SECTION VIII - THE SEXTANT

INTRODUCTION:

The SEXTANT is one of the most economical instrument for an Auxiliary member to use in determining positions of objects both ashore and afloat with a high degree of accuracy. The Three-Arm Protractor is used in conjunction with the SEXTANT in plotting positions on a chart, i.e., laying-out angles on a chart. In their ATON/CU support role, Auxiliary members need to understand the use and application of the SEXTANT and Three-Arm Protractor for determining and plotting position data.

OBJECTIVE:

1. To acquire a general knowledge of the use of the Sextant and the Three-Arm Protractor.

2. To become familiar with the use of the Davis Mark 3 and Davis Mark 15 Sextants to include the major parts and proper care:
   - How to read the Sextant.
   - How to determine the Sextant index error and adjust or apply the error.
   - How to take independent Sextant angles and develop a three-point horizontal FIX and a two-point horizontal FIX.
   - How to determine heights of an object with the Sextant.

3. To become familiar with the use of the Three-Arm Protractor:
   - How to transfer Sextant acquired data to applications with a Three-Arm Protractor.
   - How to lay-out angles on a chart with a Three-Arm Protractor.

INFORMATION:

The Sextant is an instrument for measuring angles. The Sextant is oriented vertically (held vertical) for determining a vertical angle. The Sextant is oriented horizontally (held horizontal) for determining a horizontal angle. There are several models and manufacturers of Sextants. The most economical Sextant available is the Davis Mark 3, which cost in the neighborhood of $30.00 (refer to Figure 8-1). Other higher quality model/manufacturer Sextants sell in the thousand dollar range. For Auxiliary members participating in ATON/CU activities, the Davis Mark 3 Sextant is sufficient for general use. However, the Davis Mark 15 Sextant is a somewhat more sophisticated Sextant, containing a Micrometer Drum and Vernier, and provides a higher degree of precision in reading angles (refer to Figure 8-2). Some Auxiliary members prefer the Davis Mark 15 Sextant. As such, for the purposes of this Study Guide, information on both the Davis Mark 3 and the Davis Mark 15 Sextants will be included.

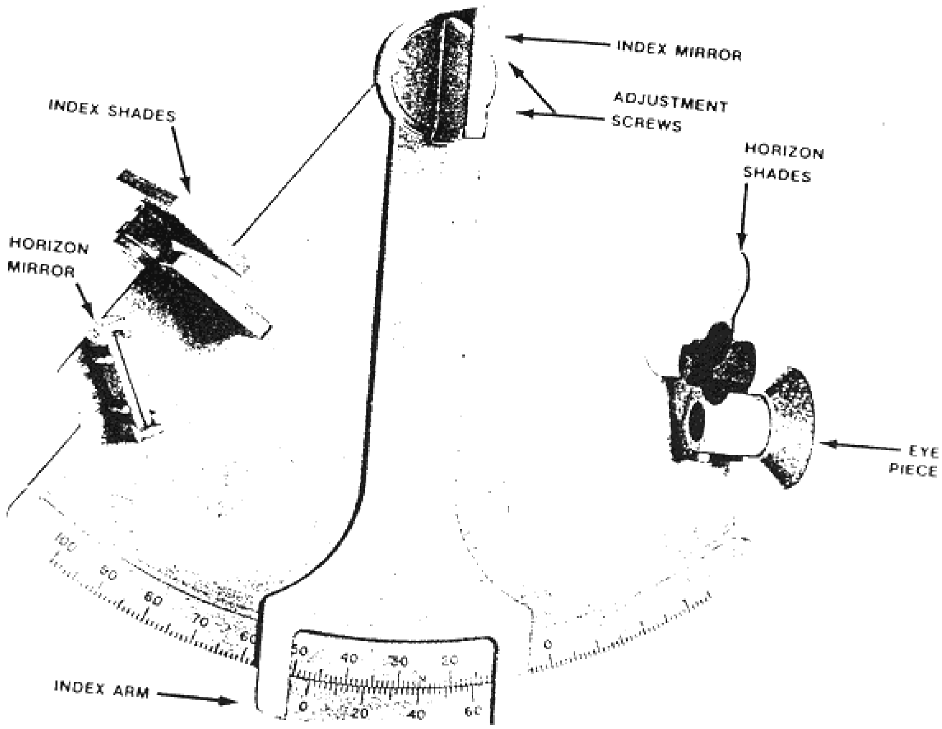


FIGURE 8-1 DAVIS MARK 3 SEXTANT

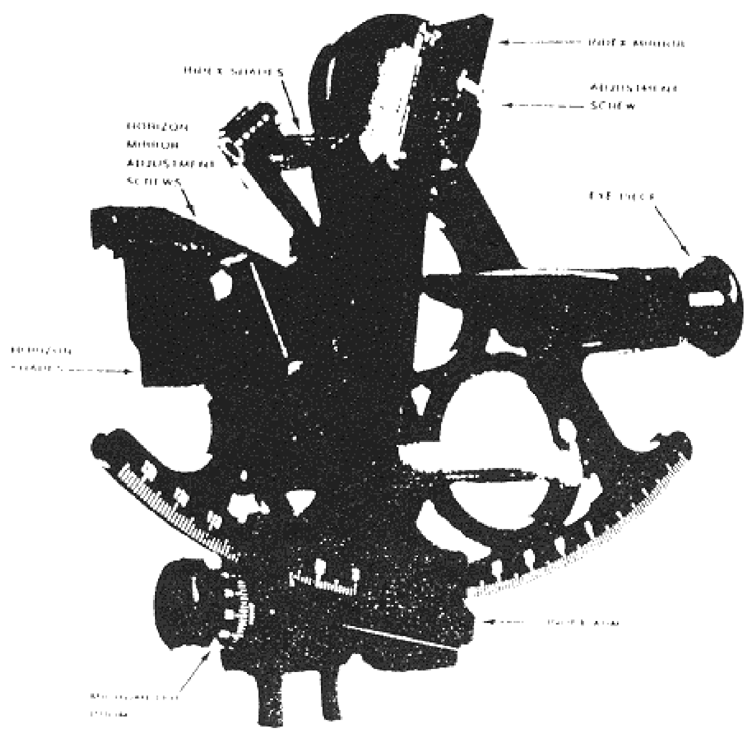


FIGURE 8-2 DAVIS MARK 15 SEXTANT

All Sextants contain two scales. The "ARC" Scale, located on the Frame of the Sextant, reads in degrees, with each mark/division/graduation equal to one degree. The "VERNIER" Scale, located on the Index Arm of the Sextant, reads in minutes, with each mark/division/graduation equal to two minutes. Some Sextants are equipped with a Micrometer Drum to read degrees, minutes and fractions of minutes. In Auxiliary ATON/CU activities only readings in degrees and minutes are required. Thus, the Davis Mark 3 Sextant is adequate.

To "Read" the Davis Mark 3 Sextant, first read the "ARC" Scale at the zero mark to determine degrees, next then look at the lower line or the "VERNIER" Scale to determine the figure that aline with a figure on the arc to the right of zero.

To "Read" the Davis Mark 15 Sextant, first "Read" the "ARC" for degrees and then the Micrometer Drum at the first longest line on the "VERNIER" Scale for minutes (refer to Figure 8-3).

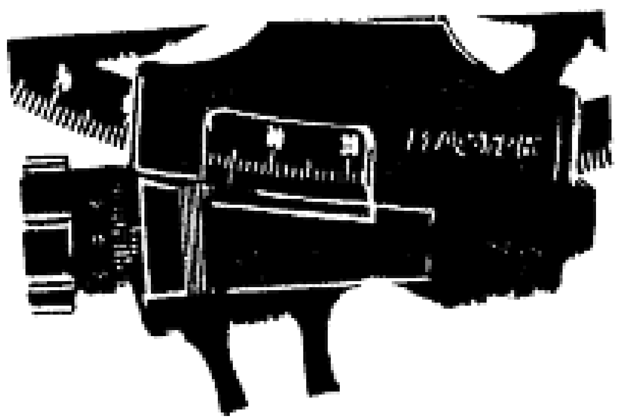


FIGURE 8-3 READING THE SEXTANT (DAVIS MARK 15)

- The following presents important information that should be considered when using a Sextant for the determination of angles:

  a. The Sextant is a very accurate but delicate instrument. Particular care should be taken when using and storing the Sextant.

  b. Determine if the telescope or clear sighting tube will be used for viewing the object. The telescope is very rarely used.

  c. Determine if any filters will be needed for the observation. If not, turn the filters away from the index mirror and horizon glass.

  d. Every effort should be made to hold the Sextant level during observations. This can be accomplished with a spirit level attached to the Sextant or by leveling the frame of the horizon glass to the actual horizon. Errors will occur if the Sextant is not held level.

e. All adjustments to the Sextant should be made before taking an observation. Recheck adjustments whenever the Sextant is moved or mishandled.

The purpose of Sextant adjustment is to insure the two mirrors are perpendicular to the frame and parallel to each other when the "ARC" and "VERNIER" scales read zero.

- The following is a summary of those adjustments:

a. <u>INDEX MIRROR ADJUSTMENT</u> - First, adjust the index mirror so that it is perpendicular to the frame by setting the Sextant to about 50 degrees. Hold the Sextant horizontal and about eight inches horizontally from the eye level and look with one eye into the index mirror. Move the Sextant until you can look past the index mirror and see the actual frame ARC as well as the reflected ARC. The two ARCs should appear as one continuous curve. If they do not, turn the adjustment screw on the back of the index mirror until the two ARCs come into alignment (refer to Figure 8-4).

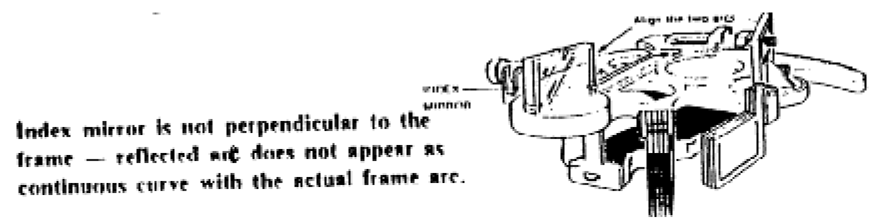
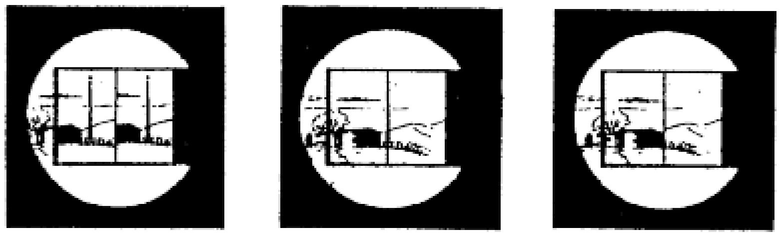


FIGURE 8-4 ADJUSTING THE SEXTANT - INDEX MIRROR (DAVIS MARK 3)

b. <u>HORIZON MIRROR ADJUSTMENT</u> - Next, adjust the horizon mirror for "side error" so that it is perpendicular to the frame. Holding the Sextant in your right hand, raise it to the eye. Look at any horizontal straight edge (horizon, roof of building, etc) and move the index arm back and forth. The real horizon will remain still while the mirror horizon will appear only when the object and the drum scales read close to zero. Line up the mirror horizon and the real horizon so that both appear as a single line. Now, without changing the setting, look through the Sextant at any vertical straight edge (flag pole, vertical edge of a building, etc.) and swing the Sextant back and forth across the vertical line. If the horizon mirror is not perpendicular to the frame, the line will seem to jump to one side as the mirror passes it. To correct this situation, slowly tighten or loosen the screw closest to the frame at the back of the horizon mirror until the vertical line no longer appears to jump (refer to Figure 8-5).



(a) Horizon mirror screw too tight. (b) Horizon mirror screw correctly adjusted. (c) Horizon mirror screw too loose.

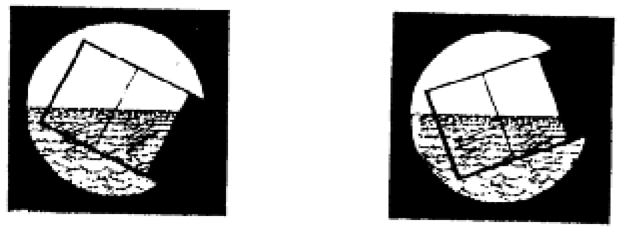
FIGURE 8-5 ADJUSTING THE SEXTANT - HORIZON MIRROR

c. <u>INDEX ERROR ADJUSTMENT</u> - The last step is to remove the index error so that the index and horizon mirrors are parallel to each other. Set the Sextant to zero degrees and zero minutes and look at the horizon or a straight horizontal line. With the Sextant at your eye, turn the top screw on the horizon mirror until the actual horizon or straight line and the reflected horizon or straight line now form one straight line (refer to Figure 8-6).

(a) Horizon mirror and index mirror not parallel. (b) Horizon mirror and index mirror parallel.

FIGURE 8-6 ADJUSTING THE SEXTANT - INDEX ERROR

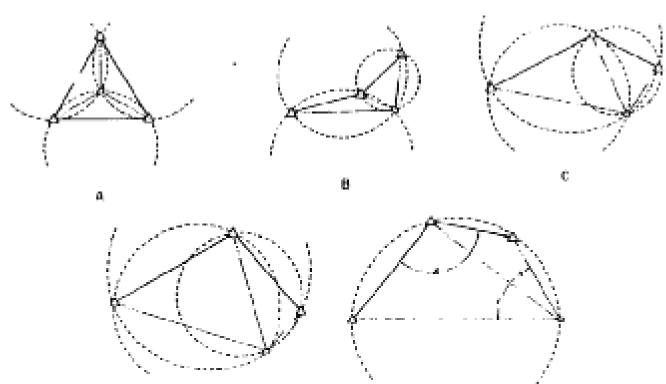
To be certain that the Sextant is correctly adjusted, incline the Sextant from side to side and the horizon should remain in a straight line. If it does not, recheck the horizon mirror adjustment (refer to Figure 8-7).



On a correctly adjusted sextant, the real and mirror horizons remain in a single line when the instrument is rocked from side to side.

FIGURE 8-7 CHECKING SEXTANT ADJUSTMENT

Once the Sextant is properly adjusted, it can be used to measure angles and determine the position of objects, i.e., obtain a FIX. A FIX is an accurate position established by the intersection, as simultaneously as possible, of two or more lines of position (LOPs) between objects. The three-point FIX (three LOPs) is the most common method used to determine the position of a charted object. When a three-point FIX is not possible, a two-point FIX is used. The selection of the points or objects will determine the accuracy of the FIX, i.e., a strong FIX. To obtain the strongest three-point FIX, the three LOPs should intersect at angles as close to 60° or 120° as possible. To obtain the strongest two- point FIX, the two LOPs should intersect at an angle as close to 90° as possible. In Figure 8-8, "A" represents the strongest three-point FIX possible, where the observer is at the center of an equilateral triangle (three LOPs with intersecting angles of 60° each); "B" is a strong FIX where the observer is closer to the center object than the right and left objects; "C" is a weak but adequate FIX and should be avoided if stronger FIXES are available; "D" and "E" are unacceptable.



— Various configurations of strong and weak three-point fixes

FIGURE 8-8 THREE-POINT FIXES - STRONG/WEAK

- The following are general rules for selecting three objects to form a strong FIX:

  a. Strong FIXES occur when the observer is inside the triangle formed by three objects.

  b. A FIX is strong when three objects lie in a straight line with the center object closest to the observer.

  c. The sum of any two angles should not be less than 60 degrees.

  d. A FIX is strong when two objects that lie a considerable distance apart are aligned and the angle to the third object is not less than 45 degrees.

When planning a FIX, use objects on the chart that are accurately positioned. Charted objects that are accurate are indicated on the chart by a circle with a dot in the center and capital letters. Charted objects that are approximate are indicated on the chart by a small circle and small letters.

To measure an angle between two objects with the Sextant: Hold the Sextant horizontal to the horizon and sight on the object to the left. Move the index arm until the object on the right moves under the left object and the two objects are aligned. (When using a Mark 15 Sextant, squeeze the release lever to move the index arm.) When the two objects are lined in the horizon glass read the "ARC" Scale first (degrees) and then the "VERNIER" Scale (minutes). Record the reading as soon as the observation is completed. Take a second reading to confirm the first reading.

The Three-Arm Protractor is an instrument used to lay-out angles on a chart, i.e., assists in position plotting. The Davis Mark 3 Sextant and the Three-Arm Protractor read very similarly. Once the angles are measured with the Sextant, the next step is to plot the information. The plotting is accomplished by the transfer of the Sextant measured information onto a chart with a specialized piece of equipment, the Three-Arm Protractor. The Three-Arm Protractor has three scales, one on each arm - a 360 degree scale on the "Center Arm," which reads in degrees, with each mark/division/graduation equal to one degree, and a 60 minutes scale on each the "Left Arm" (scale on the left side of the center line) and "Right Arm" (scale on the right side of the center line), which read in minutes, with each mark/division/graduation equal to two minutes.

- As an example, for a three-point FIX (three LOPs), to set an angle of 17° and 56' to the left of the center object:

  a. Move the "Left Arm" left until the center line on the arm is between 17° and 18° on the 360 degree "Center Arm" scale.

  b. Next fine tune the reading so that 56' on the "Left Arm" scale is perfectly aligned with a mark on the 360 degree "Center Arm" scale (refer to Figure 8-9).

c. Lock the arms of the Three-Arm Protractor in-place, accordingly, once the reading(s) is/are set.

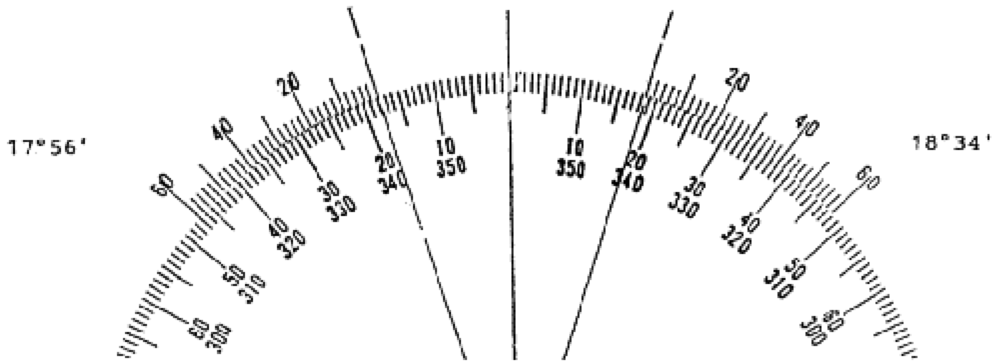


FIGURE 8-9 THREE-ARM PROTRACTOR SCALES

Now, when the two observed angles are set on the Three-Arm Protractor the position can be plotted on a chart. Thus, the angle measured between the center object and the left object is set using the "Left Arm" of the protractor, and the angle measured between the center object and the right object is set using the "Right Arm" of the protractor. In this operation, keep the "Center Arm" center line on the center object and maneuver the protractor until the "Left Arm" and "Right Arm" center lines are on their respective sighted objects. When alignment is achieved, the center pivot hole in the protractor indicates the position from which the Sextant angles were taken and should be so marked on the chart (refer to Figure 8-10).

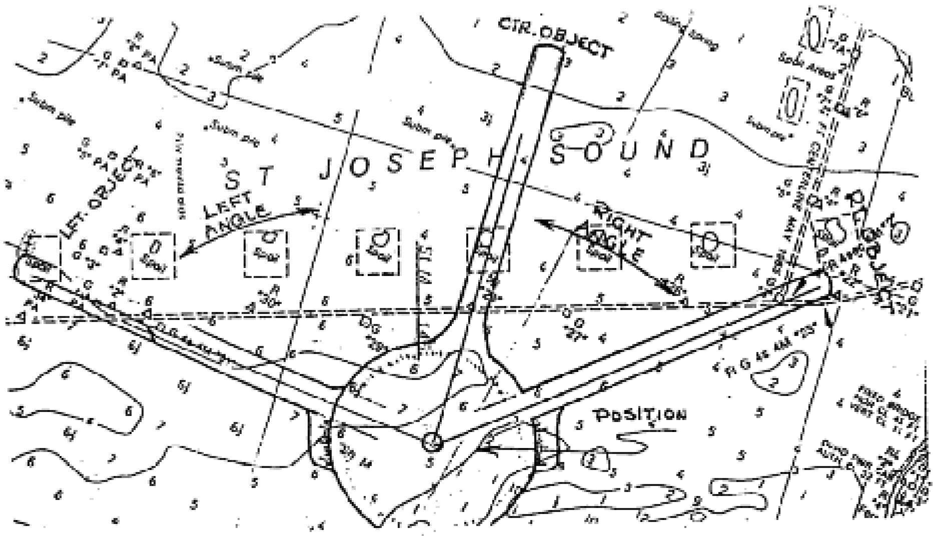


FIGURE 8-10 THREE-ARM PROTRACTOR - PLOTTING A THREE-POINT FIX

NOTE: The Three-Arm protractor should not be exposed to direct sunlight or heat as it is constructed of plastic and subject to warping.

When conditions dictate using a two-point FIX, where only two objects are available to establish a position, a bearing to one of the objects must be established. Once such a bearing is determined, the Sextant is used to measure the angle between the two objects and the FIX is established. In this connection, it is important to know that an LOP obtained from a bearing taken by magnetic compass must be corrected for variation and deviation to a TRUE bearing, before plotting on a chart. If a hand bearing compass is used to take the bearing, the observation should be taken from a deviation free location and corrected to a TRUE bearing (refer to Figure Figure 8-11).

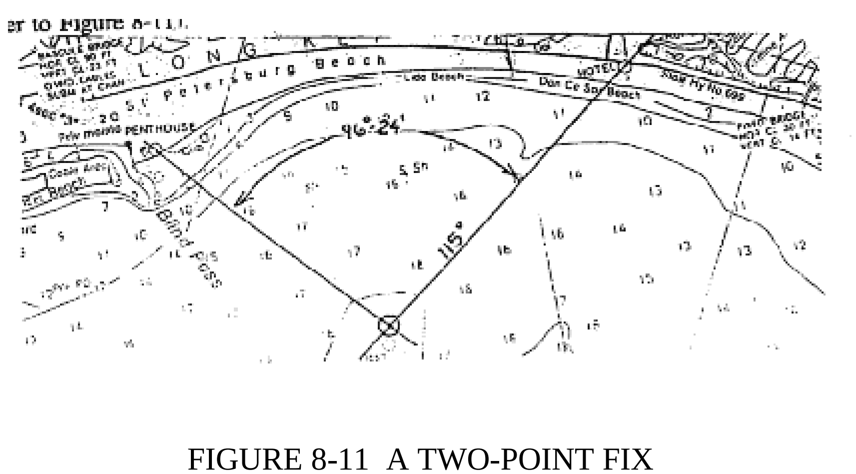


FIGURE 8-11 A TWO-POINT FIX

Understanding the techniques used to establish a position, the next step is to determine the position of an object from a charted position. In the three charted object case, three separate charted locations are used with an angle being established at each location between the object that is to be positioned and each of the charted objects. The charted objects will serve as a point of reference as angles are taken to the object to be positioned. The observer will hold the first position while the angle is measured from the charted object to the object to be positioned. The observer will then lay-out the angle using the known position and the known object as one side and the other side of the angle being an LOP from the known position through the object to be positioned. The same procedure will be repeated from the second position and third position. The chart location of the object to be positioned is at the intersection of the resulting three LOPs.

During such charting operations, the Auxiliary observer should make note of any un-charted objects, such as type of structure, color, lighting, etc. This type of information, along with Sextant measured angles, chart sections, drawings and photographs should be included as part of a NOAA 77-5 chart updating report.

For purposes of general navigation, i.e., position determination, safe passage, etc., it is necessary to know the height of an object such as tower, bridge, or building. In this regard, the height of an object is expressed in feet or meters. The Sextant is used to determine the height(s) of objects. This is accomplished by measuring vertical angles. To measure a vertical angle, hold the Sextant vertical and measure the angle from the top of the subject object/structure to the water's edge. For this operation, the Sextant index error must be checked, as such vertical angles are extremely small. Now, in conjunction with the available charted data, i.e., the charted position of the observation point and the charted position of the object/structure, the distance from the observation point to the object/structure is determined, the vertical angle of the object/structure is measured and its height determined.

- The formula to determine the height of an object is:

VerticaL Angle (in MINUTES) X Distance (in NAUTICAL MILES)/0.565 = Height of Object (in FEET)

Also, it is important to know, when the height of the object and the vertical angle are known, the distance from the observer to the object can be determined. Also, it is important to know that, the height of the object is determined in relationship to its height above the water. Refer to the following examples and illustrations:

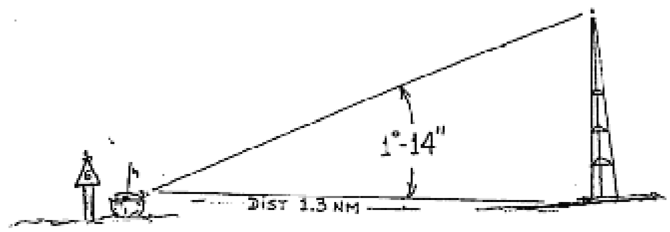
EXAMPLE #1

TO DETERMINE THE HEIGHT OF AN OBJECT FROM A KNOWN DISTANCE

a. Determine the distance to the object - expressed in NAUTICAL MILES - say for example 1.3nm

b. Measure the vertical angle of the object - expressed in MINUTES - say for example 74 minutes (one degree and 14 minutes)

c. From the formula - multiply the vertical angle (MINUTES) by the distance (NAUTICAL MILES) and divide their product by the factor 0.565 - as the example: 74 X 1.3/0.565 = 170 (feet)



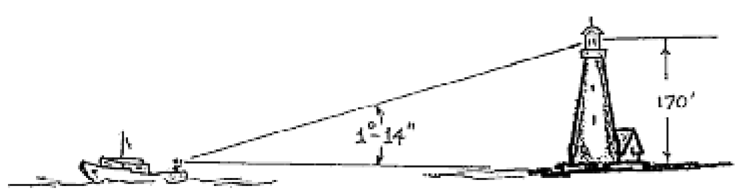
EXAMPLE #1 - DETERMINING HEIGHT OF AN OBJECT

TO DETERMINE THE DISTANCE FROM AN OBJECT OF A KNOWN HEIGHT

a. Given the height of the object as known - say 170 feet

b. Prom the formula we can say: 0.565 X Height of Object (in FEET) divided by the Vertical Angle (in MINUTES) = Distance (in NAUTICAL MILES)

c. As the example: 0.565 X 170/74 = l.3nm



EXAMPLE #2 - DETERMING DISTANCE FROM AN OBJECT

NOTE: Nautical charts are being converted to the METRIC SYSTEM with the **base unit** expressed in **meters**. The appropriate metric conversion factors apply, viz., feet-to-meters multiple by 0.30480, meters-to-feet multiple by 3.28083. Therefore, 170 FEET = 51.8160 METERS. As such, for the metric conversion of the above formula, i.e., FEET-to-METERS, change the factor **0.565** to **1.8566**, the resulting height computation will be expressed in METERS. [For Example #1 - 74 X 1.3/1.8566 = 51.8151 (meters) and for Example #2 - 1.8566 X 51.8151/74 = 1.3nm.]