angle, as the ray, while not normal to the face, remains in a plane normal to the apex adge. As shown in Figure 3, this non-normal ray follows a slightly different path but still exits with the prescribed 90° deviation angle. Rotation about either the X or Y axis produces a change in the regular deviation. This rotation places the prism faces at an angle not perpendicular to the established plane (the optical plane of the sextant) and can be likened to a lack of perpendicularity of the index and horizon mirrors of the sextant producing similar errors.

For this reason adjustment screws are provided, so that the faces of the prism can be maintained perpendicular to the frame of the sextant and can preserve the line of sight through the sextant optics parallel to the sextant frame.

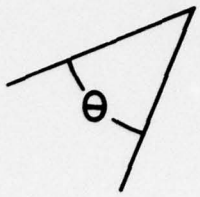
Figure 4 is an oblique view of the penta prism housing showing the bayonet stud, the housing screws and the Allen Set screws which adjust the prism inside the housing. Figure 5 shows the penta prism installed on the sextant in the NORMAL USE position. Figure 6 shows it rotated to the ADJUST position.

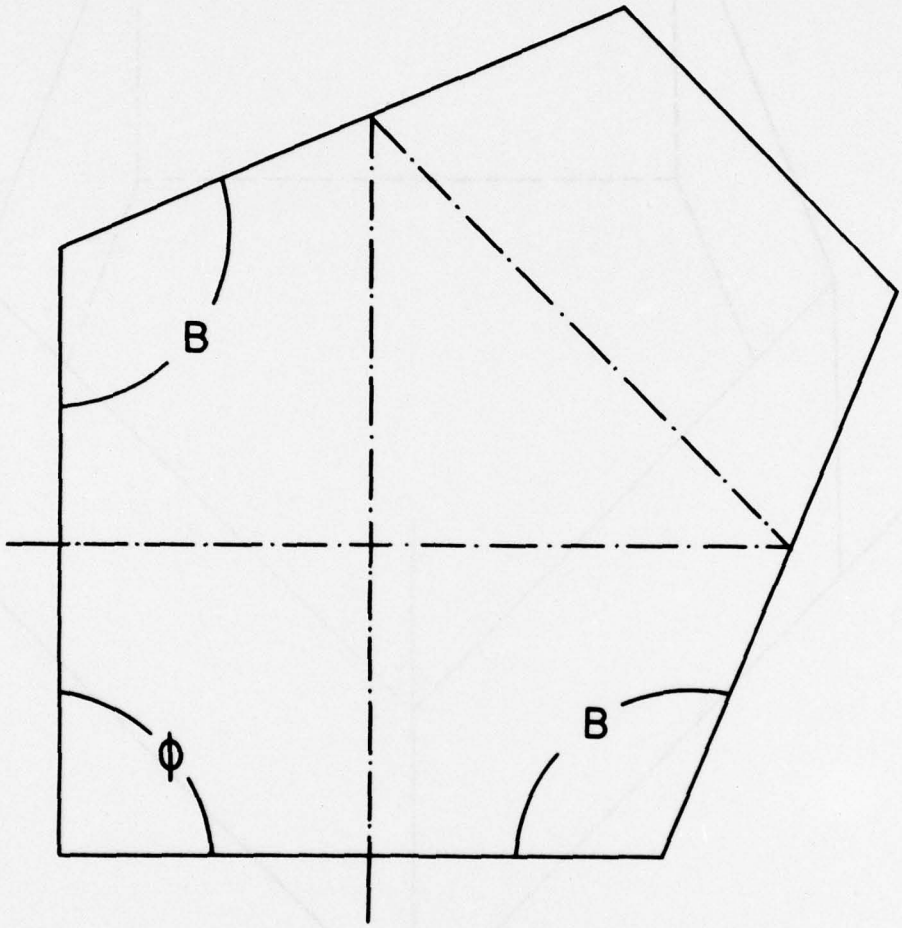
2.1 Penta Prism Adjustment Checks

2.1.1 Equipment

Verifying the alignment of, and making adjustment to the penta prism is best accomplished with the sextant on a stable platform such as a tripod. These adjustments should be performed ashore. Mounting the sextant on a tripod frees both hands for making adjustments. A simple European-American thread adapter makes it possible to mount the sextant on a standard camera tripod. Figure 7 shows a Weems and Plath Survey Sextant mounted on a tripod and adjustment being performed on the penta prism. Each sextant case contains an Allen wrench for making the adjustments.

DEVIATION OF LIGHT RAY





$\angle$ B = 112.5°

$\angle$ θ = 45°

$\angle$ ϕ = 90°

FIGURE I. PENTA PRISM TRACE

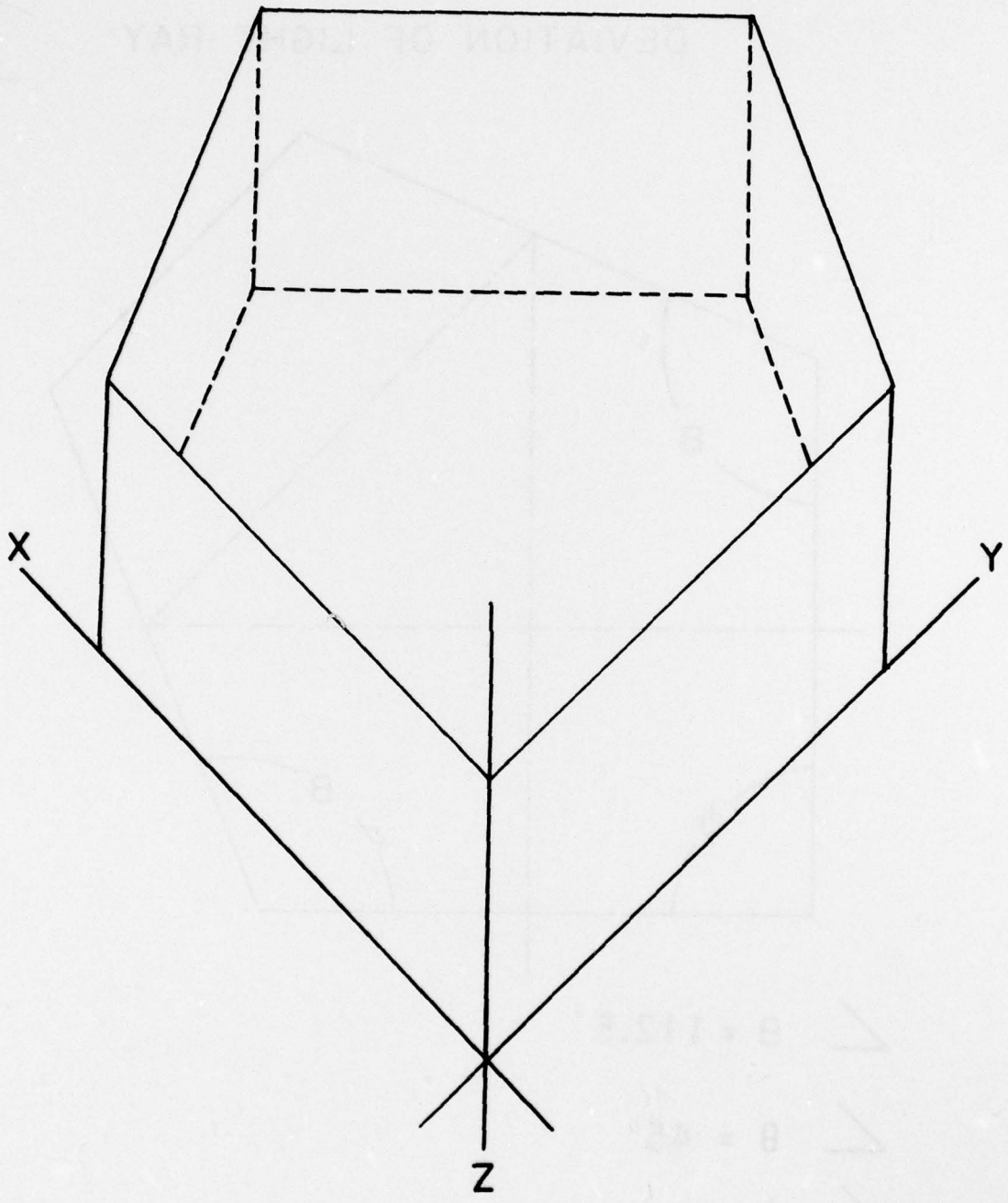


FIGURE 2. AXIS ORIENTATION

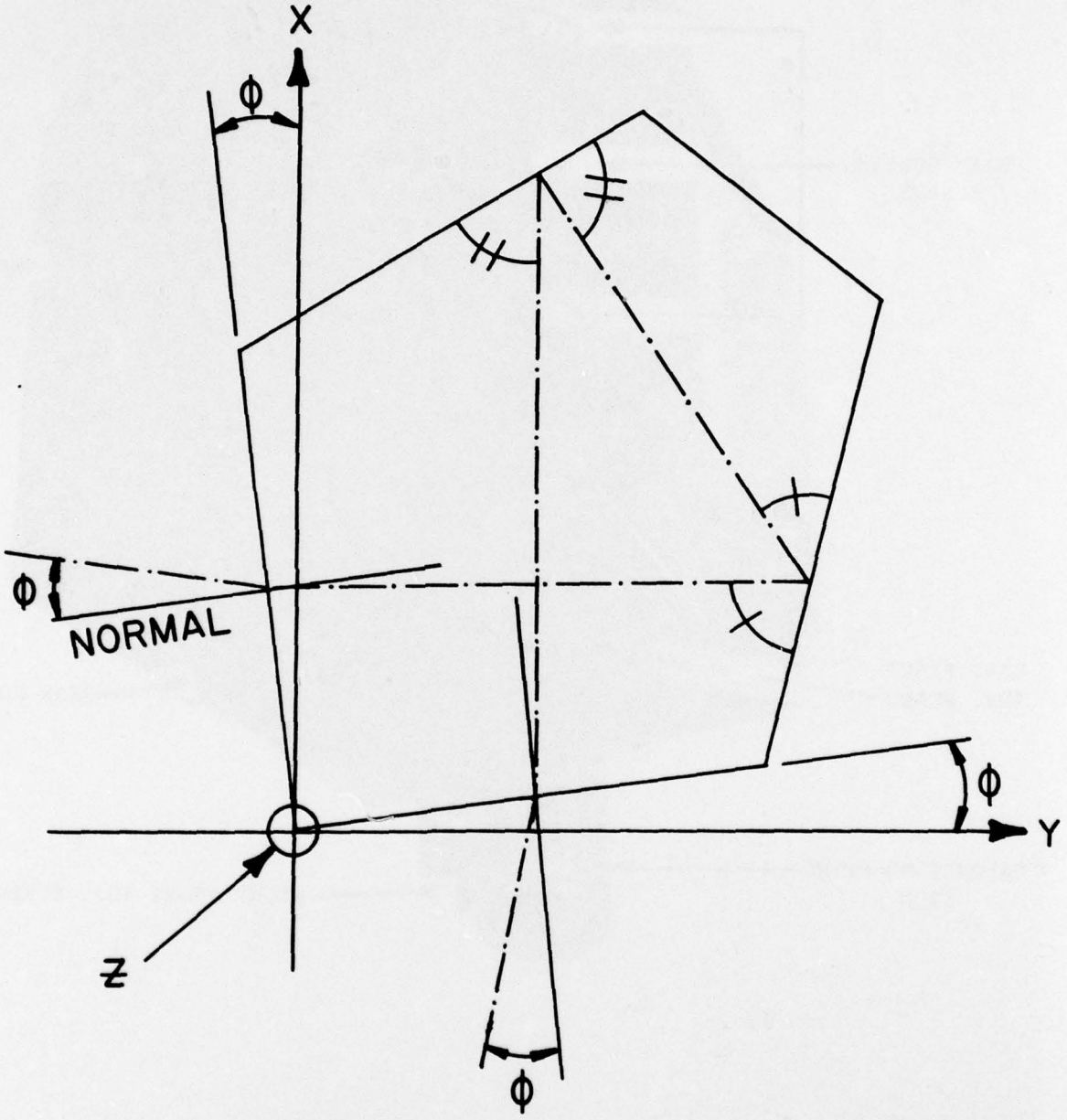


FIGURE 3. ROTATION ABOUT THE Z AXIS

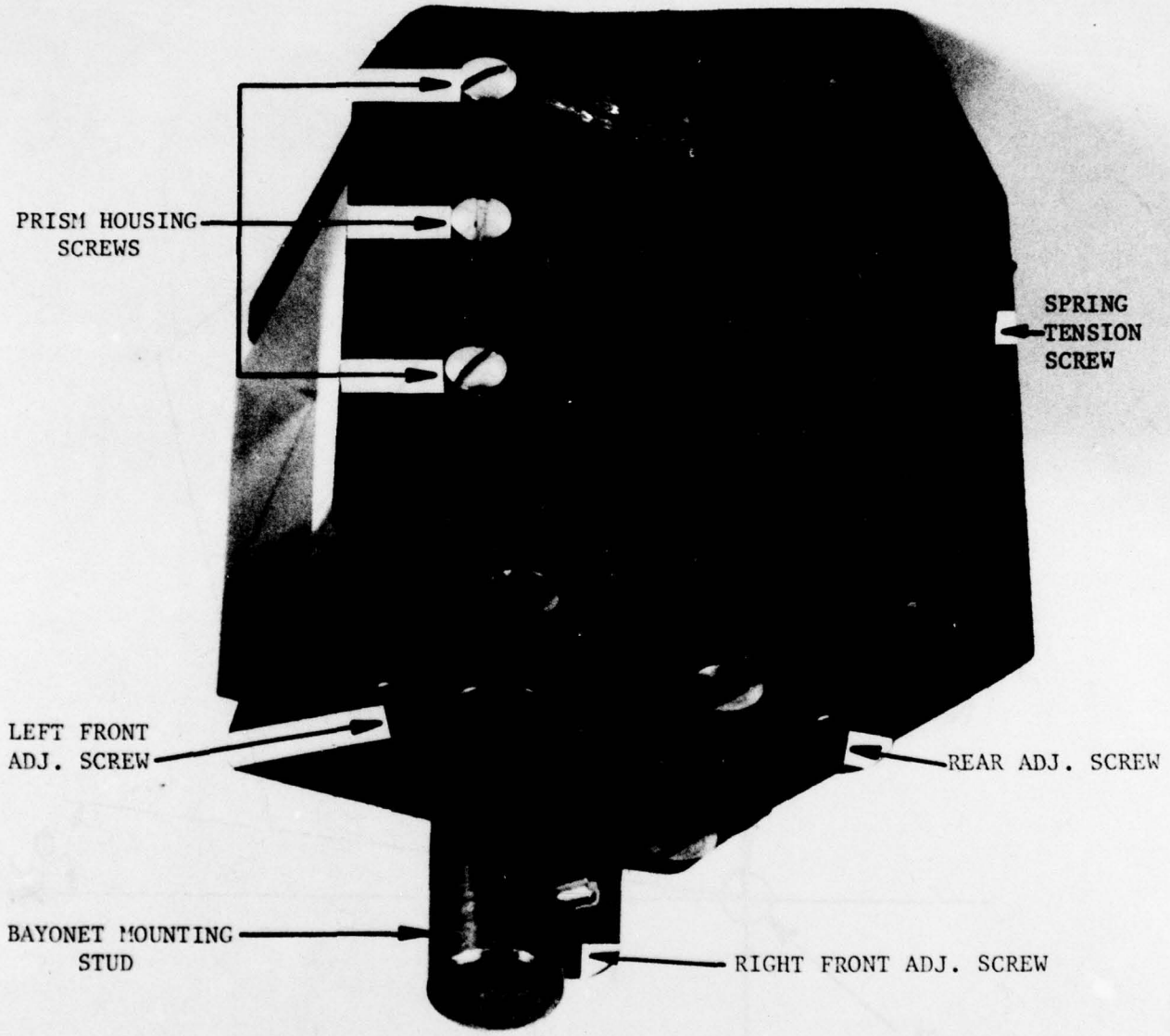


FIGURE 4. OBLIQUE VIEW OF PENTA PRISM SHOWING ADJUSTMENT SCREWS

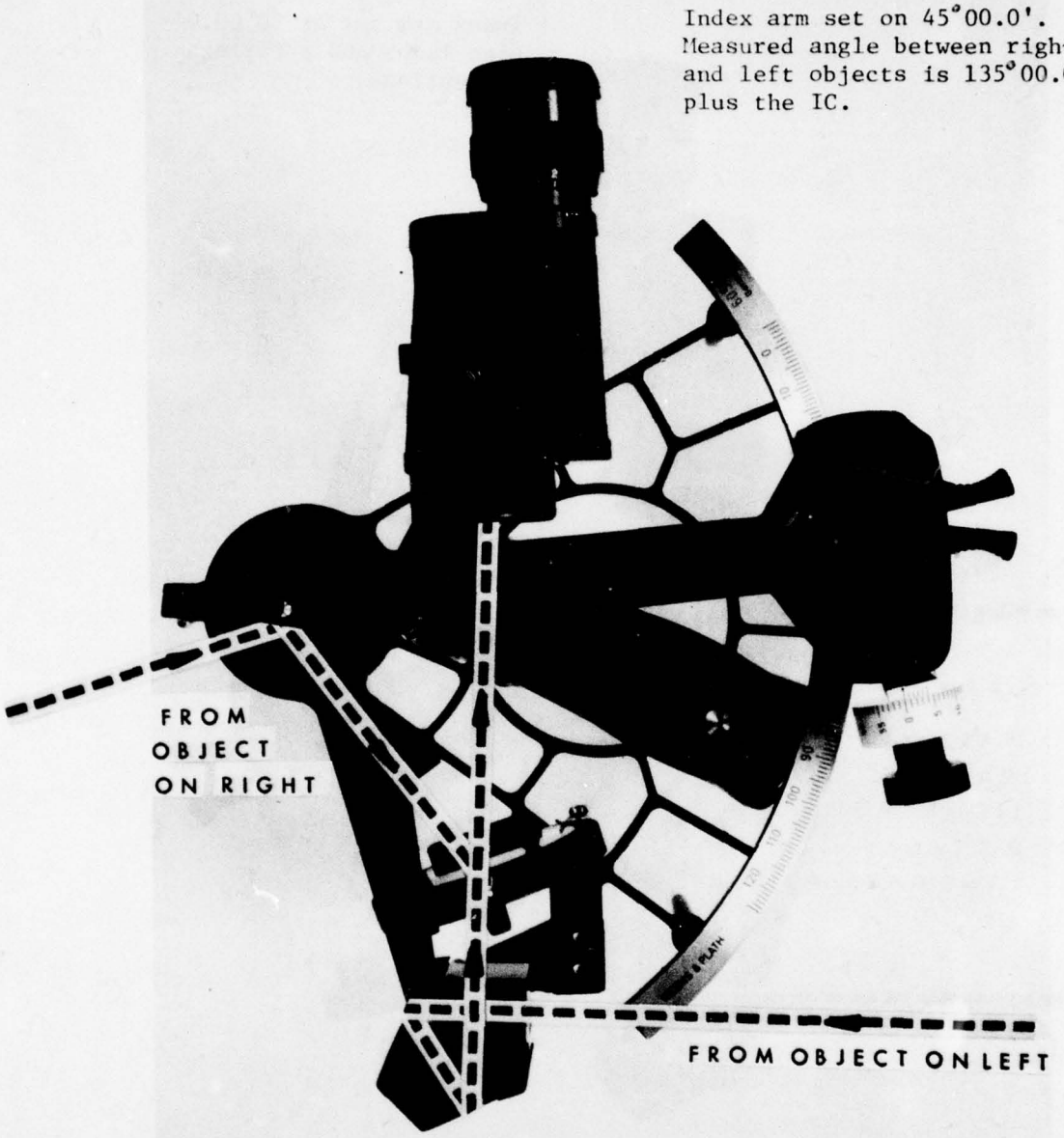


FIGURE 5. SURVEY SEXTANT WITH PENTA PRISM IN NORMAL-USE POSITION. The light beams show how the penta prism adds 90° to the index arm reading when the penta prism is inserted with a clockwise turn.

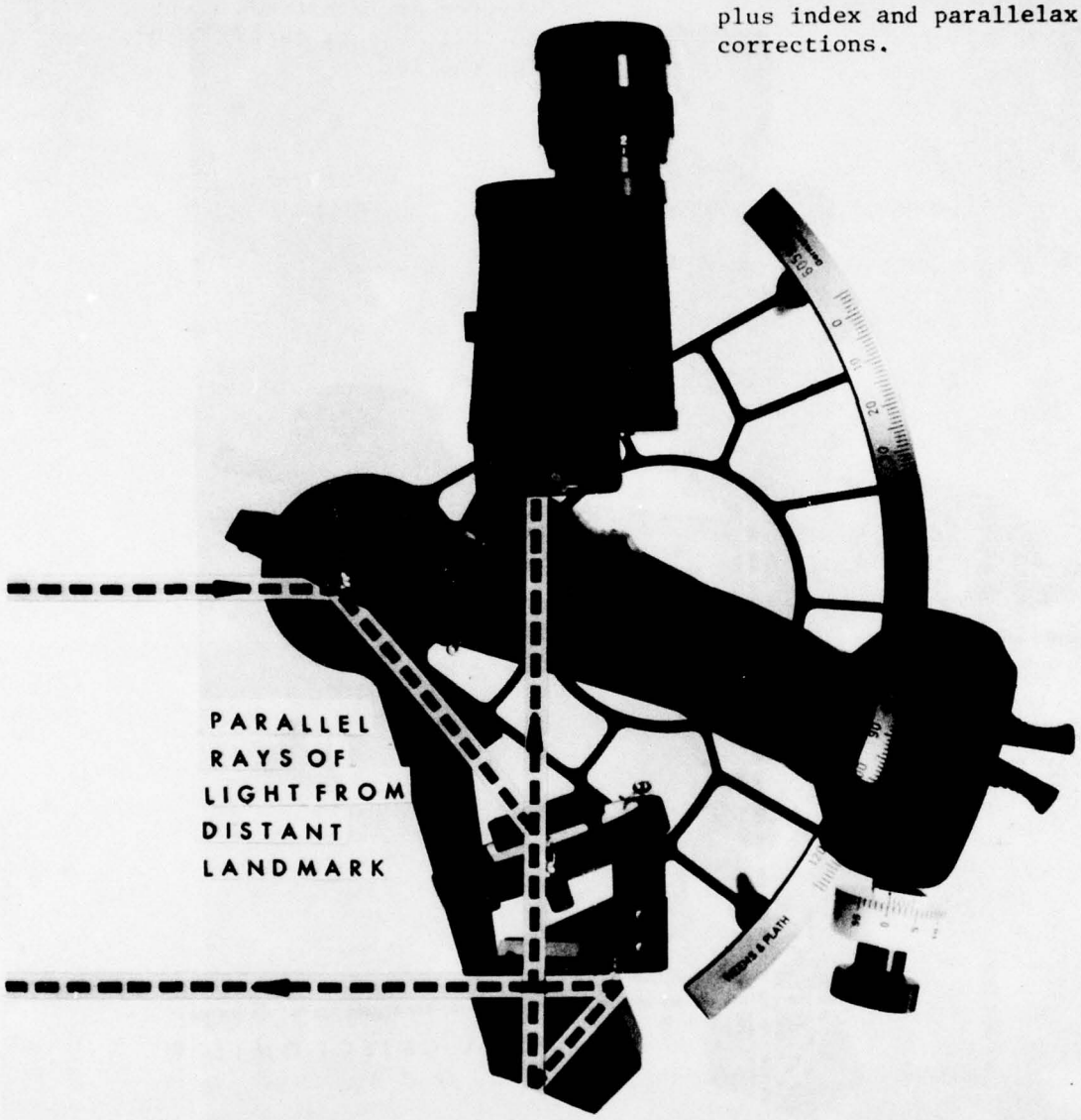


FIGURE 6. SURVEY SEXTANT WITH PENTA PRISM IN ADJUST POSITION. The light beams show how the pentaprism subtracts 90°00.0' from the index arm reading when the pentaprism is inserted with a counterclockwise turn.

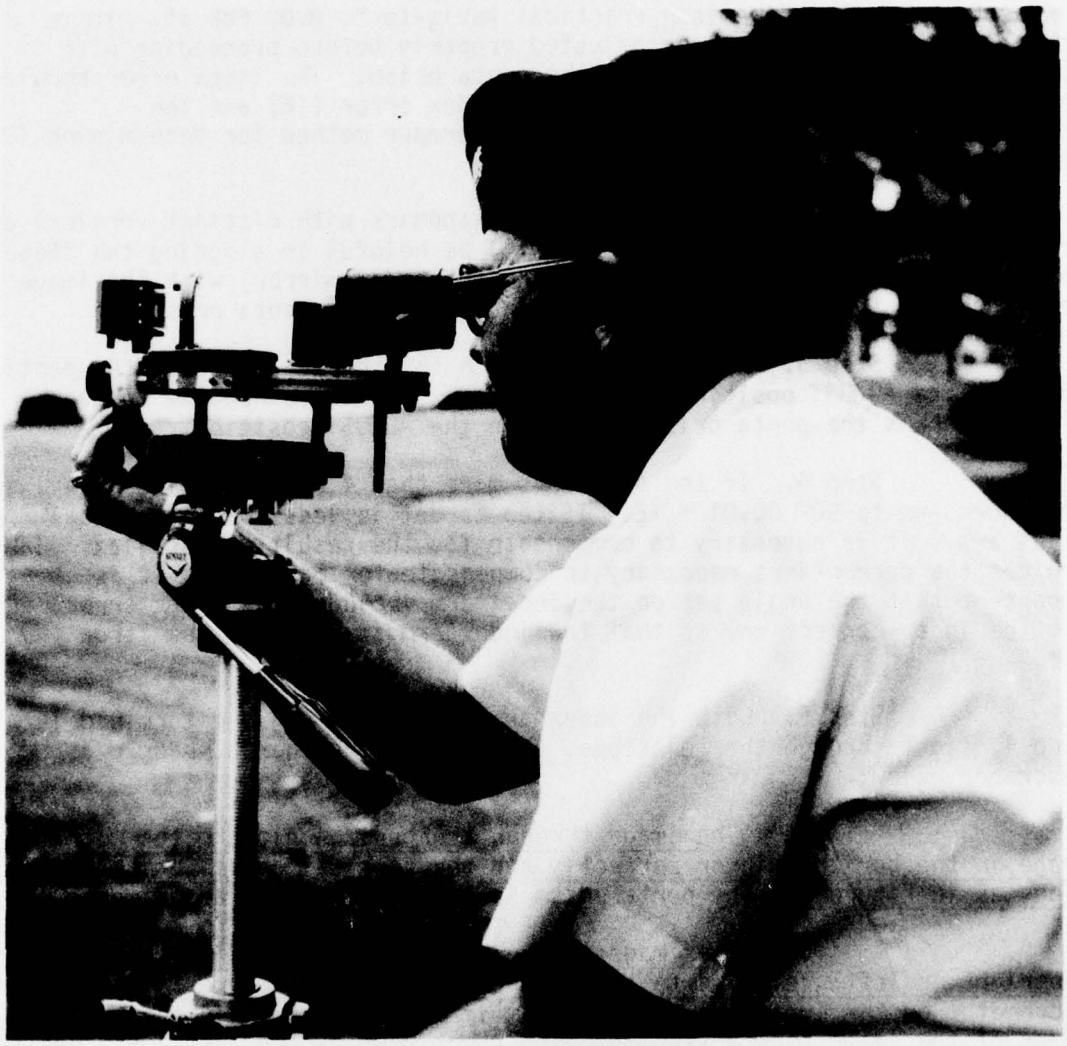


FIGURE 7. PENTA PRISM ADJUSTMENTS WITH SEXTANT MOUNTED ON A TRIPOD

2.1.2 Procedure

Step 1. Adjust the sextant without the penta prism installed. Procedures can be found in the manuals provided with the sextant; or in the AN School pamphlet "A Simple Procedure for Adjusting the Sextant"; or in the "American Practical Navigator", H.O. PUB #9. It is essential that the sextant be adjusted properly before proceeding with either the check or adjustment of the penta prism. The index error should not exceed ±2'. Measure and record the index error (IE) and the corresponding index correction (IC). The proper method for determining IE is given in the example in Table 1.

Step 2. Select a suitable landmark with distinct vertical and horizontal patterns. These patterns will be helpful in aligning the image in the horizon mirror (as reflected from the index mirror) with the image seen through the horizon glass (as seen through the penta prism).

Step 3. Mount the sextant on the tripod. Install the penta prism in the ADJUST position (inserted with a counter-clockwise turn). Figure 8 shows the penta prism mounted in the ADJUST position.

Step 4. If the target is more than 4 nautical miles away, set the index arm to 90° 00.0' + IE. If the target is less than 4 nautical miles away, it is necessary to compensate for the resulting parallax. Table 1 gives the corrections necessary to compensate for parallax. It is important that the angle set on the index arm includes the index error, and not the index correction, so that the index arm is 90° from the "true zero".

Step 5. With the index arm set at the angle determined in step 4, sight through the telescope. You will see either a, b or c as described below:

a. The image through the horizon glass mates with the image in the horizon mirror perfectly and the vertical edges form straight lines as in Figure 9. The penta prism is aligned, make no adjustments.

b. The image through the horizon glass is shifted to the right or left, relative to the image in the horizon mirror. Rotate the micrometer on the index arm to bring the images together. If the vertical edges of the image form a straight line - not bent at the junction - and the top and bottom mate properly, then the penta prism is adjusted, BUT:

(1) The sextant is not perfectly adjusted. Check the setting on the micrometer drum. Then, turn the drum to bring the images into coincidence, and note the reading in the micrometer drum. If the change is less than three minutes the sextant is adjusted adequately. If the difference is three minutes or greater, repeat steps 1 through 4. If after repeating steps 1 through 4 and checking for mistakes, the difference remains three minutes or greater, then,

TABLE 1

Correct Angles to Compensate for Parallax

Range to Landmark (yards)	Parallax Corrected Angle	+	IE for your Sextant	=	Setting on Sextant Arc
8100	90° 00.0'				
2700 - 8100	89° 59.9'				
1625 - 2100	89° 59.8'				
1160 - 1625	89° 59.7'				
900 - 1160	89° 59.6'				
740 - 900	89° 59.5'				
625 - 740	89° 59.4'				
540 - 625	89° 59.3'				
480 - 540	89° 59.2'				
425 - 480	89° 59.1'				
390 - 425	89° 59.0'				

EXAMPLE: After adjusting the sextant, the horizon was shot from a height of eye of 30 feet. Thirty feet gives a geographic range of over 6 nm, so no parallax correction to the Index Error is needed. The average reading of 8 observations (4 ascending and 4 descending) was 0° 01.6'.

Therefore, IE = +1.6'

A landmark is chosen which lies 1000 yards away. Table 1 indicates that for distances of 900 to 1160 yards, the Corrected Angle is 89° 59.6'. Therefore the arc is set for 90° 1.2'. That is,

89° 59.6'
+ 1.6'
90° 1.2'

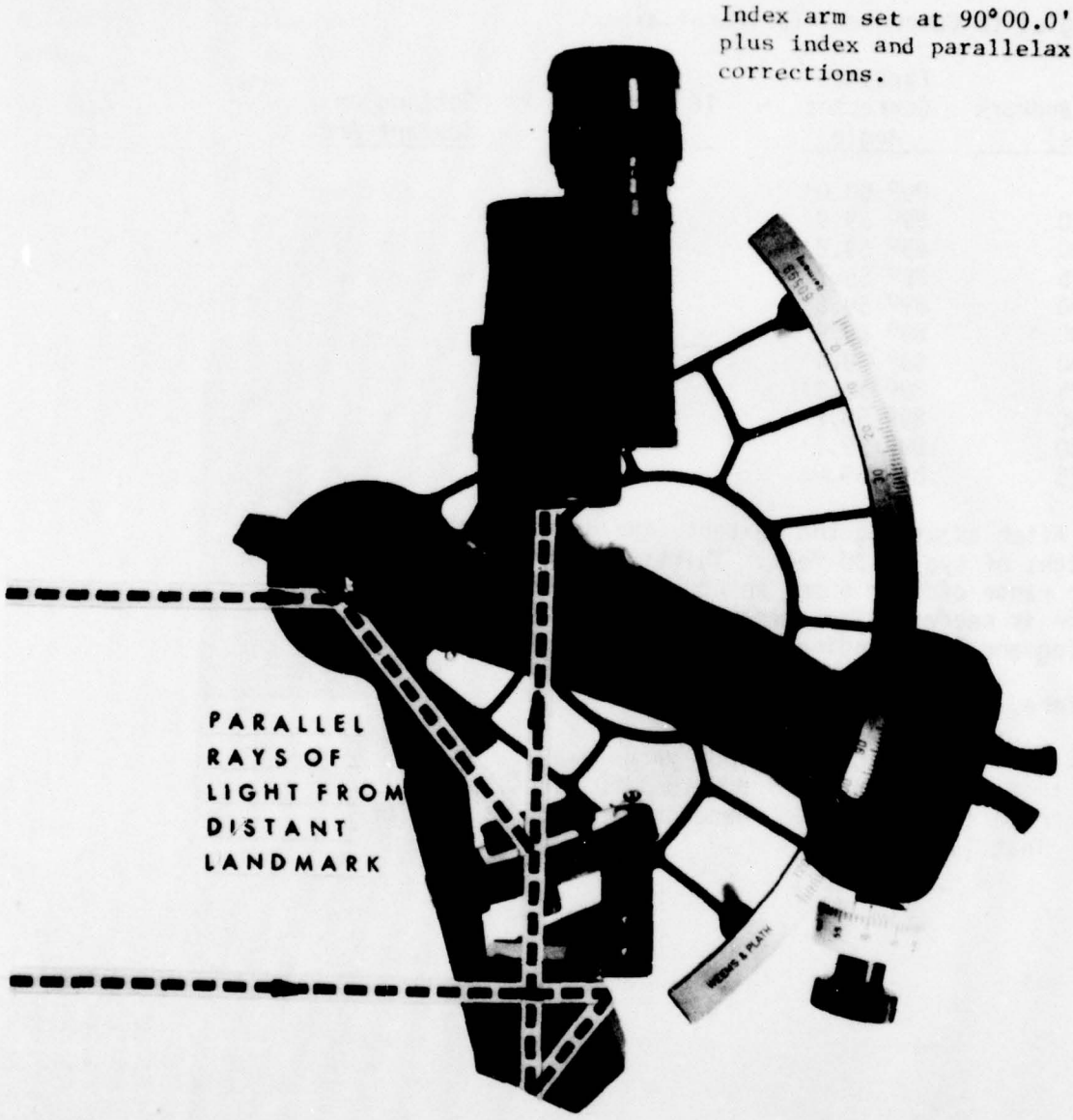


FIGURE 8. SURVEY SEXTANT WITH PENTA PRISM IN ADJUST POSITION. The light beams show how the penta prism subtracts 90°00.0' from the index arm reading when the penta prism is inserted with a counter-clockwise turn.

(2) The penta prism is not deviating the image by exactly 90°. This case, though not probable, is possible. Order a new penta prism, or use this one after determining the actual angle that the prism is deviating the image. To do this, select two distant targets 90° to 120° apart. Measure the angle with the penta prism installed, then without the penta prism. Subtract the second reading from the first. Repeat the procedure three times and determine the average of the measurements, thereby reducing the errors. The resultant angle should be used in place of 90° for all your penta prism readings.

c. The image through the horizon glass is leaning to one side, or the two halves of the image do not mate properly relative to the image in the horizon mirror (Figures 10 and 11), then the penta prism needs adjustment. Refer to the penta prism Adjustment Procedures.

NOTE: The penta prism is adjusted in the ADJUST position and used in the NORMAL-USE position (inserted with a clockwise turn). This should not cause problems unless the bayonet mount or the bayonet stud are not perpendicular to the sextant frame.

This condition will be evident when it appears that the penta prism needs adjustment when checked in the NORMAL-USE position, but is correct in the ADJUST position. If this is the case, the sextant must be sent to a repair facility.

2.2 Penta Prism Adjustment Procedures

The penta prism rarely needs adjustment. When adjustment must be done, the job is tedious and often frustrating, at times consuming more than an hour. The adjusting screws are awkward to reach and the adjustments must be repeated a number of times to "fine tune" the adjustment.

Step 1. Steps 1 thru 4 of the ADJUSTMENT CHECKS should have been completed and Step 5c has directed you to this point.

Step 2. See Figure 12. Back off the "spring tension screw" 1/2 turn.

Step 3. The penta prism is adjusted with the three Allen Set screws located on the bottom of the prism housing, as shown in Figure 12. The single rear screw is adjusted first, removing the gross vertical displacement. The two forward screws are now adjusted to level the prism by removing the remaining vertical displacement and any rotation.

Step 4. Repeat Step 3, adjusting the three screws in the same order until the target image becomes coincident, as described in Step 5(a) of the ADJUSTMENT CHECKS. See Figure 9.

Step 5. Tighten the spring tension screw 1/2 turn.

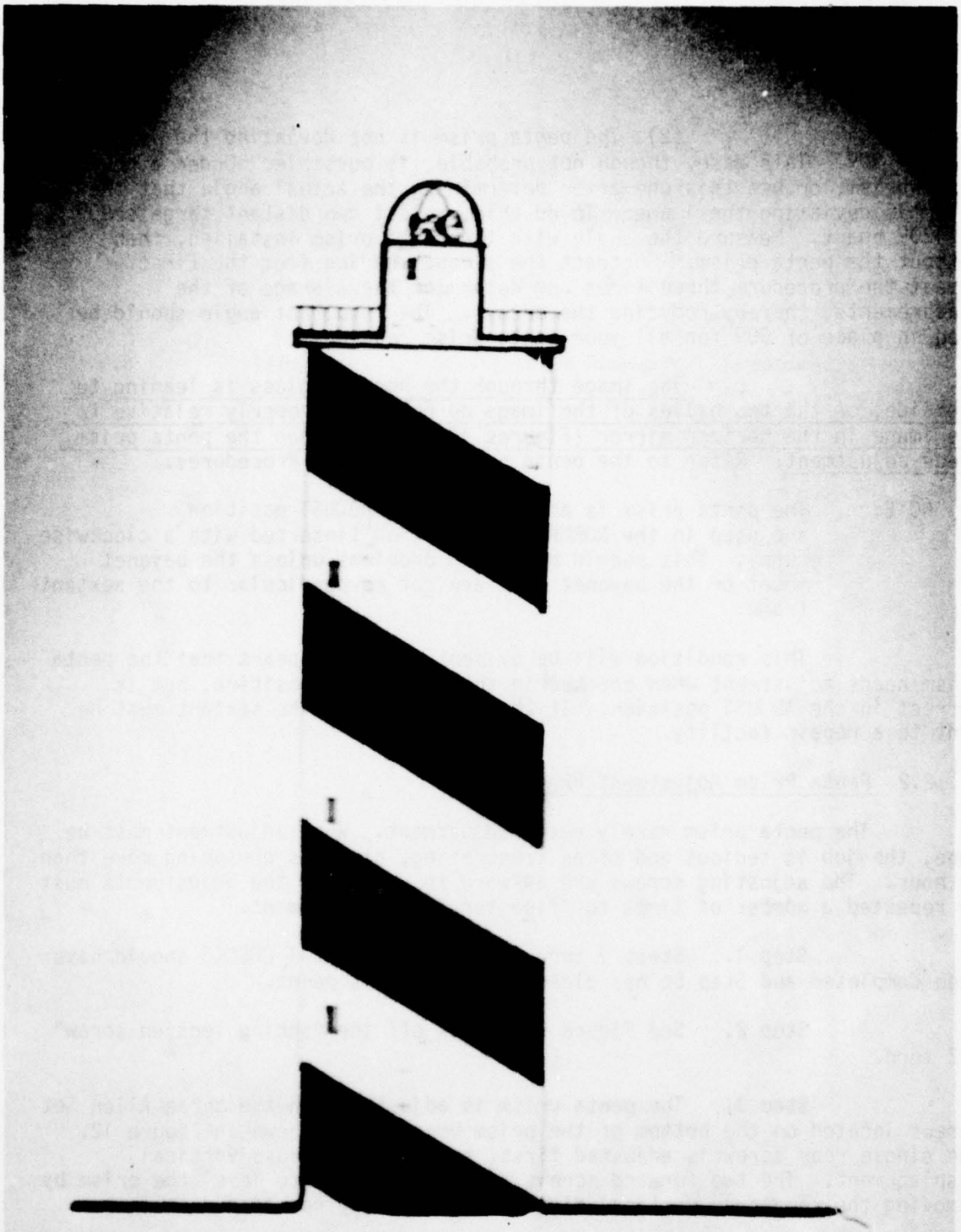


FIGURE 9. A LIGHT HOUSE AS SEEN THROUGH THE OPTICS OF A SEXTANT WITH THE PENTA PRISM PROPERLY ADJUSTED. Note: The upper portion (direct image) mates perfectly with the lower portion (reflected image). The vertical lines are straight and the two portions join smoothly.

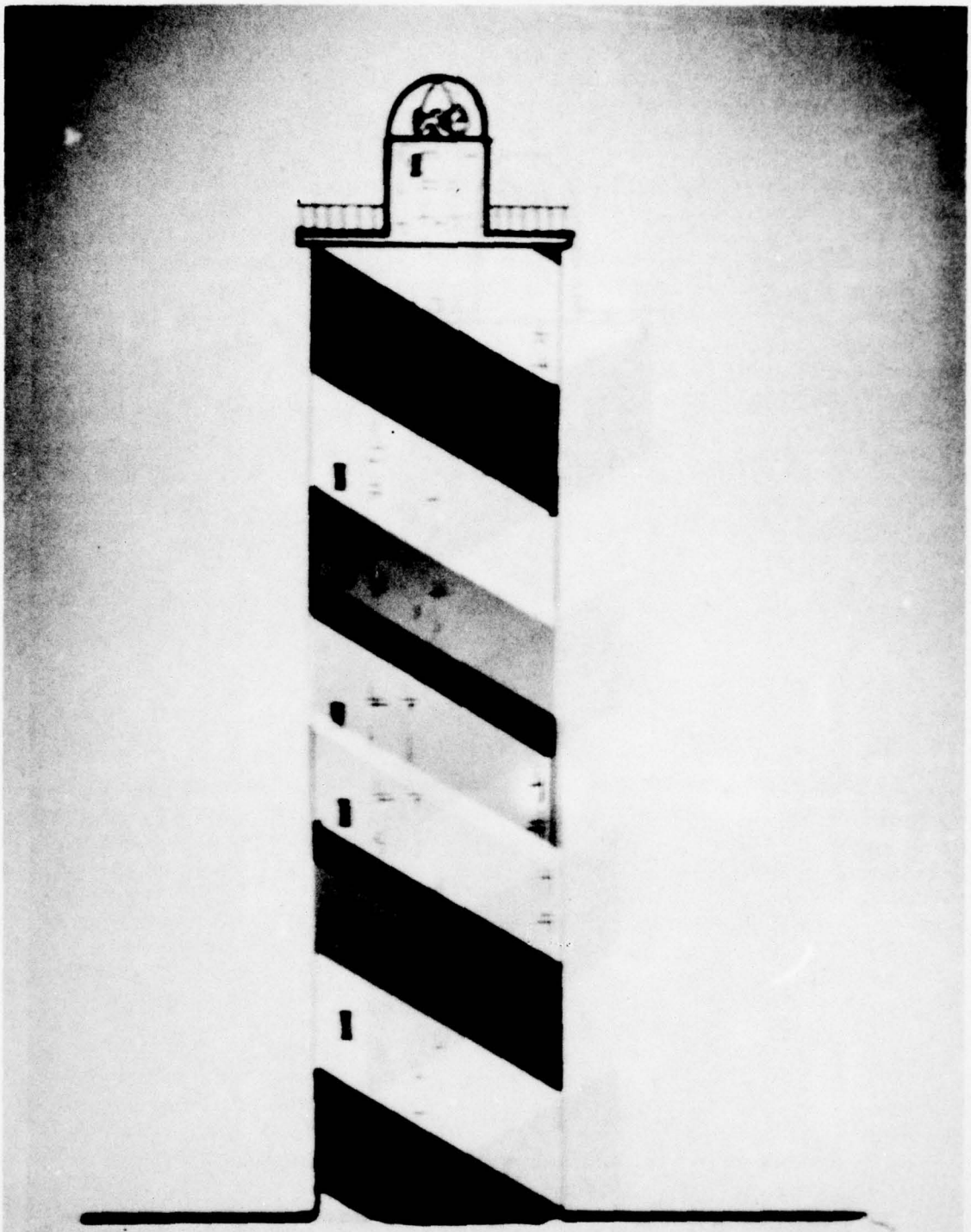


FIGURE 10. A LIGHT HOUSE AS SEEN THROUGH THE OPTICS OF A SEXTANT WITH THE PENTA PRISM NEEDING VERTICAL ADJUSTMENT. Note: Vertical displacement is illustrated by the difference in the widths and the positions of the stripes on the light house.

FIGURE 11. A LIGHT HOUSE AS SEEN THROUGH THE OPTICS OF A SEXTANT WITH THE PENTA PRISM NEEDING HORIZONTAL ADJUSTMENT. Note: The horizontal displacement of the light house sides.

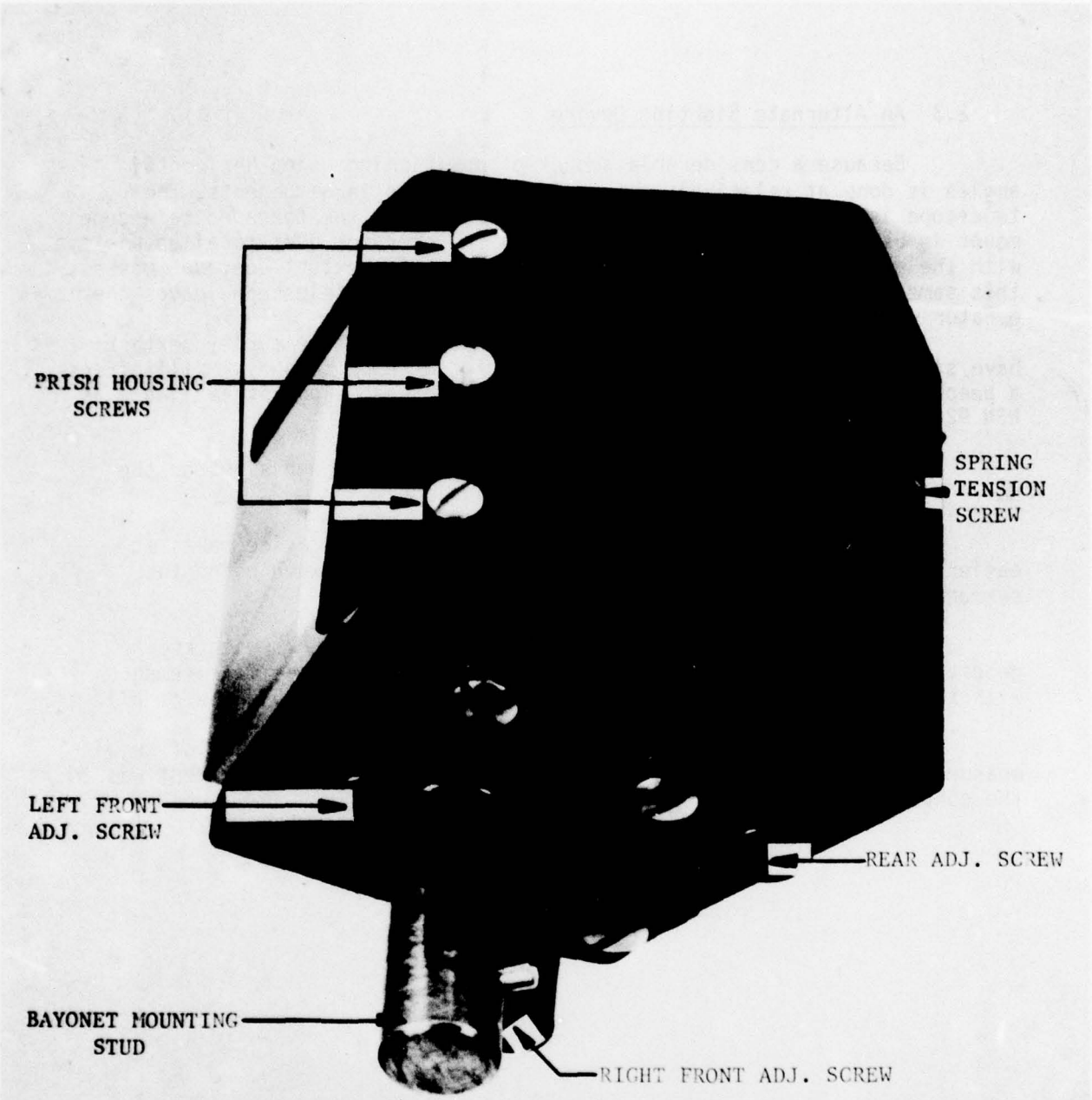


FIGURE 12. OBLIQUE VIEW OF PENTA PRISM SHOWING ADJUSTMENT SCREWS

2.3 An Alternate Sighting Device

Because a considerable amount of positioning using horizontal angles is done at relatively short distances using large objects, the telescope is not always used. With older sextants, the threaded telescope mount is used as a sighting device, which the operator uses to align his eye with the optical plane of the sextant. The survey sextant does not possess this same type of telescope mount and removal of the telescope leaves the opeator without a satisfactory sighting device.

The Navy MKIII marine navigation sextant and the survey sextant have similar telescope mounts and the manufacturer of the Navy MKIII offers a peep-sight for use as a sighting guide. This peep sight is available as NSN 9240-001/Sheet 99, currently priced at $3.16.

A short-term investigation of the use of the peep sight on the survey sextant produced the following conclusions:

A. Use of peep-sight in lieu of no sighting device makes it easier to establish the proper eye-mirror relationship when using the sextant.

B. Limited sighting between stationary landmarks with known geodetic coordinates were more precise using the telescope; measurements with the peep-sight were more precise than with no sighting guide at all.

C. While use of the peep-sight improved the precision of angular measurements over having no sighting guide, the greatest improvement was in the convenience of use.