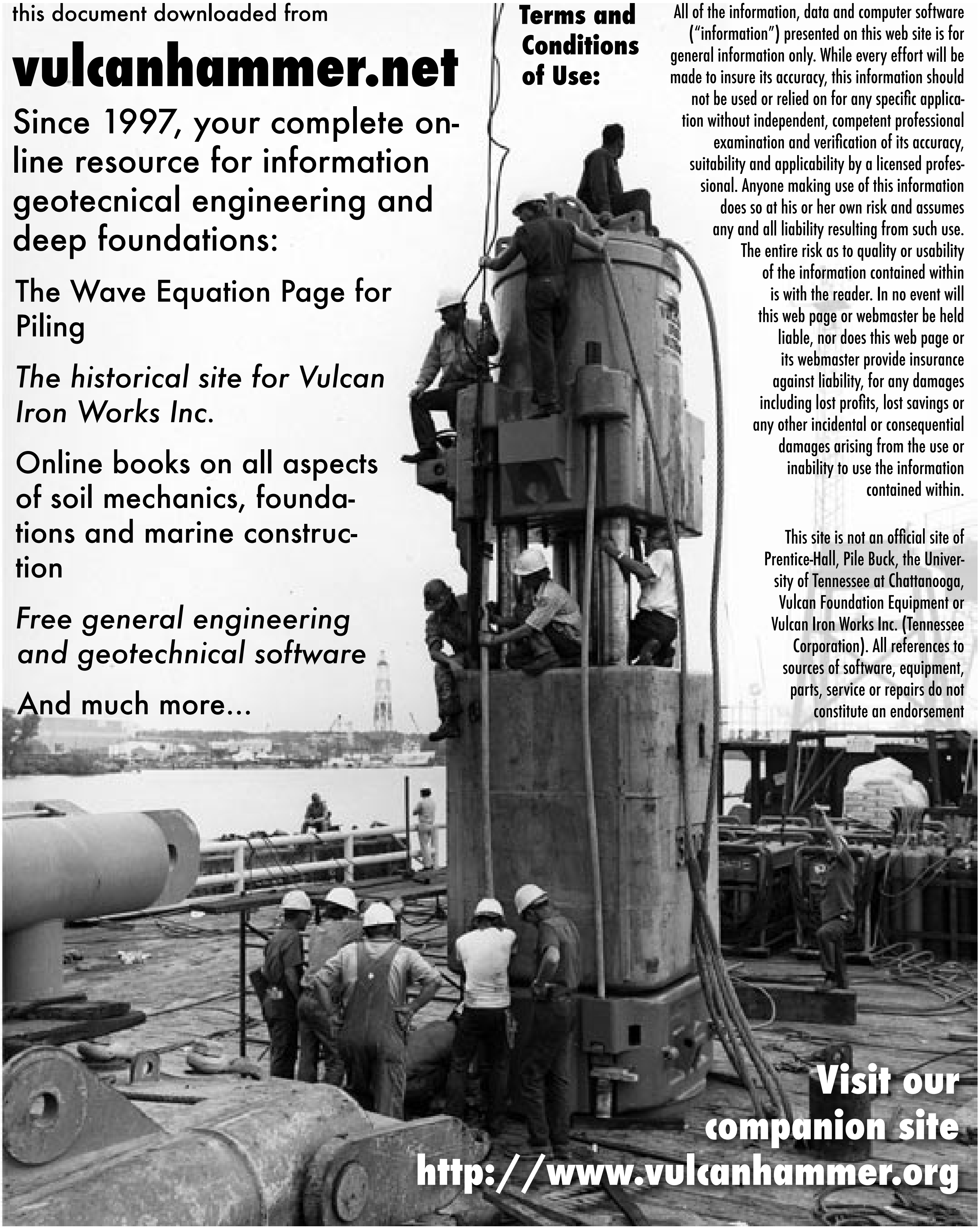


U.S. Department
of Transportation

United States
Coast Guard

Commandant
United States Coast Guard

2100 Second Street,SW
Washington, DC 20593-0001
Staff Symbol: G-NSR
Phone: (202) 267-0980

COMDTINST M16500.1C
MAR 26 1996

COMMANDANT INSTRUCTION M16500.1C

Subj: AIDS TO NAVIGATION MANUAL, POSITIONING

1. PURPOSE. This manual promulgates policy and guidance for the positioning of aids to navigation.

2. ACTION. Area and district commanders, activities commanders, commanders of maintenance and logistics commands, group commanders, unit commanding officers and officers in charge shall ensure compliance with this instruction.

3. DIRECTIVES AFFECTED. COMDTINST M16500.1B and COMDTINST 16500.22 are cancelled.

4. SUMMARY OF CHANGES. The major change is to introduce the Differential Global Positioning System as the primary means to position aids to navigation.

   a. Chapter 2 - The daily dockside reference check required in COMDTINST 16500.22 is no longer required. Instead Commanding Officers, Officers in Charge and coxswains shall ensure that the receiver is operating properly prior to positioning. Reference checks are required only when an onboard equipment configuration change has occurred. DGPS receivers are required to receive a minimum of four NMEA sentences: GGA, GRS, GST, GSA. Receivers that do not receive these sentences will not be authorized for positioning Coast Guard aids to navigation.

   b. Chapter 3 - Theory regarding electronic positioning methods is emphasized.

c. Chapter 4 - Due to the increased accuracy of electronic positioning methods, accuracy classes (AC) of some aids to navigation may need to be changed to reflect an AC that best serves the waterway. Methods for determining ACs for floating aids to navigation are provided for both electronic and traditional positioning techniques.

d. Chapter 5 - If, during a fixed structure rebuild, the most probable position of the structure is not more than ten feet from its charted position, then a chart correction need not be issued.

e. Chapter 6 - All references to the Computer Aided Positioning program (CAP II) have been replaced with the Automated Aid Positioning System (AAPS). Guidance has been provided for performing position check evaluations with both electronic and traditional visual means.

f. Chapter 7 - Guidance regarding the disposition of the Aid Positioning Record (APR) is provided. The AtoN servicing unit will maintain the original copy of the APR and forward a copy to the District. This change is preemptive to possible adoption of an electronic filing system.

g. Appendix 1 - This appendix was created to discuss historic positioning methods.

h. Enclosures - Information previously contained in enclosures (2) through (5) has been reviewed to determine its relevancy to modern day positioning. Some of this information was incorporated into the manual. Enclosure (5) has been renamed enclosure (2). Horizontal control information is provided in enclosure (3). Enclosure (4) discusses the procedure for preparing a positioning grid for use in positioning with sextants. Enclosure (5) provides information regarding DGPS RTCM broadcasts. DGPS reference station site information is contained in enclosure (6). Enclosure (7) describes the dockside DGPS reference check procedure.

/S/
RUDY K. PESCHEL
Chief, Office of Navigation Safety
and Waterway Services

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

Chapter 1. INTRODUCTION

A. General. This volume of the Aids to Navigation Manual (COMDTINST M16500.1 series) discusses the practices and procedures used by the Coast Guard to determine the position of floating and fixed aids to navigation.

B. Purpose. The purpose of this manual is to ensure aids to navigation are properly positioned in order to assist mariners to determine the position of their vessels, a safe course from that position, and to warn them of dangers or obstructions to their safe passage.

1. Aids to navigation positioning refers to the practices and procedures used by the Coast Guard to determine positions of floating and fixed aids to navigation. Results of our positioning efforts are used to advertise newly established or relocated aids and to place aids to navigation as close as practicable to established positions. Aid positioning requires more exacting procedures than those practiced in traditional navigation. This volume of the Aids to Navigation Manual contains a detailed discussion of the methods, procedures, tools and references used to position aids to navigation.

2. This manual is intended only for the internal guidance of personnel involved in positioning Coast Guard aids to navigation. The high expectations of performance contained in this manual are intended to encourage public service above and beyond the minimum threshold of "due care". Any requirements or obligations created by this manual flow only from those involved in Coast Guard aid positioning to the Coast Guard, and the Coast Guard retains the discretion to deviate or authorize deviation from these requirements. This manual creates no duties or obligations to the public to comply with the procedures described herein, and no member of the public should rely upon these procedures as a representation by the Coast Guard as to the manner of performance of our aids to navigation mission.

C. Objective. The objective of this manual is to outline guidelines and procedures for aids to navigation positioning which ensure each aid is placed as close as is reasonably possible to its assigned position. However, placing an aid at a specific geographic location is secondary to ensuring the aid's actual location marks good water and serves the purpose for which it was intended.

D. Background.

1. "Off-station" lawsuits brought against the Government beginning in 1959 and continuing through the 1960s brought to light the inadequacies in the Coast Guard buoy positioning program. In a particularly notable case involving the M/V TAMANO, a higher court made harsh and uncomplimentary comments concerning the Coast Guard's positioning program. Record keeping was found to be sloppy, inaccurate, and inadequate. Personnel were said to be grossly untrained and lacking in experience and general knowledge. The Aid to Navigation Positioning Project was begun to examine weak points and implement solutions. Primary problems and solutions found are summarized as follows:

   a. Equipment.

      (1) Problem. Sextants used to position aids were old, misused, and improperly calibrated. Unit allowances for sextants were largely incomplete. Personnel knowledge of proper care and maintenance of the instrument was poor. Use of instruments such as chart plotting tools, charts, and the 3-arm protractor to derive positions of aids lent excessive error to positioning results.

      (2) Solution. Survey sextants were purchased to fulfill positioning requirements.

   b. Records.

      (1) Problem. The space allocated on the SANDS form to record positioning results was inadequate, fostering incomplete and erroneous records.

      (2) Solution. The Aid Positioning Record (APR) was established.

   c. Standards.

      (1) Problem. Criteria used to determine if an aid was on or off station were subjective, and varied according to the scale of the chart where the buoy appeared.

      (2) Solution. Standards of aid positioning were established based on the needs of the mariner.

   d. Procedures.

      (1) Problem. Navigation procedures lacked the precision and accuracy necessary for positioning aids.

(2) Solution. Analytical procedures were implemented to replace the navigational practices used to maneuver to and determine the position of aids to navigation. The improvement of these procedures continues through Research and Development efforts. Automated positioning programs are a result of these efforts.

e. Advertising.

(1) Problem. While positioning "in the ball park," we were advertising "to the pin point." The "black dot" buoy charting symbol represented an accurate position to the mariner.

(2) Solution. The buoy symbol was changed to the "open circle," which signifies an approximate position on the nautical chart. Warnings were printed on charts and other nautical references to educate mariners with regard to the uncertainty of positions of floating aids to navigation.

f. Training.

(1) Problem. Training was nonstandard.

(2) Solution. Aid Positioning training was established both at the District and National level.

2. The solutions outlined above significantly improved the Coast Guard's performance positioning AtoN. However, poor visibility from bad weather and darkness limits the time available to position AtoN. Also, the lack of a sufficient number of surveyed objects in many areas makes visual positioning difficult and time consuming. The Coast Guard began research and development efforts to develop an easier, more efficient positioning system. Building on the technology of the Department of Defense's Global Positioning System, the Coast Guard developed the Differential Global Positioning System which provides all-weather, all-visibility, 24 hour a day, accurate positioning information.

E. Organization.

1. Commandant (G-NSR) administers the aids to navigation positioning program throughout the Coast Guard by originating policy, standards, and procedures for aid positioning. Commandant (G-NSR) also provides liaison with other Coast Guard programs and other federal agencies at the national level.

2. District Commanders (oan) implement positioning policy within their Districts and ensure that their units are trained and equipped to properly position aids to navigation. Training is provided on an annual basis by district training teams.

3. Field units position aids, report to their District office and inform their District when situations require special assistance.

4. The National Aids to Navigation (NATON) School, Reserve Training Center Yorktown, provides training in aid to navigation positioning. Personnel with positioning responsibilities should take advantage of NATON School resident and/or non-resident training opportunities.

F. Policy. This manual is intended to cover the broad universe of aid positioning. It cannot address every unique circumstance which may occur in actual aid positioning operations. When an Officer in Charge or Commanding Officer finds certain guidance in this manual to be inappropriate, inapplicable, or impractical, that guidance shall be disregarded, and the aid should be positioned using that individual's best professional judgment. In all such instances, a full explanation shall be included in the remarks section of the Aid Positioning Record (APR) or an attached memo.

G. Exemptions.

1. Not all aid placement can be achieved in accordance with procedures prescribed herein. Where it is not reasonably practical to position aids in accordance with this manual, District Commanders may exempt units from compliance.

   a. The practice of placing an aid to navigation in a waterway solely on the basis of soundings, without regard to its geographic position, is a sometimes necessary and often desirable method of marking a waterway. Hundreds of miles of Western River waterways, for example, are marked by buoys placed with respect to existing and projected water depths. Geographic positions for these aids would have no meaning or value to the mariner.

   b. Areas exist where the Global Positioning System (GPS) and Differential Global Positioning System (DGPS) are unavailable.

   c. Additionally, areas exist where an adequate spread of horizontal control is lacking and is either impractical or impossible to establish due to the physical layout of the channel and its banks.

2. Units shall request exemptions to the Coast Guard's positioning policy from their District Commander (oan). Requests shall be in writing and shall include the circumstances and conditions that preclude the aid from being positioned in accordance with the procedures in this manual. Exemptions shall be specific to the aid, waterway, or geographic area intended. In addition, the request shall include the procedures the unit intends to follow to ensure adequate placement and record keeping for the aid.

3. When a request for exemption is approved by the District Commander, a letter shall be provided to the unit with a copy to Commandant (G-NSR-1). Plenary exemptions by unit, waterway or specific portions of waterways may be made via the District Standard Operating Procedure or a District Instruction.

4. Where exemptions are granted under authority of this manual, District Commanders shall ensure procedures are established to ensure a uniform and adequate system of aid placement and record keeping.

Chapter 2. POSITIONING INSTRUMENTS AND GUIDELINES

A. General. The primary method for positioning Coast Guard aids to navigation shall be the Differential Global Positioning System. Other methods available for positioning aids to navigation include horizontal sextant angles, the Global Positioning System (GPS), gyro bearings and ranges. **Deviations from these guidelines are authorized when necessary to best meet the objectives and standards of aid positioning.**

B. DGPS. The USCG Differential Global Positioning System (DGPS) provides all-weather, all-visibility, day and night, accurate, positioning information. Use of DGPS is subject to the following conditions:

1. DGPS data must be electronically transmitted into an approved aids to navigation positioning program.

2. DGPS shall not be used to position AtoN when an unhealthy or unmonitored signal is received.

3. DGPS receivers must be capable of receiving the following NMEA sentences: GGA, GRS, GST, GSA.

4. Commanding Officers, Officers in Charge and coxswains shall ensure the DGPS receiver is operating properly prior to positioning.

    a. If a CO/OinC/coxswain has reason to doubt the performance of the DGPS receiver, receiver operation may be verified by conducting the reference check described in enclosure (7).

    b. In cases where there has been an onboard equipment (hardware) configuration change, the verification procedure in enclosure (7) must be performed prior to using the DGPS equipment for positioning.

5. DGPS shall not be used if the age of the pseudorange correction exceeds 30 seconds.

6. The DGPS receiver's datum conversion feature must be turned off. DGPS receivers are normally set by the manufacturer to convert datum data from WGS84 to NAD83. The DGPS reference station corrections are automatically converted prior to being broadcast, therefore the DGPS receiver setting must be changed to avoid duplicating this conversion. Refer to the manufacturer's operators' manual.

7. While positioning, the DGPS mode in the receiver must never be set to automatic.

8. The horizontal dilution of precision (HDOP) reading must not be zero (0). A reading of 0 indicates that the system is not functioning properly.

Note: If DGPS becomes unavailable for an extended period of time, alternative positioning methods should be considered.

C. Sextants. The Survey Sextant, Navy MK II marine sextant, and Navy MK III marine sextant are most commonly used for measuring horizontal sextant angles. (See enclosure 1 for more information on sextants.) When positioning aids to navigation using horizontal sextant angles, best results can be obtained by adhering to the following guidelines:

1. Use at least three angles with a minimum of four reference objects. Four angles, however, are recommended. The fourth angle will serve to improve fix quality. In circumstances where horizontal control is limited and the unit has only three reference objects that are surveyed to an accuracy of third order, the unit must include at least one additional line of position, such as a bearing, for use with the three possible angles.

2. When horizontal control is poor, an LOP other than a sextant angle may be necessary to produce a fix with an adequate error ellipse.

3. Use the combination of angles (best fix) that will yield the smallest error ellipse.

4. When one object is elevated significantly higher than the other, an inclined angle correction must be applied to compensate for the difference between an inclined angle and a horizontal angle (see enclosure 2).

5. Angles taken from a mobile platform should be taken simultaneously. If this is not possible, the angles should be taken in rapid succession.

6. Multiple observers should stand as close together as possible.

D. GPS. In areas where DGPS is unavailable, GPS may be used for positioning aids to navigation that have a Desired Positioning Tolerance (DPT) of 150 yards or have been granted an exemption to the Coast Guard positioning program when, in the opinion of the Commanding Officer/Officer in Charge, GPS provides the most accurate positioning information available. Use of GPS is subject to the following conditions:

1. GPS data must be electronically transmitted into an approved aids to navigation positioning program.

2. GPS <u>shall</u> not be used to position AtoN when the Horizontal Dilution of Precision (HDOP) is greater than twenty.

3. The GPS receiver must be set to convert from WGS84 to NAD83, except when positioning in WGS84.

4. The horizontal dilution of precision (HDOP) reading must not be zero (0). A reading of 0 indicates that the system is not functioning properly.

E. <u>Gyrocompass</u>. Gyro bearings do not have the inherent precision of sextant angles and may not be used as the sole means for positioning aids to navigation unless an exemption has been granted. Gyro bearings, however, may be used for positioning aids to navigation <u>in conjunction wit</u>h horizontal sextant angles if needed to strengthen the confidence of an aid's position.

1. When gyro bearings are used, calibration of the gyrocompass is essential. The gyro error should be logged and applied to any bearings used for positioning.

    a. For positioning purposes, the gyro calibration should be done with the vessel motionless or when traveling in a due east or due west direction. If the vessel is moving in other than an east/west direction, the resulting error (gyro speed error) can be as much as 2 degrees.

    b. It is important that the gyro be calibrated to the nearest one-half degree. This should be completed using a charted navigational range. Measurement of a natural range <u>from a chart</u> is not sufficiently accurate enough to use for aid positioning. Natural ranges may be used, however, if accurate positions are known for them and the range bearing calculated by an acceptable computation. Bearings for navigational ranges are listed in the light list to the nearest minute.

    c. Check the latitude adjustment to ensure that it is consistent with the area of operation.

    d. Repeater errors should be determined, logged, and applied to any bearings used for positioning.

2. <u>Gyro Speed Error</u>. The north-seeking tendency of the gyro compass is dependent upon the fact that north forms a right angle to the west to east direction of the earth's rotation. Therefore, gyro speed error occurs as the result of the gyro compass being carried over the earth's surface in a direction other than west or east.

a. When the vessel is moving in an east or west direction or is stationary with respect to the earth's surface, the compass is carried in a west or east direction.

b. When the vessel is moving in other than an east or west direction, the compass is being carried slightly to the north or south of exact east. The compass will seek a settling position which is at right angles to that direction and settle on a line a small angle off true north.

(1) This error is westerly if any component of the vessel's course is north, and easterly if any component of the vessel's course is south.

(2) The magnitude depends on speed, course and latitude.

F. Ranges.

1. Radar. Radar ranges may be used for positioning aids to navigation in conjunction with horizontal sextant angles or other LOPs when the potential error of the radar scale in use is less than the Accuracy Classification (AC) tolerance of the aid to be positioned. They should, however, only be used as a last resort.

a. Radars currently in use, even if carefully calibrated, may have an error up to 4.0% of the range scale when using the .25nm scale and 1.0% when using larger ranges. Potential error of the radar range scale in use must be calculated and evaluated against the accuracy classification of the aid to determine if a radar LOP may be used to position the aid. This potential error equates to 20 yards on the .25 mile scale, 15 yards on the .75 mile scale, 30 yards on the 1.5 mile scale, etc. Therefore, ranges taken using the .25 mile scale may only be used to position aids with ACs B through G. Ranges taken on the 3 mile scale may only be used for aids with ACs C through G, etc., (See Chapter 4 for more information on ACs). Newer model radars expected to be in use within the next few years should have significantly less error; refer to the radar's specifications.

b. Determining whether a radar range may be used is the first step. If a radar range may be used, then the actual error (normally determined during underway preparations) must be applied to the measured range before using the range as an LOP for aid positioning.

c. When radar is used, calibration of the radar is essential.

   (1) When calibrating the radar, use only computed distances. Distances scaled from the chart do not have the necessary accuracy.

   (2) Even when calibrated within normal (navigation) limits, calibration error alone may be as great as 1.0% of the range scale in use or 10 yards; whichever is greater.

d. Radar bearings are <u>never acceptable</u> for positioning aids.

2. <u>Electronic Ranging Systems</u>. Systems which provide ranges from third order, Class I surveyed positions may be used either in conjunction with other approved LOPs or alone.

3. <u>Stadimeter</u>. Ranges determined by stadimeter will not produce acceptable LOPs, unless the aid is exempt. They may, however, be a very important factor in validating an aid's position.

4. <u>Vertical Sextant Angles</u>. Ranges determined by vertical sextant angles will not produce acceptable LOPs, unless the aid is exempt. They may, however, be a very important factor in validating an aid's position.

G. <u>Charts</u>. Navigational charts, paper or electronic, shall not be used for positioning aids to navigation or to scale positions of reference objects.

1. Charts are flat representations of a round earth. A straight line on a Mercator chart (rhumb line) is not a straight line (great circle) on the earth's surface.

2. Mapping standards allow cartographer tolerances of up to 1/30th of an inch from actual positions on charts with a scale of greater than 1:20,000 and 1/50th of an inch for scales 1:20,000 and smaller.

3. Charts are compiled by the National Ocean Service (NOS). The data used by NOS is derived from many sources. NOS may receive incompatible data such as an aid position that is inconsistent with the Army Corps of Engineers (ACOE) channel location. In such a case, NOS may relocate the aid until it looks correct (good relative position) with no geographic significance.

4. Information on the chart may be out of date.

   a. Landmarks may have been destroyed, moved, or rebuilt. Charted positions of these landmarks may not reflect the newer positions.

   b. When a chart is updated, small position changes within the cartographer's tolerance are not reflected since they have no significance to the mariner.

5. The paper on which the chart is drawn changes with temperature, humidity, wear and damage.

H. Position Datums. The release of the Automated Aid Positioning System (AAPS) highlights the importance of knowing what horizontal geodetic reference datum is being used when either positioning or reporting the positions of aids to navigation.

1. To position an aid to navigation with AAPS using GPS or DGPS, the aid position must be referenced to the North American Datum of 1983 (NAD83) or the World Geodetic System of 1984 (WGS84).

2. Many of the positions of Coast Guard aids to navigation and the reference objects used for positioning with the previous positioning system (CAPII) were not referenced to the North American Datum of 1983 (NAD83).

   a. Many of the Coast Guard's CAPII aid and object files were converted to AAPS files, NAD83, in early 1992 at the Coast Guard Research and Development Center.

      (1) With the exception of the Ninth and Fourteenth Districts, many of the aid positions in the Aids to Navigation Information System (ATONIS) have also been converted to NAD83.

      (2) In areas where aid positions were referenced to older datums that could not be accurately converted to NAD83, letters were sent to the responsible district documenting the situation.

   b. North American Datum Conversion (NADCON) Software was distributed to the districts in 1992. This software will help districts perform position datum conversions from NAD27 to NAD83.

   c. Districts and units that are still in the process of converting their CAPII aid and object files to NAD83, for use with AAPS, must ensure that during this transition period the aid positions and the object positions are referenced to the same datum.

3. The majority of nautical charts published by NOAA/NOS are referenced to NAD83. The Local Notice to Mariners shall list the geographic positions of corrections in the same datum used on the current edition of the nautical chart.

4. The Aids to Navigation Manual - Administration, COMDTINST 16500.7 contains additional information on the use and implementation of NAD83.

5. To minimize the potential for confusion, the geodetic datum should be noted when recording a position for an aid to navigation. If the geodetic datum used is other than NAD27, NAD83, or WGS84, it must be listed in the remarks section of the Aid Positioning Report.

I. Sounding Equipment. Soundings must be taken each time a buoy is positioned. The buoy must mark the depth appropriate to the waterway, and the aid's position must be verified in relation to depth. The sounding should be taken as near to the buoy's sinker as possible. Where the bottom slopes sharply, soundings will add validity to a fix. Soundings will not produce acceptable LOPs, but they are a very important factor in validating positions of aids. A correct sounding will add confidence to a fix, whereas an incorrect sounding may be a clear indication that the buoy is not in its proper position. Soundings must be adjusted to charted datum by applying the proper tidal correction.

1. Electronic Soundings. When soundings are obtained by fathometer, the vertical distance from the vessel's waterline to the fathometer transducer must be taken into account. This is normally accomplished in the Automated Aid Positioning Program. Electronic sounding equipment must be calibrated IAW the manufacturer's instructions.

2. Manual Soundings.

a. Lead Line. A lead line consists of a piece of line (approximately quarter inch diameter) with a weight at one end and markings sewn on to show depth. It is important that the line used be relatively stable in length. The markings should be applied while the line is wet and under strain. A lead line will not work well in areas with significant current or extremely deep water.

b. Sounding Pole. A sounding pole is a stiff pole with a weighted metal shoe on one end. It is marked (usually in feet), and is used in protected water of less than 20 feet of depth. Since it does not change length, and the flat foot will not penetrate a soft muddy bottom as much as a lead line, it can provide a more accurate sounding in shallow water.

Chapter 3. THEORY OF POSITIONING

A. Global Positioning System (GPS). GPS is a space-based positioning, velocity, and time system that has three major segments: space, control, and user.

1. The GPS concept is predicated upon accurate and continuous knowledge of the spatial position of each satellite in the system with respect to time and distance from the user. The GPS receiver makes time-of-arrival measurements of the satellite signals to obtain the distance between the user and the satellites. These distance calculations (called pseudoranges), together with range rate information, are combined to yield system time and the user's three-dimensional position and velocity with respect to the satellite system. A time coordination factor then relates the satellite system to Earth coordinates.

2. GPS provides two levels of service for position determination, Standard Positioning Service (SPS) and Precise Positioning Service (PPS). Accuracy of a GPS fix varies with the capability of the user equipment.

   a. Standard Positioning Service (SPS): SPS is the standard specified level of positioning and timing accuracy that is available, without qualification or restrictions, to any user on a continuous worldwide basis. The accuracy of this service will be established by the U.S. Department of Defense (DOD) based on U.S. security interests. On a daily basis SPS provides worldwide horizontal positioning accuracy within 100 meters.

   b. Precise Positioning Service (PPS): PPS is the most accurate positioning, velocity, and timing information continuously available, worldwide, from GPS. This service is limited, through the use of cryptography, to authorized U.S. and allied Governments, authorized foreign and military users, and eligible civil users. On a daily basis PPS provides worldwide horizontal positioning accuracy to within 21 meters through the use of "P Code" capable receivers.

3. Fix Rate. The fix rate is essentially continuous. Actual time to a first fix depends on user equipment capability and initialization with current satellite almanac data.

4. Integrity.

   a. According to DOD's concept of operation, GPS satellites are monitored more than 95 percent of the time by a network of five monitoring stations spread around the world. The information collected by the monitoring stations is processed by the Master Control Station at Colorado Springs, Colorado, and used to periodically update the navigation message (including a health message) transmitted by each satellite. The satellite health message, which is not changed between satellite navigation message updates, is transmitted as part of the GPS navigation message for reception by both PPS and SPS users. Additionally, satellite operating parameters such as navigation data errors, signal availability/anti-spoof failures, and certain types of satellite clock failures are monitored internally within the satellite. If such internal failures are detected, users are notified within six seconds. Other failures detectable only by the ground control segment may take from 15 minutes to several hours to detect.

   b. GPS receivers use the information contained in the navigation and health messages, as well as self-contained satellite geometry algorithms and internal navigation solution convergence monitors, to compute an estimated figure of merit. This number is continuously displayed to the operator, indicating the estimated overall confidence level of the position information.

5. Multipath. Multipath is a situation created when the GPS receiver receives two identical signals at different times. This can happen in areas where a signal is reflected off a nearby building, mountain, etc. The reflected signal is received after the direct signal. If this happens, the GPS receiver will in all likelihood fail to provide any fix information.

B. Differential GPS.

1. DGPS is an enhancement of the DOD's GPS through the use of differential corrections to the basic satellite measurements performed within the user's receiver. DGPS is based upon accurate knowledge of the geographic location of a reference station, which is used to compute corrections to GPS parameters, error sources, and/or resultant positions. These differential corrections are then transmitted to GPS users, who apply the corrections to their received GPS signals or

computed position. For a civil user of SPS, differential corrections can improve navigational accuracy from 100 meters (2DRMS) to better than 10 meters (2DRMS). A DGPS reference station is fixed at a geodetically surveyed position. From this position, the reference station tracks all satellites in view, downloads ephemeris data from them, and computes corrections based on its measurements and geodetic position. These corrections are then broadcast to GPS users to improve their navigation solution. There are two well-developed methods of handling this:

a. Computing and transmitting a position correction in x-y-z coordinates, which is then applied to the user's GPS solution for a more accurate position.

b. Computing pseudorange corrections for each satellite, which are then broadcast to the user and applied to the user's pseudorange measurements before the GPS position is calculated by the receiver, resulting in a highly accurate navigation solution.

2. The first method, in which the correction terms for the x-y-z coordinates are broadcast, requires less data in the broadcast than the second method; but the validity of those correction terms decreases rapidly as the distance from the reference station to the user increases. Additionally, this method requires that both the reference station and the user compute the navigation solution using the same set of satellites, when that is not necessarily the case.

3. Using the second method, several GPS observations along with the broadcast satellite parameters are used by a reference station which compares the measured ranges (pseudoranges) for up to nine satellites in view to a precisely known geodetic position. The reference station then generates pseudorange corrections (PRCs) for these satellites. The corrections are simply the difference between the pseudorange and the calculated range of each satellite. They are calculated using the difference between the satellites broadcast position and the geodetic position of the reference station. Since the reference station does not maintain an absolute time of very high accuracy that would require expensive time transfer equipment, an equal time bias term resides in every PRC. This term is of no consequence when the user is utilizing PRCs from a single reference station since

this common time bias drops out when computing a position solution. This method provides the best position solution for the user and is the preferred method. It is the method employed by the Coast Guard DGPS Service. The major elements of DGPS are described below:

a. Reference Station. Generates corrections to pseudoranges for broadcast to users within its coverage area. This consists of a high quality, all-in-view GPS receiver with the additional computational capability to generate Radio Technical Commission for Maritime Services (RTCM) messages for the broadcast and to communicate with a remote control system. Pseudorange Corrections (PRCs) are broadcast for up to nine satellites which are above a 7.5 degree mask angle. It also accepts a "watch-dog" signal from the co-located integrity monitor, and is prepared to broadcast an integrity warning in the event of loss of monitoring, or when an anomaly is detected by the integrity monitor. Co-location with the broadcast transmitter has been found to be the most economical and highest performing option.

b. Broadcast Transmitter. A marine radiobeacon that has been modified to accept MSK (Minimum Shift Keying) modulation. MSK is a spectrally efficient, advanced form of digital modulation. Real time differential GPS correction data are input in the RTCM SC-104 format and broadcast to all users capable of receiving the signals. The Coast Guard does not plan to use data encryption. Radiobeacons were chosen because of existing infrastructure, compatibility with the useful range of DGPS corrections, international radio conventions, international acceptance, commercial availability of low cost equipment, and highly successful field tests.

c. Control Stations. Two computerized control systems operated by live watchstanders will be established, one on the East Coast (Alexandria, Virginia) and the other on the West Coast (Petaluma, California). Each will be connected to all broadcast sites in the area by a packetized data communication network. The control stations perform system level monitoring and configuration control of the data communication network and equipment at the individual sites. Each station will be capable of handling the entire network in an emergency or for maintenance purposes. With the reference station and the integrity monitor co-located, the broadcast can remain healthy for a prolonged period of time if communications are severed from the Control Station.

d. Integrity Monitor. This will consist of an MSK receiver and a GPS receiver. Integrity is monitored on both the pseudorange and the position domain level. The integrity monitor will be connected to the GPS reference receiver through a one way port, and it will continuously inform the reference receiver of the status of the broadcast as received at the broadcast site.

e. Shipboard Equipment. The Coast Guard's DGPS system will broadcast corrections to the user in the RTCM SC-104 (Version 2.1) format. The RTCM has defined data messages for use in the transmission of DGPS corrections, ancillary information, and integrity information. As the RTCM format allows flexibility in its implementation and use, the U.S. Coast Guard's Broadcast Standard, COMDTINST 16577.1 (series), further defines the use of this format along with specifying the various broadcast parameters. Shipboard equipment shall be capable of receiving those data messages listed in enclosure (5).

4. DGPS Reference Station Sites. A listing of the DGPS reference station sites, frequencies, effective ranges, and other data is contained in enclosure (6). DGPS reference station signals shall not be used for positioning aids to navigation beyond 265 NM.

5. Information Updates. The latest updated information pertaining to the DGPS Service is available through the Navigation Center (NAVCEN). This is a service which is provided by the USCG for the users of the Global Positioning System. The NAVCEN maintains a twenty-four hour watch and can be contacted at telephone # (703) 313-5900. Information on the DGPS Navigation System which is available includes:

- Current System Status
- Coverage Diagrams
- Broadcast Site Listings
- Current Plans/General Information etc.

All information which is provided can be downloaded from a computer bulletin board. For the coverage diagrams, the Tagged Image File (TIF) format will be utilized. The NAVCEN computer bulletin board may be accessed by dialing (703) 313-5910 for modem speeds of 300 - 14,400 bps. The protocol is asynchronous with 8 data bits, 1 stop bit, and no parity. A wide range of DGPS and GPS information is available ranging from DGPS Broadcast Site Listings to GPS precise ephemeris data. Current USCG publications which are of interest to a large user segment are also available on the bulletin board.

C. Horizontal Sextant Angles

1. Positioning an aid to navigation using horizontal sextant angles is based on two theories of geometry.

   a. Three points in space on the same plane not in a straight line define a circle.

   b. If two of these points are fixed, the angle formed between these two points remains constant along the circumference of the circle until passed through the chord which connects the two points.

2. The mathematical determinations of ideal angles, gradients, positive gradient direction and Best Fix are made through the use of the Automated Aid Positioning System (AAPS) software.

   a. The value of the sextant angle at the assigned position of the aid is called the ideal angle. The ideal angle represents the angle that would be measured between the two reference objects from the assigned position if there was no error in the sextant or the measurement.

   b. The Gradient of the LOP is the measurement of distance that must be travelled in order to change the sextant angle by a given amount. The gradient is expressed as a ratio of Yards to Minutes.

   c. The Positive Gradient Direction (POD) is the direction that must be traveled to INCREASE the sextant angle.

D. Lines of Position. A Line of Position (LOP) is a line on which you are presumed to be. It may be straight or curved. For the purpose of positioning we consider the circular LOP formed by a sextant angle to be a straight line, expressed as a bearing, called the LOP direction. This straight line approximation is tangent to the circular LOP passing through the aid's position.

Chapter 4. ACCURACY CLASSIFICATION FOR FLOATING AIDS TO NAVIGATION

A. Introduction. Standards for positioning floating aids to navigation have been established in order to assist units in meeting the objective of this manual as stated in Paragraph 1.C. Buoyant beacons shall be treated as floating aids for positioning purposes. These standards are designed to meet the needs of the mariner and are tempered by the unit's ability to position the aid.

B. General. Positioning standards are used to determine the accuracy classification assigned to each floating aid to navigation. Accuracy classifications are based on the risks to safe navigation in the vicinity of the aid's position. Consideration is given to the size and type of waterway, traffic density, type of user, typical cargo, hazards such as bottom type, banks and shoals, watch circle radius of the aid, and the methods available for positioning the aid.

C. Definition. The Accuracy Classification (AC) is the area, expressed as the radius of a circle in yards, around the assigned position (AP) of an aid to navigation within which the aid is considered to be on station. The AP is the precise geographic location, expressed in latitude and longitude, where the aid should be located.

1. An AC shall be assigned to all floating aids to navigation except aids that have been granted an exemption (see Paragraph 1.G. of this manual).

2. The factors used for determining an AC are Desired Positioning Tolerance (DPT), Achievable Error Ellipse (AEE), Watch Circle Radius (WCR), Target Area, and Achievable Buoy Station Dimension.

3. The AC is assigned using a letter designator from Table III (see Table of Contents for Table listings) with a corresponding tolerance (in yards).

4. The AC assigned each aid shall be reviewed at least triennially to ensure that the value assigned reasonably portrays the mariner's needs and the unit's ability to position. Some of the factors to consider when reviewing ACs are:

   a. Positioning methods available and historical results. If previous results have consistently produced better results than is reflected by the assigned AC, the unit should consider upgrading the AC.

   b. Changes in depth of water, chain length, characteristics of the waterway, or users of the waterway.

D. Accuracy Classification. Floating aids to navigation shall have assigned ACs following the procedures contained in this chapter.

1. Aids (including those that have been granted an exemption to the Coast Guard aid positioning program due to lack of adequate horizontal control) that can now be positioned by DGPS shall be assigned an AC following the procedures in this chapter. This means that in some cases, aids previously positioned with horizontal sextant angles may need a new accuracy class determined at the next service. The aid's DPT shall be used as the target area of the aid. In the event that an aid cannot be positioned within the AC calculated using the DPT, units shall follow the procedures in Chapter 1 to obtain an exemption.

2. In areas where DGPS coverage does not exist and horizontal sextant angles are the primary means of positioning aids to navigation, ACs will be calculated using the procedures in this chapter.

3. When using GPS to position aids to navigation, the accuracy classification shall be determined using the DPT as the target area. If the DPT is less than 150 yards GPS may not be used. The advertised accuracy of GPS is 110 yards.

E. Desired Positioning Tolerance. The DPT is the radius of a circle that describes the maximum desired error for positioning the aid. It is based on the navigational needs of the mariner and the service that the aid provides. The DPT specifically considers the waterway risk level, the channel width to vessel beam (W/B) risk level, and the area type. The Waterways Analysis and Management System (WAMS) analysis of the waterway can be a valuable source of information in determining these factors. For each category select the factor that best describes the waterway's conditions.

1. Waterway Risk Level. There are three waterway risk levels: great, moderate and low. The waterway risk level is based on the type and volume of traffic prevalent at the aid location, the environmental sensitivity of the waterway, and the bottom type (hard or soft). The deciding factor is the characteristic that falls into the highest risk category. Determine the waterway risk level using the following criteria:

a. Great Risk.

(1) Traffic Density. The amount of vessel traffic is substantial. Vessel congestion can be a problem.

(2) Type of Traffic. Vessel traffic consists of various types including large commercial vessels. Vessels containing hazardous cargo whose grounding and subsequent discharge would pose a substantial threat to public health or welfare, or result in critical public concern shall be classified as a Great Risk area. (This terminology is contained in the Federal Register, Part III, Council on Environmental Quality which covers the National Oil and Hazardous Substances Pollution Contingency Plan. Hazardous cargos are listed in 40 CFR Part 117.)

(3) Environment. The waterway has environmentally sensitive areas and endangered species areas that have been established and promulgated by NOAA and the National Wildlife Federation.

(4) Bottom Conditions. Hard bottom conditions (rock, coral, wreck, etc.) exist where the likelihood of holing a vessel is great.

b. Moderate Risk.

(1) Traffic Density. The amount of vessel traffic is moderate. Vessel congestion is not a problem under normal waterway conditions.

(2) Type of Traffic. Vessel traffic consists of commercial fishing fleets and smaller commercial vessels carrying non-hazardous cargo.

(3) Environment. The waterway has little effect on environmentally sensitive areas.

(4) Bottom Conditions. Bottom conditions are such that a possibility of holing a vessel exists if a grounding occurs, but not to the extent as in a Great Risk waterway.

c. Low Risk.

(1) Traffic Density. The amount of vessel traffic is light. Little or no vessel congestion exists.

(2) Type of Traffic. Vessel traffic consists of small pleasure craft, fishing boats and small commercial vessels carrying non-hazardous cargo.

(3) Environment. A marine casualty on the waterway will have little or no effect on environmentally sensitive areas.

(4) Bottom Conditions. A soft "forgiving" bottom makes the likelihood of holing a vessel remote if a grounding occurs.

2. Channel Width to Vessel Beam Risk Level. The width to beam risk level is a function of the channel width to vessel beam ratio and the traffic flow in the channel.

a. Determine if you have a one or two way channel. Select one way if the channel is part of a traffic separation scheme or regulated to allow for passage in only one direction. All others shall be considered two way channels.

b. The Width to Beam (W/B) ratio relates the size and maneuverability of the vessel to the physical size of the waterway. Determine the Width to Beam risk level using the following steps:

(1) Obtain the channel width (in feet) from the Army Corps of Engineers, the tabulated channel dimensions legend located on the chart, or hand-scaling the width from the chart.

(2) Estimate the vessel beam (in feet) of the composite user of the waterway. The "composite user" is the representative vessel; determined by averaging the characteristics of the typical user of the waterway. You may obtain this information from various sources including: Vessel Traffic Service, Captain of the Port, local Pilot association, harbor master, yacht club, or fishing fleet.

(3) Divide the channel width by the vessel beam of the composite user to obtain the entering value for the W/B Ratio in Table 1.

c. Enter Table I with one or two way traffic and the W/B ratio to determine the Width to Beam Risk Level.

TABLE I - WIDTH TO BEAM RISK LEVEL			
	W/B < 3	W/B = 3-5	W/B > 5
One-Way Channel	GREAT RISK	MODERATE RISK	LOW RISK
	W/B < 5	W/B = 5-8	W/B > 8
Two-Way Channel	GREAT RISK	MODERATE RISK	LOW RISK

3. Geographic Area Type. There are three area types. The area type should generally correspond with the Light List description of where the aid is located and the size of the waterway that the aid marks.

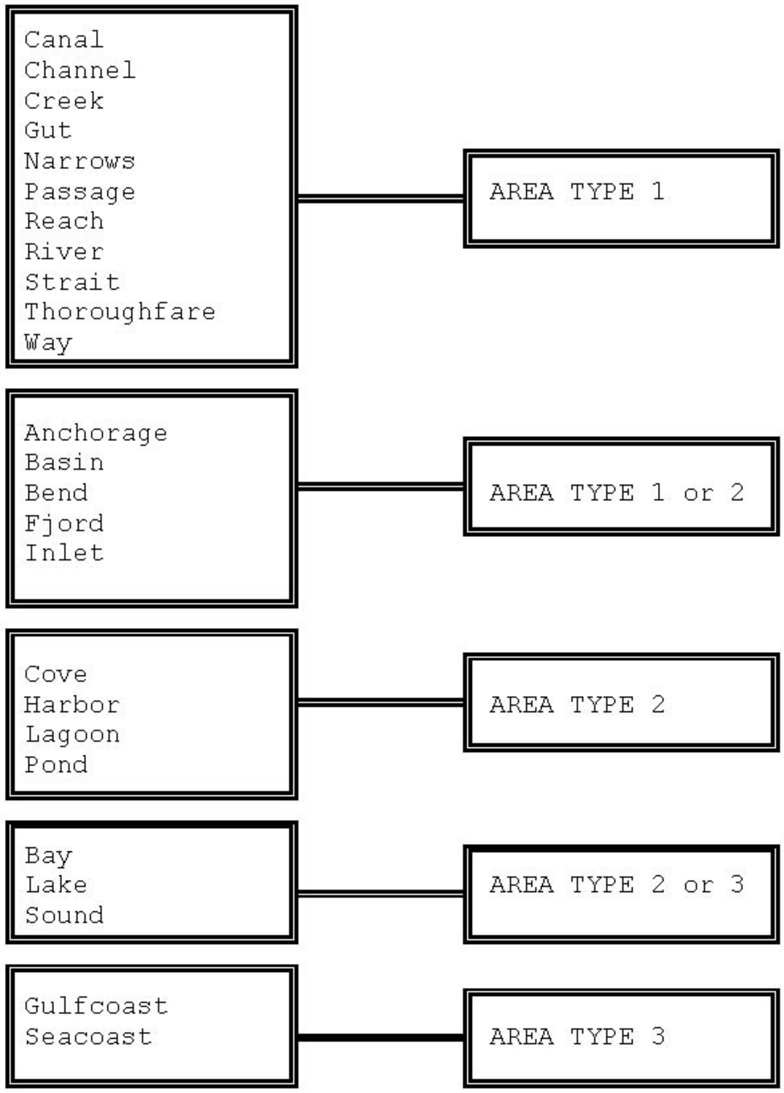
   a. Area Type 1: Area Type 1 is a narrow or restricted waterway. Waterways such as channels, rivers, or straits are typically classified as Type 1.

   b. Area Type 2: Area Type 2 has more vessel maneuvering room but may still be restrictive. Waterways such as harbors and coves are typically classified as Type 2.

   c. Area Type 3: Area Type 3 has little restriction on the maneuverability of vessels which transit the area. Coastal regions are typically classified Area Type 3.

   d. Some waterways may fit into more than one category. In these instances, the Primary Servicing Unit shall determine the appropriate Area Type depending on the size of the waterway and the aid's importance.

e. Light List Geographic Area Breakdown.



4. Computation of Desired Positioning Tolerance. Table II is used to determine the Desired Position Tolerance for each aid to navigation.

a. Locate your Area Type.

b. Compare the waterway risk level and the channel width to vessel beam risk level. Enter Table II with the **GREATER** of the two.

c. DPT is the corresponding distance in yards.

TABLE II - DESIRED POSITIONING TOLERANCES (yards)			
	GREAT RISK	MODERATE RISK	LOW RISK
AREA TYPE 1	10	25	50
AREA TYPE 2	25	50	75
AREA TYPE 3	50	75	150

F. Achievable Error Ellipse. The AEE represents an area with a 90% statistical probability for a fix with three or more LOPs. The AEE indicates the quality of fix the unit should expect to achieve at the aid's location. The AEE value is compared with the DPT to determine if horizontal control at the aid's location is adequate to produce an error ellipse (A90) to position the aid within the maximum desired error (DPT) to meet the navigational needs of the mariner.

1. The AEE value (half the length of the major axis of the ellipse) is dependent on the expected *s* value (standard deviation of residuals) of the fix and the geometrical relationship between the Assigned Position of the aid and the position of each object.

   a. Expected *s* value. The *s* value will change dependent on the unique geometrical relationship of each aid's position and the positions of the objects used, even if the same objects are used for a group of aids. Therefore, using a "standard" or "unit" *s* value is inadequate for the purpose of determining the expected *s* value for an aid.

      (1) The expected *s* value for each aid should be determined by examining historical *s* values achieved at each aid's location.

      (2) When establishing an aid with no historical data, review the *s* values from nearby aids and use an *s* value that can be reasonably expected to be achieved at the new location. This may have to be updated dependent upon actual results achieved.

      (3) When changing or increasing the number of LOPs used to position an aid, the expected *s* value may have to be revised.

(4) Always select an expected *s* that is representative of the unit's ability to position the aid.

b. Geometry of the Fix. The geometric relationship between the position of the aid and the position of each object is based on the degree of accuracy of the survey of each object's position, the distance between the aid and each object, the distance between the objects in each object pair, and the horizontal spacing (or spread) of the objects around the aid's position. The LOPs normally used to position an aid shall be, as a minimum, computed Best Fix sextant angles.

c. Object Selection. All objects used to position aids to navigation shall be surveyed to a degree of accuracy of Third Order Class I or better. Objects with an accuracy of less than this shall not be used without an exemption (see chapter 1 for details on requesting exemptions).

(1) The degree of accuracy of the survey can be found in the Discreet Independent Point File (or Quick Dump) published by NOAA.

(2) A minimum of four objects is required when using sextant angles alone.

(3) Additionally, objects selected should be easily seen from the aid's location, easily identified, and provide adequate spread around the horizon.

2. Manual Computation of the Achievable Error Ellipse. When computing the AEE, you must use the LOPs normally used to position the aid and a realistic expected *s* value.

a. Run the Best Fix program for your selected objects and obtain the A90 normalized value. The A90 normalized is computed mathematically based on the results that would be obtained from a fix with an *s* (standard deviation of residuals) of 1 minute.

b. Multiply the A90 normalized value by the expected *s* value to obtain the AEE for the computed Best Fix angles.

c. If the AEE Value determined from the three Best Fix angles is not equal to or less than the DPT, select a fourth LOP and recalculate the AEE based on the new geometry of the fix. When selecting the fourth LOP consider that angles are generally more precise than gyro bearings and that gyro bearings are generally more precise than ranges.

(1) Select a fourth angle that has a positive gradient direction (POD) that most closely parallels the ellipse orientation (A90). PGD and LOP direction are perpendicular to each other.

(2) If horizontal control is poor and a fourth angle is not available, use a gyro bearing. Select an object that has an Ideal Bearing most perpendicular to the ellipse orientation.

(3) If neither an angle or bearing is available, use a range. Select an object that has a LOP direction most perpendicular to the ellipse orientation.

d. The Best Fix program will calculate only the A90 normalized for the three Best Fix angles. To calculate the AEE for a fix of more than three LOPs, you must determine the A90 normalized manually using an Input Measurements program. Follow these procedures:

(1) Enter the Ideal measurements for three of the four LOPs.

(2) Add one minute to the Ideal measurement of the sextant angle LOPs.

(3) Plot the fix and transfer it to the APR.

(4) Obtain the A90 and s from the fix results data on the APR.

(5) Normalize the A90 by dividing it by the s value.

e. Multiply the A90 normalized by the expected *s* to obtain the AEE for a fix with four LOPs.

f. If the AEE Value determined from the four LOP fix is not equal to or less than the DPT select a fifth LOP and recalculate the AEE based on the new geometry of the fix in an attempt to obtain an AEE that meets the DPT using the same procedures as outlined above.

g. If the AEE value from the five LOP fix does not meet the DPT, then that AEE value becomes the target area.

h. Additional sources for information regarding horizontal control can be found in enclosure (3).

G. Watch Circle Radius. The WCR is the circular area around the mooring in which the aid can travel. The WCR is a factor used in determining the Achievable Buoy Station Dimension.

1. The WCR is based on the length of the mooring chain and the water depth where the aid is set. WCR will change as the depth of water changes. Therefore, when determining the Accuracy Classification of an aid, WCR is always computed using charted datum. This yields the maximum possible WCR, unless you have a negative tide value.

2. The WCR is computed by finding the square root of the chain length squared minus the water depth (charted datum) squared. Example:

$$WRC = \sqrt{(\text{Chain Length})^2 - (\text{Water Depth})^2}$$

Example: Computation of Watc Circle Radius

Chain Length = 90 ft   Water Depth (Charted Datum) = 36 ft

$$WRC = \sqrt{(90)^2 - (36)^2}$$

$$WRC = \sqrt{8100 - 1296}$$

$$WRC = \sqrt{6804}$$

$$WRC = 82.5 \text{ ft.}$$

$$WRC = 27.5 \text{ yds.}$$

(Figure 4-1)

H. Target Area. The Target Area is defined as the larger of either the AEE, or the Table II DPT. The Target Area is a factor used in determining the Achievable Buoy Station Dimension.

1. The Coast Guard would like to be able to position each aid within the maximum desired error (DPT); however, available positioning methods may limit our ability to do so.

2. If a unit is unable to position an aid within the DPT, the unit shall follow the guidelines in enclosure (3) in an attempt to obtain horizontal control adequate to lower the AEE to within the DPT. If after following these guidelines the unit is still unable to position the aid within the DPT, the AEE is the standard the unit will strive to meet when positioning the aid.

3. If the AEE is considerably smaller than the DPT, the unit may use the AEE as the Target Area to obtain a more precise Accuracy Classification.

I. Achievable Buoy Station Dimension. The Achievable Buoy Station Dimension (aBSD) is the area around an aid's assigned position where the aid can be statistically expected to be with a 90% probability. The aBSD is the entering factor for Table III.

1. The aBSD is based on the WCR and the Target Area (the degree of accuracy within which the unit can position the aid).

2. The aBSD is computed by finding the square root of the WCR squared plus the Target Area squared.

$$a\text{ BSD} = \sqrt{(\text{WCR})^2 + (\text{Target Area})^2}$$

J. Use and explanation of Table III. Table III is used to determine the AC for each aid to navigation. The entering factor is the aBSD.

1. Column 1. Locate the aBSD values in Column 1 that bracket the computed aBSD.

2. Column 2. Locate the letter designator in Column 2 directly across from the chosen values in Column 1.

3. Column 3. Locate the tolerance in Column 3 directly across from the letter designator chosen in Column 2.

4. The letter designator and tolerance are the accuracy classification for the aid.

Table III - Accuracy Classifications

TABLE III ACCURACY CLASSIFICATIONS		
Column 1	Column 2	Column 3
Achievable BSD	Accuracy Classification	Tolerance Assigned
≤ 25	A	30yds (*1)
> 25 but ≤ 40	B	50yds
> 40 but ≤ 60	C	75yds
> 60 but ≤ 80	D	100yds
> 80 but ≤ 120	E	150yds
> 120 but ≤ 160	F	200yds
> 160	G	>200yds (*2)

NOTE (*1) Districts may optionally assign a smaller tolerance to aids with an AC of Alpha to meet special requirements of narrow channels.

NOTE (*2) The Tolerance assigned to aids with an AC of Golf is determined by multiplying the Achievable BSD by 1.25. (This allows the unit a margin of error of twenty-five percent of the position fix accuracy they are capable of achieving. Prior to 1987 the on-station determination of an aid with a Golf AC was the judgment call of the Commanding Officer/OinC.)

K. Accuracy Classification Worksheet. An AC Worksheet has been developed to record the information used to assign an AC to floating aids to navigation. A copy of the worksheet is provided on page 4-14.

1. At the top of the worksheet fill in the name of the aid, the Light List number (LLNR) of the aid, and the latitude and longitude of its AP.

2. In section 1, determine and record the Area Type, Risk Type, Channel Width, Vessel Beam, Width/Beam Ratio, and the DPT.

3. If using DGPS, assign the DPT as the Target Area in section 3. Otherwise, in section 2, record the LOP type and objects used, the expected *s*, the A90 normalized (in yards), and the calculated AEE.

4. In section 3, record the Target Area as per paragraph 4.H of this manual.

5. In section 4, record the Chain Length and Water Depth. Calculate and record the WCR using the formula shown.

6. In section 5, record the Target Area and WCR. Calculate and record the aBSD using the formula shown.

7. In section 6, determine and record the Letter Designator and Tolerance using Table III. This is the assigned AC for the aid.

8. The Commanding Officer or Officer-in-Charge must sign the worksheet to authorize the AC. The original will be maintained at the unit and a copy will be sent to the District (oan). A signed copy will be forwarded to the District (oan) upon revision or completion of each triennial review.

ACCURACY CLASSIFICATON WORKSHEET

Aid Name ______________________ LLNR __________

Assigned Position ______________________

1. Desired Postitioning Tolerance (DPT)

   A. Waterway Risk Level __________

   B. Width to Beam Risk Level __________ (From Table I)

   C. Greater of A and B above __________

   D. Area Type __________

   E. DPT (From Table II) __________ YDS

2. Achievable Error Elipse (AEE)
   (AEE is only determined if horizontal sextant angles will be used)

   LOP 1 __________

   LOP 2 __________

   LOP 3 __________

   LOP 4 __________

   A90 norm _____ M **X** 1.094 =

   A90 norm _____ YDS

   Expected "s" _____ **AEE** _____ **YDS**

   (AEE = Expect. "S" **X** A90 normalized in yards)

3. Target Area (DPT or AEE, whichever is larger) __________ **YDS**

Note: Where possible the DPT should be used (see 4.H.2)

4. Watch Circle Radius (WCR)

   A. Chain Length _______ FT

   B. Water Depth _______ FT

   C. WCR (feet) _______ FT

   D. WCR (yards) _______ YDS

   $\sqrt{\text{Chain Length}^2 - \text{Water Depth}^2}$

5. Buoy Station Dimension Achievable

   A. Target area _______ YDS

   B. WCR _______ YDS

   C. BSD Achievable _______ **YDS**

   $\sqrt{\text{Target Area}^2 + \text{WCR}^2}$

6. Accuracy Classification (Use Table III)

   A. Letter Designator _______

   B. Tolerance _______ **YDS**

NOTES:

If AC is G: Tolerance = BSD Achievable X 1.25

If AC is A the District may assign a smaller tolerance for narrow channels

CO / OINC Signature: ______________________ Date: __________

REVIEWED

CO / OINC Signature: ______________________ Date: __________

CO / OINC Signature: ______________________ Date: __________

CO / OINC Signature: ______________________ Date: __________

CO / OINC Signature: ______________________ Date: __________

Chapter 5. POSITIONING METHODS FOR FIXED AIDS TO NAVIGATION

A. Introduction. Standards for positioning fixed aids have been established in order to assist units in meeting the positioning objectives.

B. General. Positioning fixed aids is similar to the positioning of floating aids; however, there are some differences:

1. Fixed aids are required to be positioned to higher degrees of accuracy than floating aids.

2. The stability of the construction platform will normally result in better positioning results.

3. Once a fixed aid is established it does not need to be position checked with each visit due to its permanent nature.

C. Accuracy Requirements. There are two levels of accuracy assigned to fixed aids. They are High Level and Low Level of Accuracy. The level assigned depends on the use of the fixed aid.

1. High Level of Accuracy. High Level of Accuracy aids shall be surveyed to a minimum of Third Order Class I accuracy. (The specifications required are provided in the Federal Geodetic Control Committee publication Standards and Specifications for Geodetic Control Networks.) All range structures shall be classified as High Level of Accuracy aids. Additionally, all fixed aids used as reference objects for fixing the position of other aids to navigation shall be classified as High Level of Accuracy aids.

2. Low Level of Accuracy. All fixed aids used solely for navigation shall be classified as Low Level of Accuracy aids. Low Level of Accuracy aids do not require surveyed positions. However, it is important to position these aids accurately since they are viewed by the mariner with more confidence than are floating aids.

3. Maximum Allowable Error. For fixed aids classified as having Low Level of Accuracy, Table IV lists the maximum error allowed to be advertised with a closed circle navigation symbol. The Table IV values are generated by applying the cartographer's tolerance to the chart scale of the largest scale chart the aid appears on.

a. The cartographer's tolerance is 1/30th of an inch for charts with a scale of 1:20,000 or larger and 1/50th of an inch for scales smaller than 1:20,000.

b. The scale of the chart is divided by the cartographer's tolerance times 36. (See example - figure 5-1.)

$$\frac{6000}{(36 \times 30)} = 5.56 \text{ yards}$$

(Figure 5-1)

T A B L E IV

Cartographer's Tolerance

Chart Scale	Maximum Error
1 : 2,500	2.32 yds
1 : 5,000	4.63 yds
1 : 6,000	5.56 yds
1 : 7,500	6.95 yds
1 : 10,000	9.26 yds
1 : 12,000 to 1 : 20,000	11.11 yds
1 : 25,000	13.89 yds
1 : 30,000	16.67 yds
1 : 40,000	21.22 yds
1 : 50,000	27.78 yds
1 : 60,000	33.33 yds
1 : 80,000	44.44 yds
1 : 100,000	55.55 yds
1 : 150,000	83.34 yds
1 : 200,000	110.12 yds

4. Positioning Fixed Aids to Navigation with DGPS.

a. The advent of DGPS has allowed many fixed aids to be positioned with greater accuracy.

b. To position fixed aids to navigation with DGPS and the AAPS program you must:

(1) Determine the chart scale of the largest scale chart on which the aid appears.

(2) Enter TABLE IV with the chart scale and obtain the Maximum Error (ME).

(3) Enter the assigned position of the aid in the AAPS program. Leave the accuracy classification blank and ensure that the tolerance is zero.

(4) If the 2DRMS is greater than the ME the aid is advertised as "position approximate".

(5) If the AP to MPP distance is 3 yards or less a chart correction and AP change are not required. For all others, the Most Probable Position (MPP) becomes the new AP and should be appropriately advertised in the LNM, noted on the APR, and changed in AAPS and ATONIS. This is because NOS charting standards state that if the actual position of an object is within ten feet or one tenth of one second of its charted position it is charted accurately.

5. Use the following guidelines when positioning Low Level of Accuracy fixed aids with horizontal sextant angles:

a. Thoroughly investigate all available horizontal control in the vicinity.

b. Consider whether any elevation of the reference objects will require an inclined angle correction.

c. Enter the AP of the aid in the AAPS program. Leave the accuracy classification blank and ensure that the tolerance is zero.

d. Run the selected objects through a Best Fix program.

e. Determine the chart scale of the largest scale chart on which the aid appears.

f. Enter TABLE IV with the chart scale and obtain the Maximum Error (ME).

g. If the fix A90 is greater than the ME, select additional LOPs (up to a total of five) to try to lower the A90.

h. If the A90 is less than the ME, the aid is advertised with a closed circle navigation symbol.

i. If the A90, for a 5 LOP fix, is greater than the ME the aid is advertised as "position approximate".

j. If the AP to MPP distance is 3 yards or less a chart correction and AP change are not required. For all others, the most probable position (MPP) becomes the new AP and should be appropriately advertised in the LNM, noted on the APR, and changed in AAPS and ATONIS.

D. Advertising Standards. Advertising standards pertain to the precision with which aid positions are advertised on charts and in notices to mariners. (Advertising standards are also discussed in Chapter 13 of COMDTINST M16500.7 - Aids to Navigation Manual - Administration.)

1. Fixed aids that can not be positioned to the listed accuracy in Table IV must be reported and advertised as "Position Approximate".

2. Only fixed aids rebuilt or relocated more than three yards from AP must be reported as relocated in notices to mariners.

Chapter 6. POSITION CHECK EVALUATIONS

A. General. The AP, the precise geographic location, expressed in latitude and longitude, where the aid should be located, is normally assigned by the District Commander.

B. Purpose. The Coast Guard must consistently position its aids to navigation within a reasonable tolerance of their APs. The Coast Guard must also exercise "due care" to ensure the AP continues to serve the purpose for which the aid was intended.

1. If an aid's AP no longer adequately marks the waterway due to shoaling or other environmental factors, the aid must be relocated to reasonably mark good water.

2. When an aid's AP must be changed by a unit, the unit must promptly inform the District Commander of the new location.

C. Automated Aid Positioning System (AAPS). The latest version of AAPS is the only authorized aid positioning computer program. Backups of the AAPS data files shall be conducted, at the minimum, according to the following schedule: (1) A full backup once a year. (2) An incremental backup once a month. (3) A backup at the end of each ATON workday of the aid and object files accessed. When completing backups, include the APR file named REPORTS.LST if APRs are not printed immediately after return from an AtoN trip.

D. GPS or DGPS. Positioning aids to navigation with GPS or DGPS is similar to positioning aids with horizontal sextant angles. This section will discuss only the differences.

1. Evaluation of the Aid's Position. The quality of a GPS/DGPS fix cannot be predetermined from past performance. It is a function of the satellite configuration overhead at the time of the fix and is expressed by the values of HDOP and 2DRMS.

2. Horizontal Dilution of Precision - HDOP. The HDOP recorded must be greater than zero. A reading of zero indicates the system is not operating properly. There is no maximum HDOP. If the satellite geometry is poor, the HDOP will be high and cause the aid to plot off station.

3. Altitude Error. Altitude is of little concern, in positioning aids, when the receiver antenna is within 100 feet of sea level. Units that are positioning aids where antenna height is greater than 100 feet above sea level must do so in the 3D mode.

4. Two Distance Root Mean Square - 2DRMS. The 2DRMS represents the radius of a circle of probable error where the MPP will be located with a 95% probability. 2DRMS is similar to the A90 of a sextant angle fix. 2DRMS is used in determining the BSD of the aid and whether or not the aid plots on station.

   a. For a GPS fix the 2DRMS equals 109.36 yards.

   b. For a DGPS fix the 2DRMS equals five times the HDOP.

E. Sextant Angles.

1. Determination of Best Fix. The Best Fix program in the AAPS determines the three best sextant angles for positioning an aid. Best Fix will be determined on scene after suitable reference objects have been selected based on the given visibility.

   a. Best Fix selects the three angles that together produce the smallest error ellipse (A90 Normalized) given the geometry between the AP and reference object positions.

      (1) To determine which angle combination will produce the smallest error ellipse, a Best Fix calculates the A90 normalized for each possible fix. The A90 normalized is the fix result that would be obtained for an s value of one minute.

      (2) When conditions are such that it is necessary to use LOPs other than the 'best' Best Fix angles, a new Best Fix shall be calculated for the objects available for that visit.

   b. Best Fix also computes the ideal angle, gradient, and positive gradient direction (POD) for each LOP. This information may be used to construct a positioning grid for maneuvering to the aid site. (See enclosure (4) for instructions on grid construction.)

F. Maneuvering to the Aid's Position. The two preferred methods for maneuvering to an aid's position are the electronic and paper maneuvering grids.

1. Electronic Maneuvering Display. The electronic maneuvering display is a tool within the AAPS designed to assist the unit in maneuvering to the aid's AP.

   a. Position measurements are manually or electronically entered and displayed on a screen.

b. When using reliable electronic measurements, the determined position can be automatically updated, providing the most accurate and up to date position available.

c. The display shows the range and bearing to the AP, a visual representation of the unit's location with respect to AP, and a determination of fix quality.

2. Paper Maneuvering Grid. The paper grid is a tool designed to assist the unit in maneuvering to the aid's AP.

a. The observations are plotted on the grid and provide a visual representation of the movement of the vessel in relationship to the AP.

b. Instructions for drawing and using grids with horizontal sextant angles are contained in enclosure (4).

3. Fixed Glass Method. The fixed glass method of maneuvering is done by presetting the ideal angles on each sextant. The observers call out to the Conning Officer or Coxswain whether their angle is 'large', 'small', or 'marking'.

a. A 'large' angle exists when the reflected object appears to the right of the direct object. Maneuver away from the objects if the angle is large.

b. A 'small' angle exists when the reflected object appears to the left of the direct object. Maneuver towards the objects if the angle is small.

c. A 'marking' angle exists when both the reflected object and the direct object appear to be in range.

d. The fixed glass method provides rapid information and allows for extremely precise positioning especially in areas where conditions (ie. strong currents) allow predetermination of the ship's head. **However**, it does not give a visual plot of the vessel's movement or show the rate of change of the angles and, therefore, is not recommended for use as the primary means for maneuvering to AP.

e. If the fixed glass method is used, a third angle shall be used to provide a check for the maneuver.

4. Riding the Arc. The method of 'riding the arc' is useful if a particular LOP Direction is desired with respect to the wind or current direction.

   a. The vessel maneuvers until it is 'marking' on the ideal angle of the selected LOP. Once 'on the arc' the vessel approaches the AP maneuvering to stay 'on the arc' while measuring the other sextants' angles.

   b. The Conning Officer or Coxswain may use the Radian Rule to adjust the vessel's speed during the maneuver. The Radian Rule can be used to determine the distance from the vessel to the AP.

      (1) Locate an object abeam of AP in respect to your desired heading.

      (2) Determine the distance between AP and the object.

      (3) Divide the distance by 60 to obtain the distance per degree.

      (4) Multiply the distance per degree by the difference between the ideal bearing (to AP) and the observed bearing from the vessel

5. Natural Ranges. Natural ranges can be useful when maneuvering to AP and they are especially useful for station keeping while at the aid's position. A natural range exists when two objects line up one in front of the other. Natural ranges cannot be used as an LOP for positioning an aid.

6. Marker Buoys. Marker buoys can be used to maneuver to the approximate area of the assigned position or to mark bottom hazard(s).

   a. Marker buoys are not intended for use as the sole method in setting the aid but as a visual aid to the Conning Officer or Coxswain.

   b. Exercise caution when using marker buoys in strong currents.

   c. If practical, marker buoys shall be retrieved prior to departing the area.

G. Computation of the Aid's Position. An aid's position, position error, and fix information are calculated through either a resection solution of angles, bearings, and ranges or an electronic positioning device.

1. Position Checks at Short Stay. Short stay assumes the horizontal position of the aid and sinker are the same.

   a. Short stay is when the chain is "up and down" and all excess chain is on deck or when the position check is done as the sinker is let go.

   b. A position check at short stay is far more conclusive than a position check not at short stay because it is not necessary to estimate the location of the sinker.

2. Position Checks Not at Short Stay. When a buoy is positioned while not at short stay, the location of the sinker must be estimated because the buoy travels around the sinker as a result of the forces acting on the buoy hull.

   a. Excursion is the true direction and distance in yards that the buoy is being forced away from the sinker's position as a result of the forces acting on the buoy's hull. When an aid is not at short stay, excursion must be estimated and entered into the fix calculations.

      (1) Presently, there is no one way to determine excursion that would be applicable for all positioning platforms and conditions. The variables affecting the determination of excursion include: the size of the positioning platform vs. the size of the buoy, the size and/or length of the mooring, the sea conditions, the speed of the current, the weight of the sinker, the depth and the bottom type.

      (2) When not at short stay, you must estimate the location of the sinker. This estimate is called the Center of Watch Circle (CWC). The CWC will be displaced from the MPP by the buoy's excursion.

      (3) Any noticeable current will typically be the most dominant force acting on a buoy. Two knots of current is equal to 35-45 knots of wind, while three knots of current is equal in force to 60-75 knots of wind, depending on the buoy's hull type.

(4) When two or more forces are acting to produce excursion, then the separate force vectors must be combined to produce total excursion.

(5) The buoy's actual movement resulting from the combined forces will lag the forces by approximately an hour, more or less. The time of returning to the CWC would not necessarily coincide with the time of slack water.

(6) The Buoy Mooring Selection Guide for Chain Moorings, COMDTINST M16511.1, contains force estimates for current, wind, and wave strengths for estimating buoy excursion.

H. Soundings. A sounding **MUST** be taken each time a buoy is positioned.

1. The sounding shall be taken as close to the sinker as possible. The sounding value should account for the distance from the waterline to the fathometer transducer of the vessel used for positioning.

2. Soundings shall be adjusted to datum, by applying the tide correction, and compared with charted datum.

3. The aid MUST mark the depth of water appropriate to the waterway. Ensuring that an aid reasonably marks "good" water is of more importance than ensuring that the aid marks a precise geographical position.

I. Explanation of the Fix Results Data.

1. MPP - Most Probable Position. The MPP represents the position of the sinker for an aid positioned at short stay. When the aid is positioned when not at short stay, the MPP represents only the location of the buoy hull. MPP is the center of the error ellipse and BSD only when the aid is positioned at short stay. MPP is expressed in latitude and longitude.

2. CWC - Center of Watch Circle. The CWC represents the estimated position of the sinker for an aid positioned not at short stay. CWC is based on the estimated excursion and is the center of the error ellipse and BSD. CWC is expressed in latitude and longitude.

3. AP to MPP Distance. AP to MPP distance is the true bearing and distance from the assigned position to the most probable position.

4. AP to CWC. This is the true bearing and distance from the assigned position to the center of the watch circle.

5. Observer Bearing and Distance. This is the relative bearing and distance from the Navigation Sensor or angle takers used to position the aid to the buoy port.

6. A90. The A90 value represents half the length of the major axis of the error ellipse and is computed for a probability of 90%.

7. B90. The B90 value represents half the length of the minor axis of the error ellipse and is computed for a probability of 90%.

8. Orient. The orientation of the error ellipse is the true direction of the major axis.

9. Standard Deviation of Residuals (s). *s* is the random error inherent to the fix. It indicates the CONSISTENCY (or repeatable accuracy) of the observers. It is expressed in minutes of arc for a sextant angle fix.

   a. If other LOP types are used with sextant angles, the error of the LOPs is factored into the *s* by being weighed mathematically.

   b. If no sextant angles are used, *s* is expressed in the unit of measurement of the LOPs used.

      (1) Gyro Bearing error will be expressed as units of degrees.

      (2) Range error will be expressed as units of Yards.

10. HDOP - Horizontal Dilution of Precision. HDOP for a GPS/DGPS fix describes the satellite geometry's effect on position (latitude and longitude) errors (BOWDITCH).

   a. The HDOP recorded must be greater than zero. A reading of zero indicates the system is not operating properly.

   b. There is no maximum HDOP for DGPS. If satellite geometry is poor, the HDOP will be high and cause the aid to plot off station. For GPS, HDOP must be less than 20.

11. 2DRMS - 2 Distance Root Mean Square. 2DRMS represents the radius of a circle of probable error within which the MPP will be located 95% of the time for a GPS/DGPS fix. 2DRMS is similar to the A90 of a sextant angle fix.

a. For GPS, 2DRMS equals 109.36 yards which is the advertised accuracy of GPS.

b. For DGPS, 2DRMS equals HDOP times five. The factor of five was chosen because, statistically, it provides a 95% confidence interval.

12. BSD - Buoy Station Dimension. BSD is the radius of a circle, in yards, centered about the MPP or CWC, within which the aid is expected to be 90% of the time.

a. The BSD for horizontal sextant angle position calculations is determined as follows:

$$BSD = \sqrt{(WCR)^2 + (A90)^2}$$

b. The BSD for GPS /DGPS position calculations is determined as follows:

$$BSD = \sqrt{(WCR)^2 + (2drms)^2}$$

When using GPS, AAPS will default to the value of 109.36 yards for 2DRMS. When using DGPS, AAPS will default to the value of 5 X HDOP, for 2DRMS.

J. ON/OFF Station Determination. The determination of whether an aid is on or off station is made by the Commanding Officer or Officer-In-Charge. This determination is subject to review by the District Commander (oan).

1. The AAPS generated Aid Positioning Record (APR) will print out a mathematical determination as to whether the aid plots ON or OFF station. This determination is based on mathematical computations only and does not take into consideration any additional factors.

a. The AAPS finds the aid is on station if the AP to MPP distance (at short stay) or AP to CWC distance (not at short stay) plus the BSD is equal to or less than the AC tolerance.

   (1) See Figure 6-1 for an aid position checked at short stay.

   (2) See Figure 6-2 for an aid position checked not at short stay.

b. AAPS finds the aid off station if the AP to MPP distance or AP to CWC distance plus the BSD is greater than the AC tolerance.

   (1) See Figure 6-3 for an aid position checked at short stay.

   (2) See Figure 6-4 for an aid position checked not at short stay.

2. Evaluation of the AAPS generated fix results data is required. Additionally, other factors must be considered, even if AAPS plots the aid on station, when making the ON/OFF station determination.

   a. One of the objectives of aid positioning is to place the aid as close as reasonably possible to the AP. To meet this objective the AP to MPP (or AP to CWC) distance should be closely evaluated.

   b. In addition to placing the aid near AP, the depth of water corrected to datum <u>MUST</u> be consistent with the charted depth.

   c. The aid should appear to be in correct alignment with the channel and other aids.

   d. In narrow channels the orientation of the error ellipse may be critical. If using sextant angles, it may be necessary to select angles that produce an error ellipse parallel to the channel line.

   e. <u>There is no minimum or maximum</u> *s* <u>value</u>. The *s* value must be used <u>in conjunction with the A90</u> to evaluate the quality of a visual fix.

      (1) The s should only be compared with past values to determine the consistency of the observer(s). If you use the same LOPs each visit you should be able to position the aid with the same degree of accuracy. Therefore, *s* can be used to grade your performance. However, if you change or introduce additional LOPs, *s* cannot be exactly compared to past (historical) *s* values.

(2) The *s* value and A90 value are proportional. To accurately evaluate the *s* value of a fix, it must be viewed with respect to the distance it represents. (The distance the *s* value represents will be dependent on the sensitivity of the gradients.) Consider that a larger *s* with a small A90 is a better fix than a smaller *s* with a larger A90.

(3) The A90 is part of the error ellipse which gives a 90% probability as to where the sinker is located. The A90 is also a factor used in determining if the aid plots on or off station.

f. The exact quality of a DGPS fix cannot be predetermined from past performance. It is a function of the satellite constellation overhead at the Lime of the fix. Aids located where a large portion of the satellite constellation is obscured due to cliffs, buildings, mountains, etc. may experience consistently higher HOOP's (and proportionally higher 2DRMS values).

K. <u>Advertising Relocated, Removed or Temporarily Off Station Aids</u>.

1. The district shall advertise an aid's position as a Broadcast Notice to Mariners and in the Local Notice to Mariners when that aid has been found or set off station and left that way. These aids should continue to be advertised as discrepancies until they are relocated to their AP.

2. Aids moved from their AP for a period of six months or less or aids moved to facilitate dredging operations shall be advertised as temporary relocations in the Local Notice to Mariners.

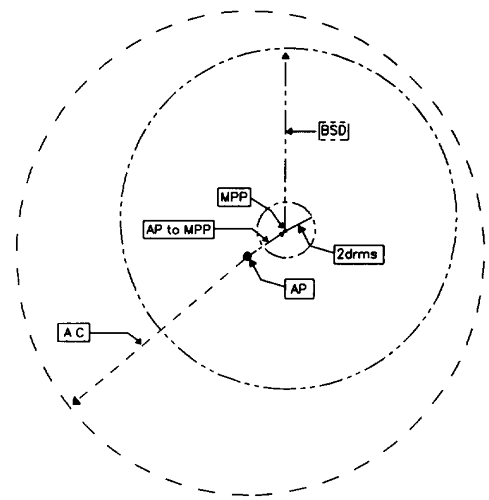
3. The District shall advertise in the Local Notice to Mariners when that aid has been permanently relocated or disestablished.

****

Aid plots ON STATION, positioned AT Short Stay
(DGPS)

EXAMPLE: Aid found ON station; checked at short stay
Accuracy Classification : B = 50 yds

2drms = 6.10 YDS.
WCR = 35.01 YDS
BSD = 35.5 YDS
AP to MPP = 054 deg T at 7.14 YDS
AP to MPP + BSD = 42.68 yds.

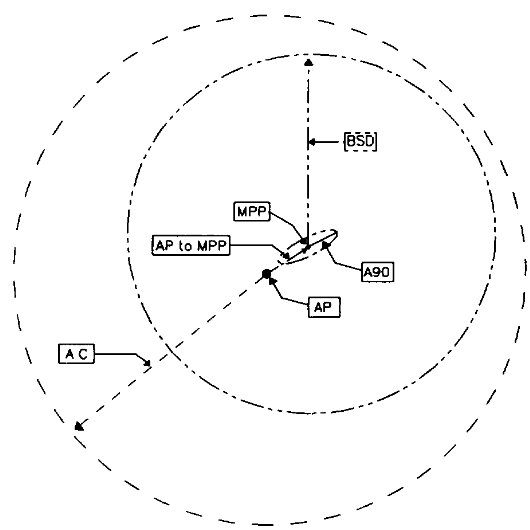


****

Aid plots ON STATION, positioned AT Short Stay
(SEXTANTS)

EXAMPLE: Aid found ON station; checked at short stay
Accuracy Classification : B = 50 yds

A90 = 4.51 YDS.
WCR = 35.01 YDS
BSD = 35.3 YDS
ORIENT = 060 deg T
AP to MPP = 054 deg T at 7.14 YDS
AP to MPP + BSD = 42.44 yds.



****

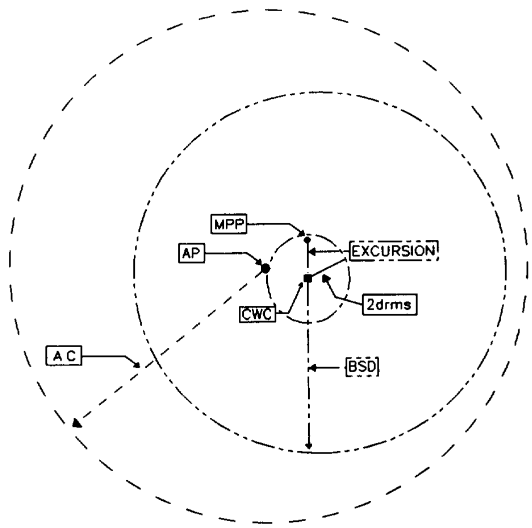
(Figure 6-1)

****

Aid plots ON STATION, positioned NOT AT Short Stay
(DGPS)

EXAMPLE: Aid found ON station; checked not at short stay
Accuracy Classification : B = 50 yds

2drms = 6.10 YDS.
WCR = 35.01 YDS
BSD = 35.5 YDS
AP to MPP = 054 deg T at 7.14 YDS
EXCURSION = 000 deg T at 5.0 YDS
AP to CWC = 100 deg T at 6.00 YDS
AP to CWC + BSD = 41.50 yds

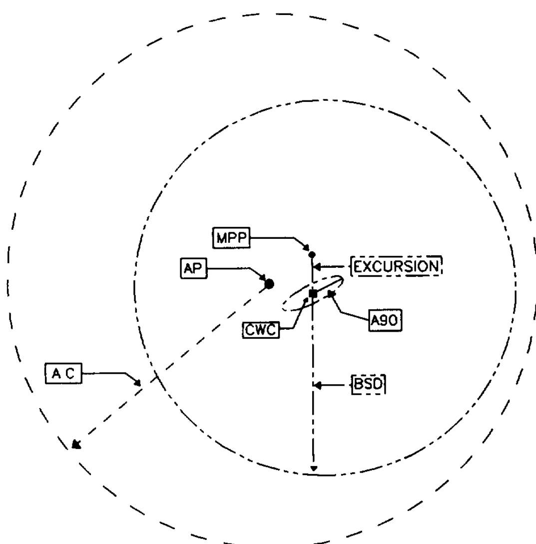


****

Aid plots ON STATION, positioned NOT AT Short Stay
(SEXTANTS)

EXAMPLE: Aid found ON station; checked at short stay
Accuracy Classification : B = 50 yds

A90 = 4.51 YDS.
WCR = 35.01 YDS
BSD = 35.3 YDS
ORIENT = 060 deg T
EXCURSION = 000 deg T at 5.0 YDS
AP to CWC = 100 deg T at 6.00 YDS
AP to CWC + BSD = 41.30 yds



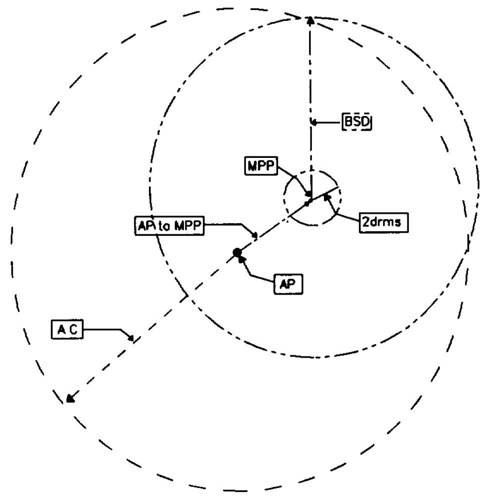
****

(Figure 6-2)

****

Aid plots OFF STATION, positioned AT Short Stay (DGPS)

EXAMPLE: Aid found OFF station; checked at short stay
Accuracy Classification : B = 50 yds

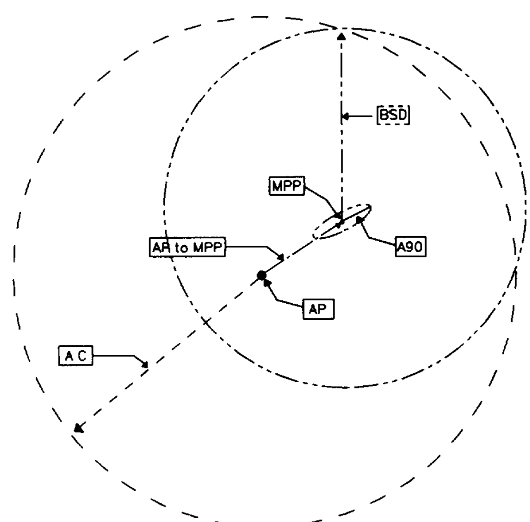


2drms = 6.10 YDS
WCR = 35.01 YDS
BSD = 35.5 YDS
AP to MPP = 054 deg T at 17.14 YDS
AP to MPP + BSD = 52.68 yds

****

Aid plots OFF STATION, positioned AT Short Stay (SEXTANTS)

EXAMPLE: Aid found OFF station; checked at short stay
Accuracy Classification : B = 50 yds



A90 = 4.51 YDS
WCR = 35.01 YDS
BSD = 35.3 YDS
ORIENT = 060 deg T
AP to MPP = 054 deg T at 17.14 YDS
AP to MPP + BSD = 52.44 yds

****

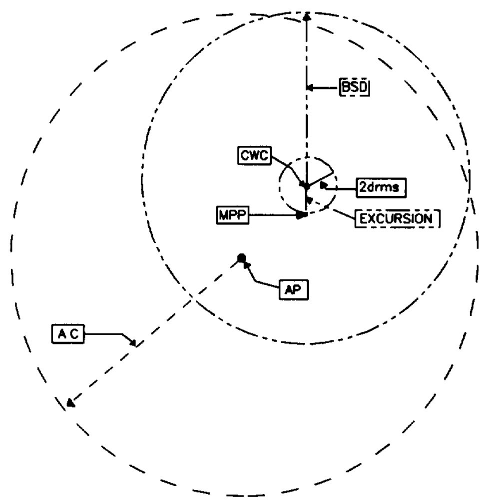
(Figure 6-3)

****

Aid plots <u>OFF STATION</u>, positioned NOT AT Short Stay (DGPS)

EXAMPLE: Aid found OFF station; checked not at short stay
Accuracy Classification : B = 50 yds

2drms = 6.10 YDS.
WCR = 35.01 YDS
BSD = 35.5 YDS
AP to MPP = 054 deg T at 17.14 YDS
EXCURSION = 180 deg T at 5.0 YDS
AP to CWC = 043 deg T at 20.0 YDS
AP to CWC + BSD = 55.50 yds.

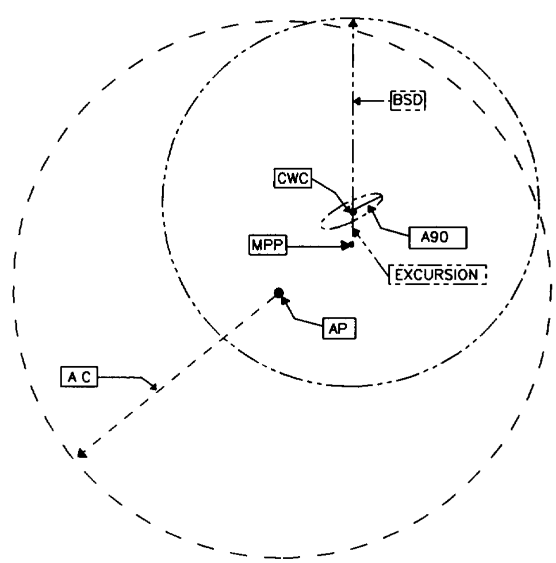


****

Aid plots <u>OFF STATION</u>, positioned NOT AT Short Stay (SEXTANTS)

EXAMPLE: Aid found OFF station; checked not at short stay
Accuracy Classification : B = 50 yds

A90 = 4.51 YDS
WCR = 35.01 YDS
BSD = 35.3 YDS
ORIENT = 060 deg T
AP to MPP = 054 deg T at 17.14 YDS
EXCURSION = 180 deg T at 5.0 YDS
AP to CWC = 043 deg T at 20.0 YDS
AP to CWC + BSD = 55.30 yds



****

(Figure 6-4)

Chapter 7. AID POSITIONING RECORD

A. Introduction. The Aid Positioning Record or APR is the document used to record relevant and necessary information used to determine the position of an aid to navigation. The purpose of the APR is to document observations made, calibration of equipment, environmental data, and actions taken when positioning an aid to navigation.

1. All relevant information shall be recorded so, if necessary, verification or validation of an aid's position can be performed at a later date.

2. Irrelevant data and observations made but not used shall not be recorded on the APR.

B. Submission of Reports. Each time a floating aid to navigation is visited, units shall complete an APR. units will complete an APR for a fixed aid to navigation when it is initially built or if it is moved or rebuilt. A copy of the APR must be submitted to the District (oan) by the unit within ten working days of the visit or upon first return to port, whichever is later. The original APR will be retained in the unit's aid file.

C. Disposition of Reports. The APR will be disposed of in accordance with the Paperwork Management Manual COMDTINST M5212.12.

1. Original APRs filed under previous guidance shall not be refiled in the unit's aid folder, but shall remain filed at the District (oan) until properly disposed of a outlined below.

2. Copies may be destroyed after ten years.

3. Originals may be destroyed three years after discontinuation of the aid.

4. APRs with historical or legal significance shall not be destroyed unless microfilmed, or stored on other digital media, for future reference.

D. Instructions for completing the APR. The AAPS is the primary means for completing APRs. The use of non-AAPS generated APRs shall be explained in the remarks section of the APR. The following fields are required to be completed on the APR.

1. Aid Name. The aid name shall be the same as it appears in the Light List.

2. Aid Number. The aid number represents the ATONIS number of the aid.

3. Unit/Vessel. The Unit/Vessel name represents the name of the unit and the platform used to position the aid.

4. Location. The Location is the name of the file where the aid is located in AAPS.

5. Latitude. Latitude of the assigned position.

6. Longitude. Longitude of the assigned position.

7. LLNR. Enter the Light List number of the aid. For those aids with more than one LLNR the lowest number is used.

8. Chart. Enter the number of the largest scale chart on which the aid appears.

9. ED. Enter the Edition number of the chart used.

10. Geodetic Datum. Represents the datum of the assigned position and reference objects/satellites.

11. Accuracy Class. Represents the letter designator of the positioning tolerance for the aid. Leave blank for fixed aids.

12. Tolerance Radius. Represents the positioning tolerance of the aid in yards. Enter zero for fixed aids.

13. Objects. When using visual means to position, the objects used are listed.

14. Fix Date. Enter the date the fix was taken.

15. Fix Time. Enter the time the fix was taken. If both a found and a set fix were taken, enter the time of the set fix here and record the time of the found fix in the remarks section.

16. EST Wind. Enter the estimated direction the wind is coming from at the time the aid was positioned. The direction shall be entered in degrees true and the speed shall be entered in knots.

17. EST Current. Enter the estimated direction the current is going towards at the time the aid was positioned. The direction shall be entered in degrees true and the speed shall be entered in knots.

18. Measured Depth. Represents the depth of water measured at the time of the fix. Depth shall be measured by echo sounder, leadline, or sounding pole.

19. Draft. Represents the draft of the vessel used to visit the aid. If depth was obtained by leadline or sounding pole, the draft must be zero.

20. Tide Corr. Represents the tide correction computed from the Tide Tables for the time of the fix.

21. Datum. Represents the corrected water depth for the time of the fix and is calculated using the measured depth, draft and tide correction. This depth shall be compared with the charted datum to ensure the aid marks good water.

22. Chain. Represents the length of the mooring in feet.

23. WCR. Represents the maximum distance in yards the aid may travel from the sinker and is calculated using the computed Datum and chain length.

24. Aid Type. Represents the type of aid (fixed or floating) serviced.

25. GPS Receiver Type. The manufacturer and model of the GPS unit.

26. DGPS Receiver Type. The manufacturer and model of the DGPS unit.

27. Serial #. The serial number of the GPS or DGPS unit.

28. Measurement Section. APRs will include measurements used to calculate the found and/or set fix.

    a. When positioning with DGPS this will include: corrected true heading and the NMEA 0183 sentences GGA, GRS, GSA, and GST. Information on the NMEA sentences can be found in enclosure (5). The above four NMEA sentences are the minimum required for positioning with DGPS.

    b. When positioning with sextants this will include: object pairs, ideal angles, measured angles, instrument corrections, observer offset, gyro bearings, corrected true heading, and, if used, radar ranges and Loran-C data.

    c. When positioning with GPS this will include: corrected true heading and, at a minimum, the NMEA 0183 GGA sentence.

29. Results Section.

a. The Fix Results data is electronically transmitted to the APR and can not be edited. All changes must be done in the Observations section (of AAPS program), then re-transmitted to the APR section.

b. Remarks. The remarks section shall be used to record any additional information necessary to verify or validate the aid's position. At a minimum the following items will be entered if not previously recorded:

(1) Aid On or Off Station when found.

(2) Light List verification.

(3) ATONIS verification.

(4) Chart verification.

(5) Reason for AtoN visit.

(6) Departures from normal procedures (if any).

(7) Inclined Angle Corrections (if applicable).

(8) If excursion was used, the method used to determine excursion must be listed.

(9) Any other information that may be required by the district office.

c. Signatures.

(1) Prepared by. This line shall be signed by the individual completing the form.

(2) CO/OINC. This line shall be signed by the Commanding Officer or Officer-in-Charge.

Purpose of CO/OinC signature is to verify:

(a) APR complete.

(b) Aid on station.

(c) Aid adequately marks hazard/channel.

(d) Light List/ATONIS/Chart have been verified.

(3) District Review. This line shall be signed by the District representative responsible for reviewing the APR for compliance and correctness, after the review is completed.

Aid Positioning Record 11/30/1995 06:44:24

Aid Name : York Pier LB 18
Latitude : N 37-13-04.899
Longitude : W 076-28-50.758
ACC Class : B - 50.0 yds
Unit/Vessel: USCGC NATON

Aid Number : 323
LLNR : 1724
Chart : 12241 ED: 18
Geodetic Datum: NAD 83
Location : CANFIEL2.

Objects

1. TANK YORKTOWN
2. VEPCO STACK
3. FLARE STACK
4. YORKTOWN MONUMENT
5. TANK GLOUESTER
6. TUE MARSHES LT
7.
8.
9.

[Buoy Set Data]

Date: 11/30/95 Time: 06:43:14
EST. Wind : 98 T 15.0 KTS
EST. Current: 130 T 0.5 KTS

Measured Depth: 19.0 ft
Tide Corr. : -1.0 ft
Datum : 31.0 ft
Chain : 70.0 ft
Draft : 13.0 ft
WCR: 20.92 yds Aid Type: Floating

Corrected Heading: 0.0 T MEASUREMENTS USED WHEN AID FOUND

	Type	Description	Ideal	Measured	Correction	Station	Units
1.	A	OBJ 5,1	59-35.7	59-34.0	(+) 0-00.0		DDD-mm.mm
2.	A	OBJ 5,2	121-49.8	121-54.4	(+) 0-00.0		DDD-mm.mm
3.	A	OBJ 5,6	97-45.3	97-48.8	(+) 0-01.3		DDD-mm.mm

Corrected Heading: 40.0 T MEASUREMENTS USED WHEN AID SET

	Type	Description	Ideal	Measured	Correction	Station	Units
1.	A	OBJ 5,1	59-35.7	59-35.7	(+) 0-00.0		DDD-mm.mm
2.	A	OBJ 5,2	121-49.8	121-55.1	(+) 0-00.0		DDD-mm.mm
3.	A	OBJ 5,6	97-45.3	97-47.3	(+) 0-01.3		DDD-mm.mm

FIX RESULTS (Primary LOPs)

MPP Latitude : N 37-13-05.133
MPP Longitude : W 076-28-50.078
AP To MPP Bearing: 66.69 T
AP To MPP Range : 19.95 yds
Buoy Station Dim.: 21.07 yds
A90: 2.49 yds B90: 0.46 yds
Orient: 97.54 T
Standard Dev. : 0.159
ON/OFF Station : ON

[FOUND RESULTS]
Obsvr Offset: 15.95 R / 14.56
AP To MPP Bearing: 40.34 T
AP To MPP Range : 17.41 yds
ShortStay (Y/N) : Y
Buoy Excursion : 0.0 yds
Bouy Set : 0.0 T

[SET RESULTS]
Obsvr Offset: 15.95 R / 14.56 yds

ShortStay (Y/N) : Y
Buoy Excursion : 0.0 yds
Buoy Set : 0.0 T

REMARKS
FOUND ON STATION. ATONIS, LIGHT LIST, AND CHART VERIFIED.

Prepared By (Signature): ______________________ Date: __________
CO/OINC (Signature): ______________________ Date: __________
DISTRIC REVIEW (Signature): ______________________ Date: __________
Comments: ______________________________________

Aid Positioning Record 11/30/1995 06:44:24

Aid Name : York Pier LB 18
Latitude : N 37-13-04.899
Longitude : W 076-28-50.758
ACC Class : B - 50.0 yds
Unit/Vessel: USCGC NATON

Aid Number : 323
LLNR : 1724
Chart : 12241 ED: 18
Geodetic Datum: NAD 83
Location : CANFIEL2.

Objects

1. TANK YORKTOWN
2. VEPCO STACK
3. FLARE STACK
4. YORKTOWN MONUMENT
5. TANK GLOUESTER
6. TUE MARSHES LT
7.
8.
9.

[Buoy Set Data]

Date: 11/30/95 Time: 06:43:14
EST. Wind : 98 T 15.0 KTS
EST. Current: 130 T 0.5 KTS

Measured Depth: 19.0 ft
Tide Corr. : -1.0 ft
Datum : 31.0 ft
Chain : 70.0 ft
Draft : 13.0 ft
WCR: 20.92 yds Aid Type: Floating

Corrected Heading: 0.0 T MEASUREMENTS USED WHEN AID FOUND

	Type	Description	Ideal	Measured	Correction	Station	Units
1.	A	OBJ 5,1	59-35.7	59-34.0	(+) 0-00.0		DDD-mm.mm
2.	A	OBJ 5,2	121-49.8	121-54.4	(+) 0-00.0		DDD-mm.mm
3.	A	OBJ 5,6	97-45.3	97-48.8	(+) 0-01.3		DDD-mm.mm

Corrected Heading: 40.0 T MEASUREMENTS USED WHEN AID SET

	Type	Description	Ideal	Measured	Correction	Station	Units
1.	A	OBJ 5,1	59-35.7	59-35.7	(+) 0-00.0		DDD-mm.mm
2.	A	OBJ 5,2	121-49.8	121-55.1	(+) 0-00.0		DDD-mm.mm
3.	A	OBJ 5,6	97-45.3	97-47.3	(+) 0-01.3		DDD-mm.mm

FIX RESULTS (Primary LOPs)

MPP Latitude : N 37-13-05.133
MPP Longitude : W 076-28-50.078
AP To MPP Bearing: 66.69 T
AP To MPP Range : 19.95 yds
Buoy Station Dim.: 21.07 yds
A90: 2.49 yds B90: 0.46 yds
Orient: 97.54 T
Standard Dev. : 0.159
ON/OFF Station : ON

[FOUND RESULTS]
Obsvr Offset: 15.95 R / 14.56
AP To MPP Bearing: 40.34 T
AP To MPP Range : 17.41 yds
ShortStay (Y/N) : Y
Buoy Excursion : 0.0 yds
Bouy Set : 0.0 T

[SET RESULTS]
Obsvr Offset: 15.95 R / 14.56 yds

ShortStay (Y/N) : Y
Buoy Excursion : 0.0 yds
Buoy Set : 0.0 T

REMARKS
FOUND ON STATION. ATONIS, LIGHT LIST, AND CHART VERIFIED.

Prepared By (Signature): ____________________ Date: __________
CO/OINC (Signature): ____________________ Date: __________
DISTRIC REVIEW (Signature): ____________________ Date: __________
Comments: ______________________________

HISTORIC POSITIONING METHODS

A. LORAN-C

1. General. Loran-C is a long range hyperbolic radionavigation system of high accuracy which processes a pulsed low frequency (100kHz) signal by both time difference and phase comparison methods. A Loran-C chain is comprised of a master transmitting station, two or more secondary transmitting stations and, if necessary, a system area monitor (SAM) station.

2. Purpose. Loran-C is generally not the preferred method of positioning aids to navigation. However, when poor visibility precludes positioning aids by horizontal sextant angles and in areas where there are no visible reference objects or DGPS, Loran-C may be the only alternative.

3. Errors. To properly use Loran-C you must first understand the associated errors. These are propagation error, transmission timing error and receiver error.

    a. The propagation, or speed of the signals can be predicted with great accuracy through free-space. Propagation error is the speed error of the receipt of the transmission signals by the receiver. This error is due to a signal being delayed by factors such as the earth's terrain, seawater, atmospheric and meteorological conditions, and man-made objects. The compensations for these delays, Secondary Phase Factor (SF) corrections for signal transmissions over seawater paths and Additional Secondary Phase Factor (ASF) corrections for transmission over land paths, are not accurate enough to position floating aids to navigation.

    b. The Transmission timing error is caused by a variation in the synchronization between the Loran-C Master and Secondary transmitters.

        (1) Transmission timing errors, although small, will result in positioning errors if they are not detected and compensated.

        (2) Most Loran chains have a SAM that keeps a constant watch on timing drift, and typically controls the synchronization to within .05 microseconds. When this error exceeds .1 of a microsecond (1/10 millionth of a second), without being compensated for, that Loran-C signal will be blinked to advise mariners the signal is not usable. Read the specifications of your Loran-C receiver to be able to recognize the 'blink' signal.

c. Your Loran-C receiver may also contain constant or random errors called receiver error.

(1) Latitude/longitude converters (microprocessors that compute geographic positions from TDs) differ from manufacturer to manufacturer. These differences are due to a variety of reasons including the mathematical algorithms used in the receiver's programming. Additionally, ensure that both your receiver and your positioning data are using the same NAD.

(2) Improper operation may cause large offsets in TDs through improper tracking of signals.

(3) Additionally, error may be caused by lack of resolution of your receiver. A receiver with a 1/10 microsecond resolution can resolve a TD with a gradient of 300 yds per microsecond to only the nearest 30 yards.

4. Establishing Loran-C Historical TDS. The most accurate means of positioning aids to navigation with Loran-C is with historical TDs. This method allows a unit to return to a known geographical location because of the repeatability of the change in the signal from one location to another.

a. This method is used for aids that are normally positioned with horizontal sextant angles but due to restricted visibility reference objects can not be seen.

b. The key to success with this method is to maintain an accurate history of the TDs.

5. Explanation of how to determine Loran-C HistoricalTDS.

a. Choose a reference point. The pier you moor at or a structure that you can come alongside are good choices. Shoot three or four horizontal sextant angles and enter them into the AAPS Post-Obs program to obtain the MPP Latitude and Longitude. This Latitude and Longitude represents your reference position. (Use an observer offset from the Loran antenna.)

b. Log your reference position TDs prior to getting underway.

c. When you position check the aid, shoot your horizontal sextant angle fix and record the observed Loran-C TDs at the same time.

d. Enter the sextant angles in AAPS to obtain the MPP Latitude and Longitude of the aid.

e. In most cases, the aid will not be exactly on AP. You must therefore adjust the observed TDs to reflect what they would be at the Assigned Position. Use the following steps:

   (1) Run the AAPS Loran-C Pre-Comp using the Reference Position and the AP of the aid to obtain grid construction data.

   (2) On a Maneuvering Board, draw each LOP passing through the center (AP) in their LOP Direction with dashed lines. Label each LOP with its rate (i.e.. 9960-W) and gradient.

   (3) Plot the MPP on the Maneuvering Board. Use the AP to MPP Bearing and Range to do this.

   (4) Draw parallel lines for each LOP passing through the MPP of the Aid. Label these lines with the observed TDs.

   (5) Measure the perpendicular distance between each observed TD LOP and the ideal TD LOP (passing through AP).

   (6) Divide each distance by the gradient to obtain the amount of change (in the TD from MPP to AP) in microseconds from the observed to the ideal TDs.

   (7) If MPP is going towards the PGD, SUBTRACT the change from the observed TD to obtain what the TD would read at AP.

   (8) If MPP is going away from the PGD, ADD the amount of change.

f. Once you adjust the observed TDs to reflect what they would read at AP, compare the adjusted TDs to the Reference Position TDs. This difference is your TD for that visit.

g. Record the TD on your APR and in your Historical TD Log.

h. On the occasion when you need to position one of your aids using the historical TDs, take all the TDs and determine the average TD for each rate. Apply the average TD to the reference position TD readings on that day to obtain your Ideal TD readings.

B. THREE ARM PROTRACTOR.

1. The three arm protractor is an instrument that can be used to plot the intersection of two horizontal angles on a nautical chart. It is made of either metal or plastic. A discussion of three arm protractors and their use in navigation is contained in The American Practical Navigator (Bowditch).

2. Though an excellent navigational tool, the three arm protractor will induce too many errors into a fix to be used in aid positioning, therefore it shall be used only as a last resort. Aid positions obtained with a three arm protractor shall be considered approximate positions and shall be followed up as soon as practicable with a properly calculated Most Probable Position (MPP) via prescribed methods.

C. NATURAL RANGES. While an excellent maneuvering tool, natural ranges do not have the inherent precision of sextant angles and may not be used as the sole means for positioning aids to navigation unless an exemption has been granted.

SEXTANT USE AND MAINTENANCE

Section I GENERAL SEXTANT INFORMATION

A. General. The sextant is an instrument designed specifically for measuring angles. Sextants are remarkably tough and durable instruments that, with reasonable care, will last several generations. Sextants, however, cannot be banged carelessly around and remain capable of precise measurement.

B. The Principal of the Sextant. The sextant works on the principle of double reflectivity. A ray of light bouncing off the surface of a mirror departs at the same angle at which it arrived. The angle of incidence equals the angle of reflection. A ray of light bounced, in sequence, off two mirrors will maintain the in-out equality. A sextant in true adjustment set on exactly zero will achieve this condition.

C. Nomenclature.

1. Frame. The frame is the main body of the sextant to which all the other parts are attached.

2. Limb. The limb is an integral part of the frame and forms the curved, reinforced lower edge. The limb has two components, gear rack and arc scale.

3. Gear Rack. The bottom edge of the limb that has precision machined gear teeth cut into it. There is one gear tooth for each degree of arc.

4. Arc Scale. The arc scale is graduated in whole degrees from -5 to 125 (or 145 on a marine sextant) and is attached to or cut into the limb itself. Each line or mark represents one degree and is precisely aligned with the teeth on the gear rack.

5. Index Arm. The index arm is the prominent moving part of the sextant. Its pivot and drive arrangement along the limb are critical for precision. The index arm extends beyond the limb forming a plate that has an aperture that contains the index mark on its lower edge.

6. Index Mark. The index mark is used to read the arc scale.

7. Index Mirror. The index mirror is a piece of silvered plate glass located at the top of the index arm, mounted perpendicular to the frame. As the index arm is moved along the limb the index mirror moves, varying the angle of the reflected image by the amounts shown on each scale.

8. Index Mirror Adjustment Screw. There is one adjustment screw on the back of the index mirror. It is used to adjust the index mirror perpendicular to the frame.

9. Micrometer Drum. The micrometer drum is graduated in whole minutes from 0 to 60 minutes. One complete revolution equals one degree on the Arc scale.

10. Tangent Worm Screw. The tangent worm screw is arranged on the lower end of the index arm so as the micrometer drum is turned it will move along the limb.

11. Release Lever. The release lever is used to disengage the tangent worm screw by spring pressure so the index arm can be moved freely and quickly along the arc.

12. Vernier Scale. The vernier scale is adjacent to the micrometer drum and allows the sextant to be read to one tenth of a minute.

13. Telescope. The telescope is rigidly attached to the rear edge of the frame so that its line of sight is parallel to the frame and passes through the center of the horizon glass.

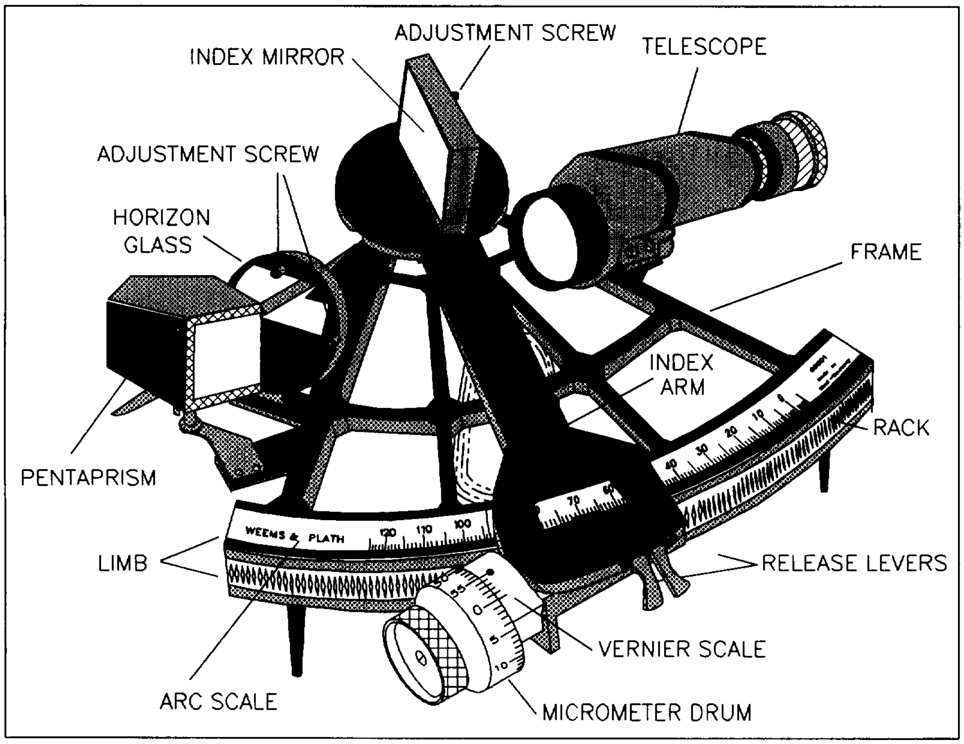
14. Horizon Glass. The horizon glass is a piece of optical glass located on the front edge of the frame and mounted perpendicular to the frame. The lower half is silvered to make a mirror while the upper half remains clear in order to permit a simultaneous viewing of a direct image and a reflected image.

15. Horizon Glass Adjustment Screws. There are two adjustment screws on the back of the horizon glass. The one farthest from the frame adjusts the horizon glass perpendicular to the frame. The one closest to the frame adjusts the horizon glass parallel to the index mirror.

16. Pentaprism. The pentaprism is an attachment for a survey sextant that adds 90 degrees to the observed angle. The pentaprism allows the measurement of angles up to 215 degrees.

17. Pentaprism Bracket. A spring loaded bracket on the edge of the frame and is used for installing the pentaprism.

18. Handle. The handle on most sextants is made of wood or plastic and is mounted on the bottom of the frame. It is generally designed to be held in the right hand. An optional handle that screws into the bottom of the mounted handle which can be held in either hand is available.



D. Inspection. To ensure the sextant is in good working condition both optically and mechanically, it must be inspected prior to use. Sextants shall be inspected and checked prior to use in accordance with Table I.

1. Examine the mirrors and telescope lens for dirt, dust, scratches, nicks, and cracks. Clean if necessary.

2. Inspect rubber eyeguard for deterioration, cracks, and tears.

3. Examine worm and rack for dirt, dust, and excessive wear. Clean as necessary.

4. Inspect mirrors for loose or missing screws.

5. Check the operation of the index arm release lever for positive engagement and disengagement of the worm and rack.

6. Check operation of the micrometer drum for smooth movement and travel.

7. Examine arc, drum, and vernier scales for dirt and illegible numbers.

8. Examine frame, index arm, handle, legs, and brackets for misalignment, cracks, breaks, and other damages.

9. Check mirrors for breaks and scratches. Have mirrors replaced if damaged.

E. Maintenance. The accuracy of the sextant depends directly on the precise relationship between one revolution of the tangent worm screw and a change of one degree of the index arm along the arc scale. Excessive wear of the screw or the teeth of the limb will alter this relationship. Accumulation of dirt and grit in the teeth of the limb will also alter the relationship. Regular cleaning and lubrication is important.

1. Do not polish the arc. Brass polish is gritty and will wear down the gears and other metal to metal parts. The right way to clean the arc is with ammonia and a cotton-tipped swab. The ammonia loosens the dirt and grime so it can be removed with the small sextant brush or a toothbrush without doing any damage.

2. Cleaning delubricates the sextant leaving metal to metal contact. To prevent damage the sextant must be lubricated after cleaning. A good oil to use is Clock Oil 140-B. This is a thin oil which leaves a surface film that acts like wax. Another good oil is Jojoba oil which can be bought commercially at most health food stores.

   a. To lubricate the sextant, start by turning it upside down. Set the index mark to zero on the arc scale, then oil the tangent worm screw. Turn the screw until it moves along the entire length of the arc. This will lubricate each tooth of the limb in succession. Next, put a small drop of oil on the head of each adjustment screw and wipe away the excess. (If these screws are not lubricated they will corrode and stick making proper adjustment difficult or impossible.) Also, put a drop of oil as close to the pivot pin at the top of the index arm as you can. This keeps the index arm moving freely.

   b. Wipe off all excess oil. Wipe the frame of the sextant with the cloth used to wipe up the excess oil. Be careful not to yet any oil on the glass or mirrors. WD-40 is also good for wiping the frame because it has no sticky components.

3. If a sextant has been exposed to saltwater, rinsing the sextant (with telescope removed) with running fresh water or submersing it in a bucket of fresh water is the best way to clean it. Wipe the sextant dry with a cloth and place it in a breezy, low humidity environment to complete drying process. Don't forget to relubricate the sextant.

F. Table I. Table I shows the minimum required time period between each maintenance procedure listed. At a minimum, sextants must be inspected and lubricated QUARTERLY.

TABLE I

MAINTENANCE	TIME PERIOD
Check Index Error	Before each use
Check Pentaprism	Before each use
Sextant Adjustment	When I.E. exceeds 2 min
Pentaprism Calibration	When I.E. exceeds 8 min
Inspection	Before each use
Clean Mirrors	Before each use (if needed)
Lubrication	After washing/cleaning

Section II USE OF THE SURVEY SEXTANT

A. General. The sextant is a hand-held instrument used to measure angles. The survey sextant is a basic marine sextant, modified for use in measuring horizontal sextant angles between terrestrial objects. The survey sextant has three destinct advantages over the marine sextant for positioning aids to navigation.

1. The larger horizon glass provides a larger field of view for sighting objects.

2. There is a mounting bracket for a pentaprism.

3. The spring-tensioned mirrors make the survey sextant easier to adjust.

B. Pentaprism. The survey sextant comes with an attachable pentaprism to allow the measuring of angles beyond the normal range of the sextant's arc scale. The pentaprism allows the user to measure angles up to 90 degrees greater than the calibration of the Arc Scale.

C. Reading the Survey Sextant.

1. Read the arc scale using the index mark. The index mark will fall between two of the lines on the arc scale. The lesser of the two will be your reading in whole degrees.

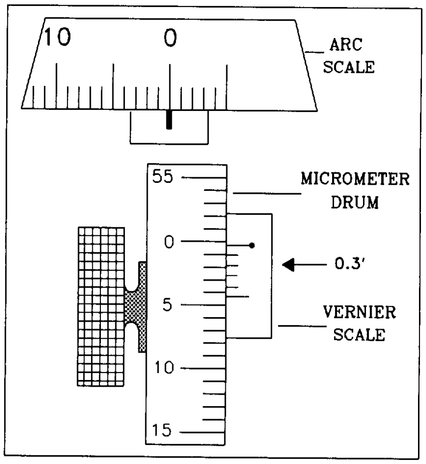
2. Read the micrometer drum using the reference mark on the vernier scale. The reference mark is used the same way the index mark is used; choose the lesser of the two lines on the micrometer drum that the reference mark falls between. This will be your reading in whole minutes.

3. Read the vernier scale to the closest tenth of a minute. The lines on the vernier scale start with the reference mark which equals zero. Each subsequent line increases in value by 2/10s of a minute.

   a. If any line on the vernier scale forms a straight line with any line on the micrometer drum the reading will be an even tenth correlating to the value of that vernier scale line.

   b. If none of the lines on the vernier scale form a straight line with a line on the micrometer drum then the reading will be an odd tenth.

II (1) If the sextant has the old style vernier scale, find the two lines on the vernier scale that fall inside two lines on the micrometer drum. The reading will be the odd tenth between those two lines on the vernier scale.



Example 1

(Old Style Vernier)

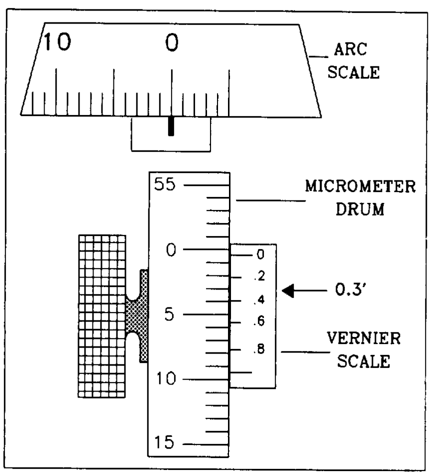
The ARC Scale reads 0 Degrees

The micrometer drum Reads 0 minutes

The Vernier Scale reads .3 minutes

(2) If the sextant has the newer version vernier scale, find the two lines on the vernier scale that fall inside three lines on the micrometer drum. The reading will again be the odd tenth between those three lines on the vernier scale.

I8479*IMAGES:



Example 2

(New Style Vernier)

The ARC Scale reads 0 Degrees

The micrometer drum Reads 0 minutes

The Vernier Scale reads .3 minutes

D. Index Error. Index error (IE) is the error in the sextant.

1. The IE of each sextant shall be determined prior to every use.

II 2. The person who will measure the sextant angle shall determine the IE.

3. If the IE without the pentaprism attached exceeds 2.0 minutes, the sextant shall be adjusted before further use.

4. If the IE with the pentaprism attached exceeds 2.0 minutes, it may be used as long as the error remains consistent and does not exceed 8 minutes.

E. Index Correction. Index correction (IC) is the correction applied to the observed angles to compensate for IE.

1. If your IE is ON the arc, subtract the IC.

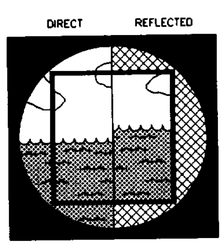
2. If your IE is OFF the arc, add the IC.

F. Determination of Index Error (without pentaprism attached).

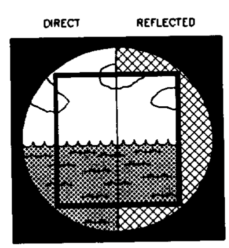
1. Set the arc scale and micrometer drum to approximately zero.

2. Hold the sextant vertically and sight the horizon. The horizon must be a minimum of two miles away. If the horizon is less than two miles away, any object with a straight line (building, lighthouse, etc.) may be used.

3. Use the micrometer drum to bring the direct and reflected images of the horizon to a straight line.



HORIZON NOT IN LINE



HORIZON IN LINE

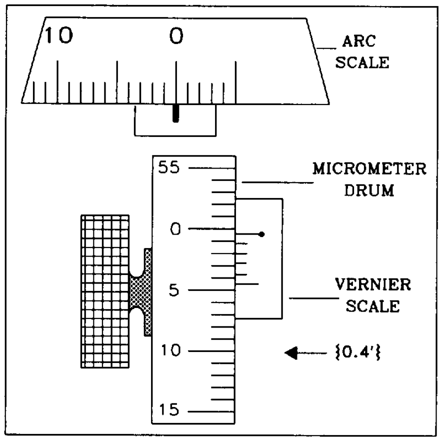
4. Read the measurement on the sextant.

a. If the measurement is greater than zero the IE is ON THE ARC and the correction is subtracted.

b. If the measurement is less the zero the IE is OFF THE ARC and the correction is added.

5. Repeat this procedure two more times.

6. Average the three errors to determine the index error for the sextant for that use.



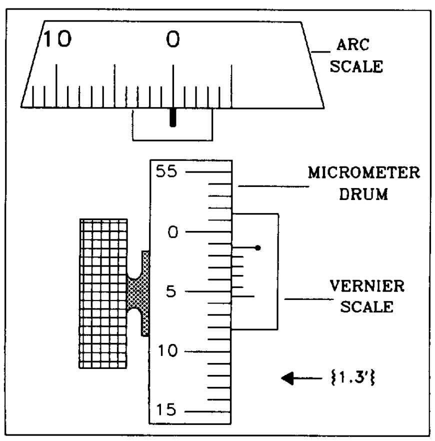
Example 2

The ARC Scale reads 0 degrees

The micrometer drum reads 0 minutes.

The Vernier Scale reads 4 minutes

Index Error is 0.4 ON the ARC.



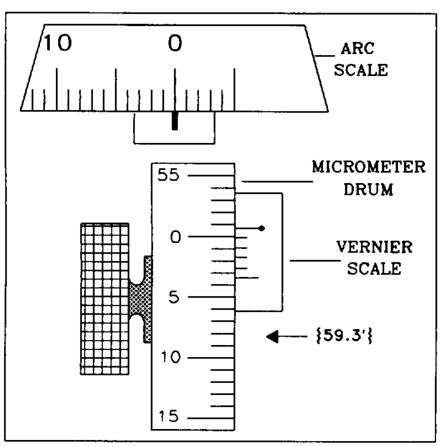
Example 3

The ARC Scale reads 0 degrees

The micrometer drum reads 1 minutes.

The Vernier Scale reads .3 minutes

Index Error is 1.3 ON the ARC.



Example 4

The ARC Scale reads 0 degrees

The micrometer drum reads 59 minutes.

The Vernier Scale reads .3 minutes. (This reading is less than zero so subtract 59.3 from 60.0 to get 0.7 mins)

Index Error is 0.7 OFF the ARC.

G. Determination of Index Error (with pentaprism attached).

1. Attach the pentaprism to the sextant and rotate it **counterclockwise.**

2. Set the arc scale to 90 degrees and the micrometer drum to approximately zero.

3. Hold the sextant vertically as though looking at the ground and sight the horizon. The horizon must be a minimum of four miles away. (See Table IV if the horizon is less than four miles away.)

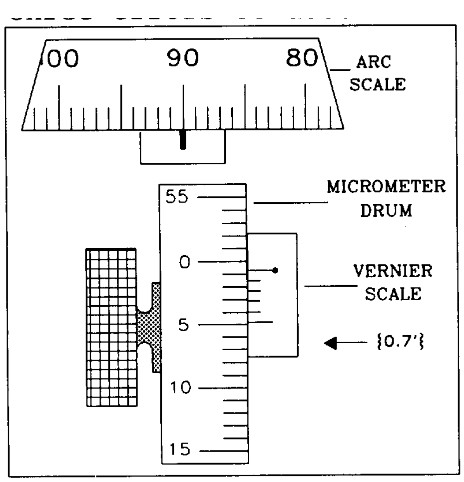
4. Use the micrometer drum to bring the direct and reflected images of the horizon to a straight line.

5. Read the measurement on the sextant.

   a. If the measurement is greater than 90 degrees, subtract 90 degrees from the measurement to get the index error. The IE is ON THE ARC.

   b. If the measurement is less than 90 degrees, subtract it from 90 degrees to get the index error. The IE is OFF THE ARC.

6. Repeat this procedure two more times and average the three errors to determine index error.



Example 4

The ARC Scale reads 90 degrees

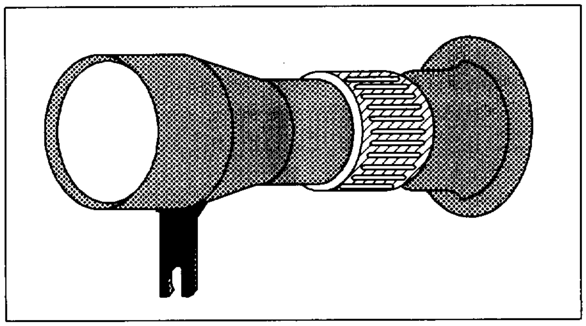
The micrometer drum reads 0 minutes.

The Vernier Scale reads .7 minutes.

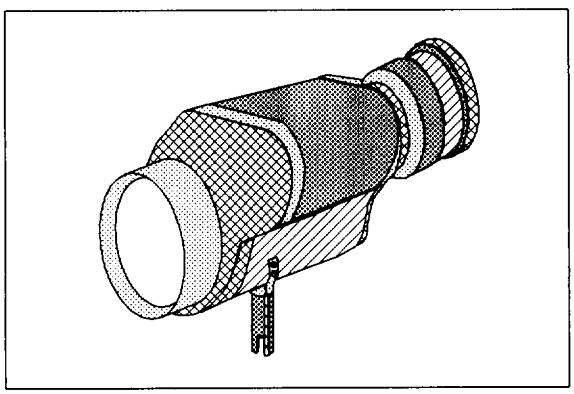
Index Error is 0.7 ON the ARC.

H. Telescopes.

1. The survey sextant comes with a 4 X 40 telescope. To install the telescope slide it on to the telescope collar bracket on the rear edge of the frame. Use the knurled knob to secure the telescope in place.



2. The 6 x 30 telescope may be purchased as an optional telescope for use with the survey sextant.



3. An optional sight piece is available (from C.Plath) known as a circular collar or peep sight. It is attached the same as the telescope.

I. Measuring Horizontal Sextant Angles of less than 125 Degrees

1. Determine the IE.

2. Set your scales to zero.

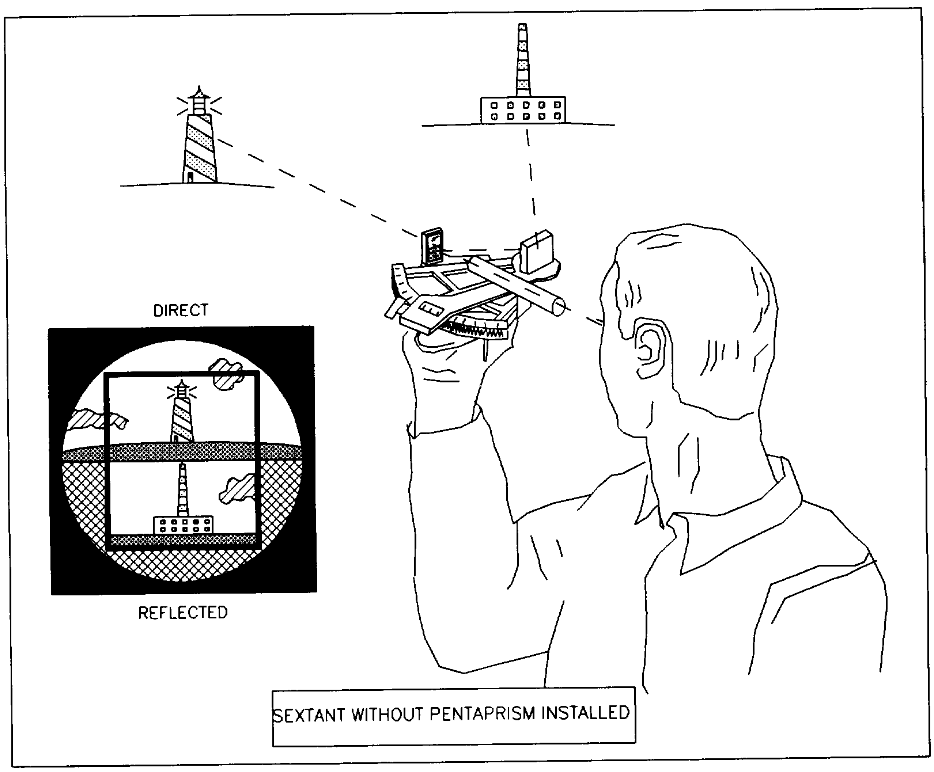
3. Hold the sextant horizontally.

4. Look through the telescope and find the object on the left in the top (clear) half of the horizon glass. This is the direct image.

5. Continue to look through the telescope keeping the direct image in view in the clear (top) half of the horizon glass. Use the release lever to move the index arm along the arc scale. Hunt for the object on the right, which will be reflected through the index mirror into the bottom (mirrored) half of the horizon glass.

6. As both images come into view in the horizon glass, use the micrometer drum to superimpose the object on your right (the reflected image in the bottom half of the horizon glass) over the object on your left. You must use the surveyed point of each object. The order for location on the object of the surveyed point is normally as follows:

   a. The light
   b. The point
   c. Top center



7. Obtain the reading from the arc scale, micrometer drum, and vernier scale.

8. Apply the IC to your measurement to obtain the horizontal sextant angle.

J. Measuring Horizontal Sextant Angles Greater than 125 Degrees

1. Install the pentaprism onto the mounting bracket on the front edge of the frame.

2. The pentaprism mounting bracket is spring loaded. To measure angles of greater than 125 degrees install the pentaprism by pressing down on the top and turning it **clockwise.**

3. Determine the IE.

4. Set your scales to zero.

5. Hold the sextant horizontally.

6. Face approximately in the positive gradient direction (POD). Place the object on the left off your left shoulder. The POD may be found on the Best Fix screen in AAPS.

7. Look through the telescope and find the object off your left shoulder. This object will be reflected through the pentaprism into the top half of the horizon glass.

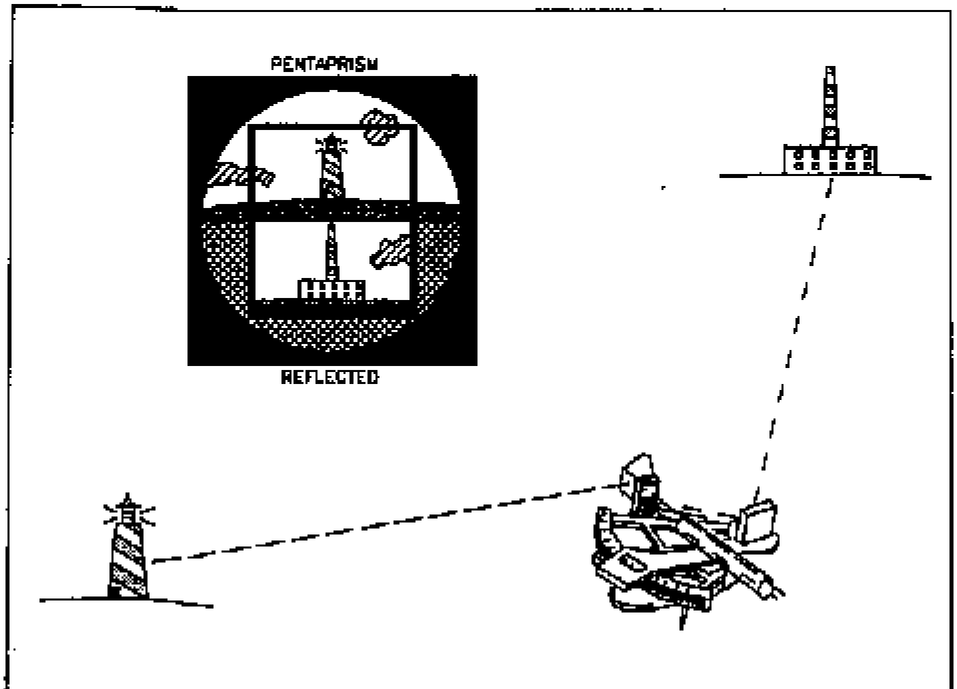
8. Continue to keep that reflected image in the top half of the horizon glass. Use the release lever to move the index arm along the arc scale. Hunt for the object on the right, which will be reflected through the index mirror into the bottom half of the horizon glass.

9. As both images come into view in the horizon glass, use the micrometer drum to superimpose the object on your right (the reflected image in the bottom half of the horizon glass) over the object on your left. It is extremely important when using the pentaprism to make sure the sextant is level. If the objects appear to be leaning in opposite directions the sextant probably is not level.

10. Obtain the reading from the arc scale, micrometer drum, and vernier scale.

11. Add 90 degrees to the reading on the arc scale to account for the 90 degree reflection of the pentaprism.

J. 12. Apply the IC to your measurement to obtain the horizontal sextant angle.



SEXTANT WITH PENTAPRISM INSTALLED

Section III SURVEY SEXTANT ADJUSTMENT AND PENTAPRISM ALIGNMENT

A. General. It is a good practice to adjust the sextant only when the error exceeds acceptable limits. If frequent adjustment is necessary, it may indicate the sextant is worn or being mishandled.

B. Adjustments.

1. Adjusting the Index Mirror Perpendicular to the Frame.

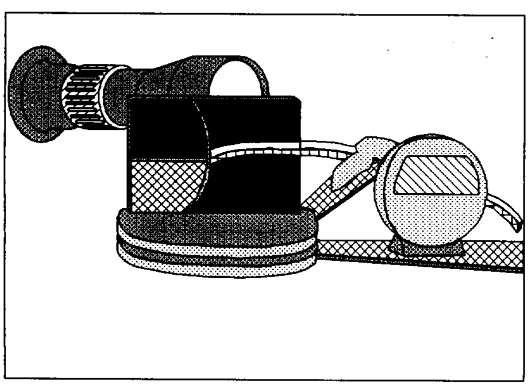
   a. Set the index mark to approximately 35 degrees on the arc scale.

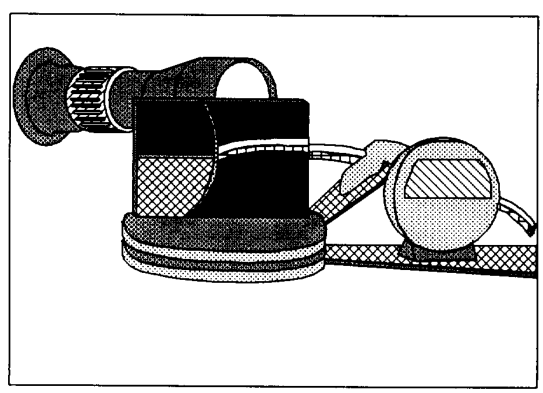
   b. Place the sextant on a flat surface with the Index Mirror facing you.

   c. Look at the arc scale while simultaneously looking at the reflection of the far end of the arc scale in the Index Mirror. Observe both the reflected image of the arc scale (about 120 degrees) in the index mirror and the actual arc scale (about zero degrees).

   d. The arc scales should form a continuous line.

   e. If they do not, use the adjustment tool in the adjustment screw on the back of the index mirror until the actual and reflected images form a continuous line. Turn the adjustment tool clockwise to raise the reflected image and counterclockwise to lower the reflected image. If the reflected image is high, the mirror is leaning forward. If the reflected image is low, the mirror is leaning back.



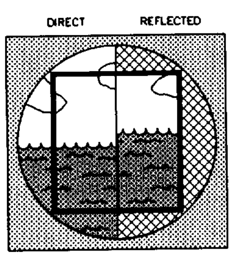


2. Adjusting the Horizon Glass Perpendicular to the Frame.

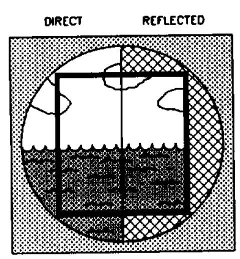
    a. Set the arc scale to approximately 0.

    b. Hold the sextant vertically and sight the horizon (at least two miles away).

    c. Rotate the micrometer drum until the direct and reflected images of the horizon form a continuous line.



HORIZON NOT IN LINE



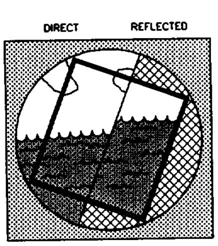
HORIZON IN LINE

    d. Rock or tilt the sextant to the side.

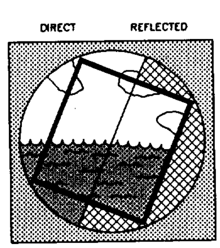
    e. The horizon should continue to form a continuous line.

    f. If the horizons split, the sextant has side error.

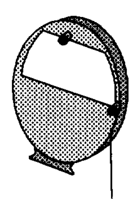
    g. With the sextant tilted to the side, use the adjustment tool in the adjustment screw on the back of the horizon glass that is closest to the frame until both the direct and reflected images of the horizon move back together to form a continuous line.



SIDE ERROR



NO SIDE ERROR

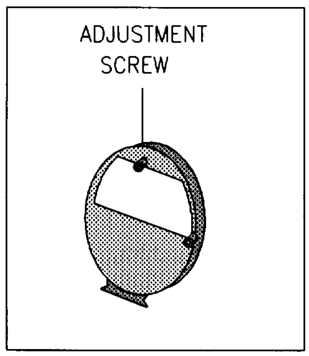


3. Adjusting the Horizon Glass Parallel to the Index Mirror. The leading cause of IE is the horizon glass not being parallel to the index mirror.

   a. Set the sextant to exactly 0.

   b. Hold the sextant vertically and sight the horizon (at least two miles away).

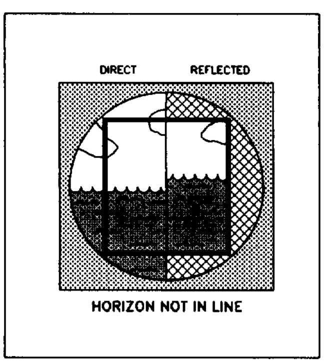
   c. If the images are split, use the adjustment screw on the back of the horizon glass that is furthest from the frame until both the direct and reflected images of the horizon form a continuous line. The adjustments of the horizon glass for perpendicularity and parallelism are mutually dependent.

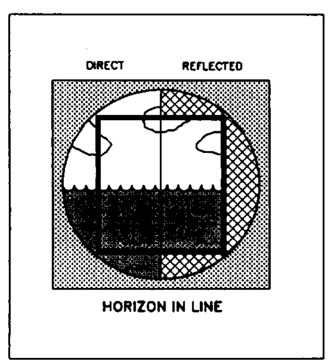


   d. The adjustment for perpendicularity may induce additional error for parallelism and vice versa; therefore, check for side error after IE has been eliminated.

   e. If side error is found after the adjustment, check for IE.

   f. Repeat these checks until all errors are eliminated or reduced to less than 2 minutes.





C. Checking Pentaprism Alignment.

1. Check the IE of the sextant without the pentaprism installed.

   a. IE should not exceed +/- 2 minutes.

   b. If IE exceeds +/- 2 minutes adjust the sextant before proceeding to the next step.

   c. Record the IE and IC.

2. Select a landmark with distinct horizontal and vertical patterns. The patterns are helpful in aligning the 2 images.

3. Install the pentaprism in the adjust (counterclockwise) position.

4. Set the index mark to read 90 deg from "true zero". This means that you have to include the IE into the setting, not correct for it.

5. If the landmark is > 4NM away, set the index mark to read 90 deg 00.0 min. + the IE.

   EXAMPLE: The IE was 0 deg 01.6 mini this is the average of 8 observations (4 ascending and 4 descending).

   Therefore IE is 01.6 ON the arc. We are including the IE so we will ADD 1.6 min to 90 deg.

```
 90-00.0
+00-01.6
 90-01.6
```

6. If the landmark is < 4NM away, calculate the parallax error using Table II.

TABLE II					
Correct angles to compensate for parallax					
Range to Landmark (yards)	Corrected Angle	+	Parallax IE for Your Sextant	=	Setting On Sextant Arc
8100	90° 00.0'	+		=	
2700 - 8100	89° 59.9'	+		=	
1650 - 2700	89° 59.8'	+		=	
1160 - 1650	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'	+		=	

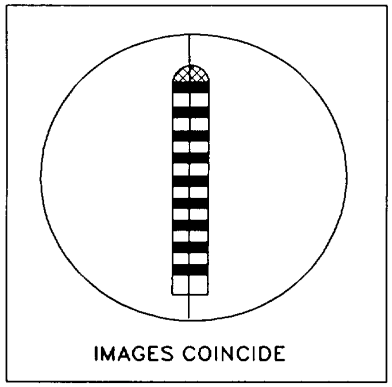
EXAMPLE: The landmark is 1000 yards away. This falls between 900 to 1160 in the Table. The corrected angle is 89 deg 59.6 min.

The index error was 0 deg 01.6 min; the same as above.

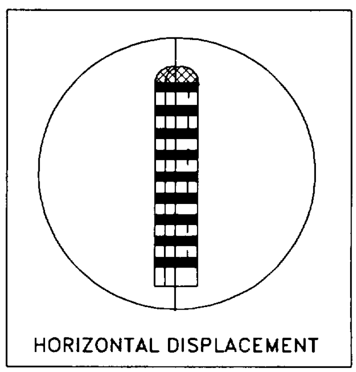
```
 89-59.6
+00-01.6
 90-01.2
```

7. With the index mark set at the angle determined, sight the landmark through the telescope. You will see one of the following images.

a. Images Coincide. The image through the horizon glass mates with the image in the horizon mirror perfectly and the vertical edges form straight lines. The pentaprism is aligned and needs no adjustment.



b. Horizontal Displacement: The image through the horizon glass is shifted to the right or left, relative to the image in the horizon mirror. Rotate the drum to bring the images together. If the images mate then the pentaprism is adjusted. Two possible reasons for horizontal displacement are:



(1) Reason 1 - The sextant is not perfectly adjusted. Complete the following steps:

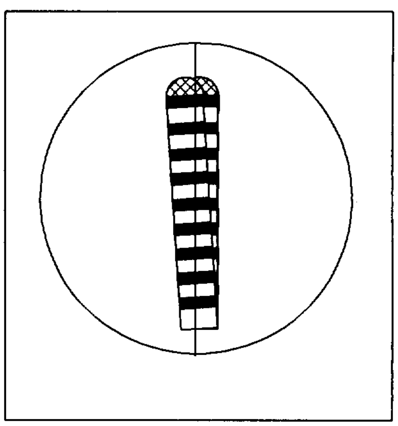
- Return to the original setting on the drum.
- Turn the drum until the images coincide.
- Read the drum.
- If the change is less than 3 minutes, the sextant adjustment is adequate. If the change is greater than 3 minutes the sextant must be readjusted.

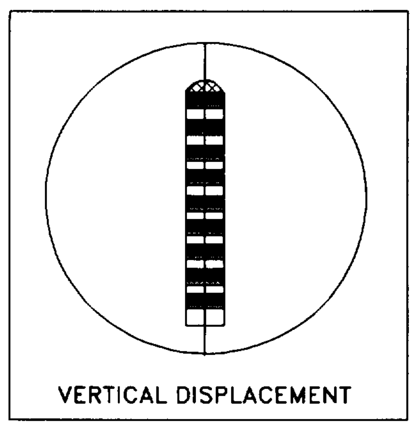
(2) Reason 2 - If after repeating the above procedures the change remains greater than 3 minutes then the pentaprism is not deviating the image by exactly 90-00.0 degrees.
- Send the bad pentaprism to be repaired, or
- order a new pentaprism.

(3) If the pentaprism must be used, it may be used only after the ACTUAL angle that the pentaprism is deviating is determined.

- Select two landmarks 90 deg to 120 deg apart.
- Measure the angle **with** the pentaprism installed.
- Measure the angle **without** the pentaprism installed.
- Subtract the reading without the pentaprism from the one with the pentaprism.
- Repeat 3 times and determine the average.
- The average must be added or subtracted from 90, and the resultant angle used in place of 90-00.0 degrees for all pentaprism angles.

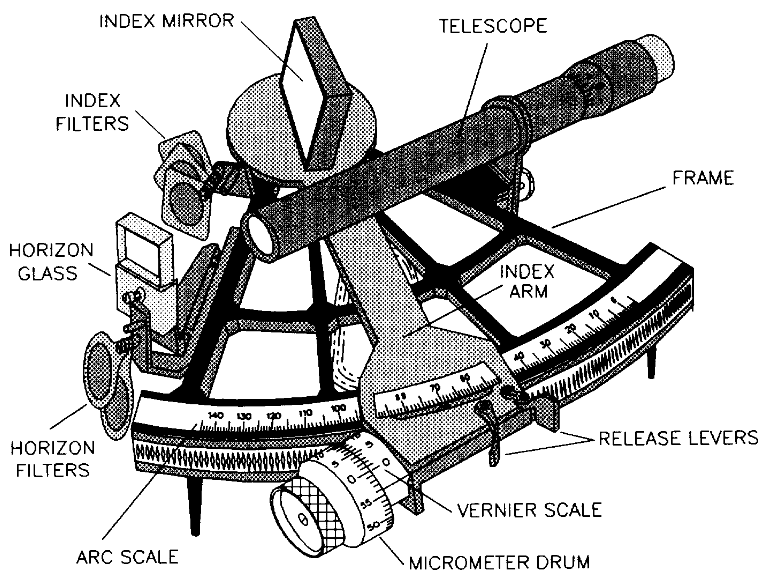
c. If the image through the horizon glass is leaning to one side, or one image is higher than the other, you must:
- Send the bad pentaprism to be repaired, or
- order a new pentaprism.





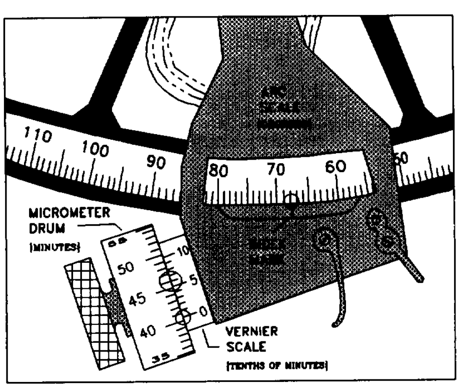
Section IV USE OF THE MARINE SEXTANT

A. General. The marine sextant may be used for positioning aids to navigation. The most common marine sextants available are the Navy MK II and the Navy MK III models. The primary difference between the marine and the survey sextant is that the marine sextant has filters instead of a pentaprism. Instructions for adjustment and maintenance of marine sextants may be found in The American Practical Navigator-BOWDITCH, volume I.



U. S. NAVY MKII MARINE SEXTANT

B. Reading the Marine Sextant. The marine sextant is read the same way the survey sextant is read. There may be differences in the way the vernier scale is labeled, depending upon the year the marine sextant was built.



Sextant Reading is
67 - 40.6

INCLINED ANGLE CORRECTION

A. General. To accurately measure horizontal sextant angles, the sextant must be parallel to the horizon.

1. When one object is elevated significantly higher than the other, the sextant must be held on an incline to observe both objects. When the sextant is held inclined to the horizon an error is induced in the measured angle.

2. An inclined angle correction shall be calculated and applied to compensate for the difference between the inclined angle and the true horizontal angle

B. Determination of an Inclined Angle Correction. To determine the correction for an inclined angle, the nomograph is used. (Figure 2-1). The entering factors are the inclined angle and the altitude angle of the elevated object.

1. Determine the inclined angle by measuring the angle between the surveyed points of each object with the sextant on an incline to allow both objects to be visible.

2. Determine the altitude angle of the elevated object by measuring the vertical angle between the surveyed points of each object. Since both objects can not be seen simultaneously with the sextant held vertically, a horizontal plane from the lower object to the higher object must be established.

   a. Hold the sextant horizontally and bring the lower object over to the elevated object.

   b. Choose a background object on the same horizontal plane as the lower object that also appears to be on a vertical plane with the elevated object.

   c. With the sextant held vertically bring the surveyed point of the elevated object down to the background object. This is the altitude angle.

C. Use of the nomograph. The values on the left margin of the nomograph represent the altitude angle of the elevated object, the curved lines on the nomograph represent the observed inclined angle, and the values on the bottom margin of the nomgraph represent the inclined angle correction.

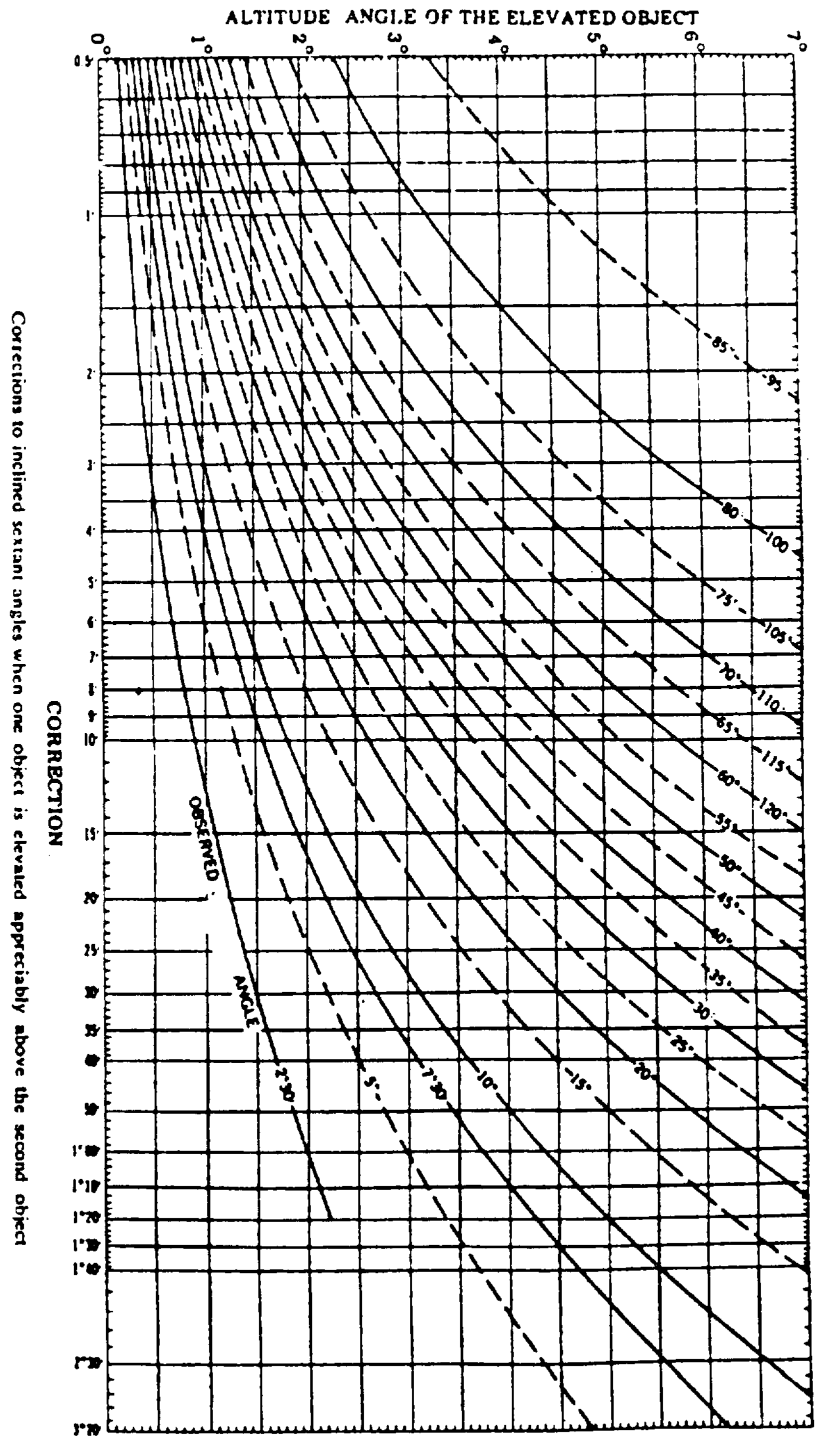
1. Enter the left margin of the nomograph with the altitude angle of the elevated object.

2. Extend a horizontal line from this point across the nomograph until it intersects the curved line with a value equal to the inclined angle. If the inclined angle does not exactly correspond to one of the curved lines, interpolate to find the closest point to your measurement.

3. Extend a vertical line from the intersection point of the altitude angle and inclined angle to the bottom margin of the nomograph to obtain the inclined angle correction.

4. If the inclined angle is greater than 90 degrees ADD the correction.

5. If the inclined angle is less than 90 degrees SUBTRACT the correction.


ALTITUDE ANGLE OF THE ELEVATED OBJECT
CORRECTION
OBSERVED ANGLE
Corrections to inclined sextant angles when one object is elevated appreciably above the second object

HORIZONTAL CONTROL INFORMATION

A. Reference Object Management. If aids in a specific location will be positioned with horizontal sextant angles, the servicing unit shall keep a list(s) of visible reference objects that meet third order, class I survey requirements for positioning aids to navigation. This list shall contain the name of the reference object, the latitude and longitude of the object, the order of survey, and a general description of the object. The following resources provide position information for landmarks.

1. Discreet Independent Point File (DIP File). This file, commonly referred to as the National Ocean Service (NOS) Quick Dump, contains a listing of all charted objects. The NOS no longer provides this information.

2. NOAA Form 76-40. NOS distributes form 76-40 which contains updated positions, for the next chart update, of Coast Guard fixed and floating aids and other charted objects.

3. Geodetic Control Data Sheets. These sheets contain position information on each point of horizontal control catalogued by the National Geodetic Reference System (NGRS) and may be obtained from NGS. For information on current procedures contact NGS at (301) 443-8631.

4. Master Fixed Aid File. The Master Fixed Aid File, maintained by the district office, contains information for each fixed aid maintained by the district, and may be used as a source of reference object data for positioning aids. It will also identify aids that require further positioning or survey activity to meet their standards.

B. SURVEY CONTROL. Requirements for geodetic control surveys are most critical where intense development is taking place, particularly offshore areas, where surveys are used in the exploration and development of natural resources, and in delineation of state and international boundaries.

1. In surveying and mapping large areas, it is first necessary to establish frameworks of horizontal, vertical, and gravity control. These provide a common basis for all surveying and mapping operations to ensure a coherent product. A reference system, or datum, is the set of numerical quantities that serves as a common basis. Three National Geodetic Control Networks have been created by the Government to provide the datums. It is the responsibility of the National Geodetic Survey (NGS) to actively maintain the National Geodetic Control Networks (appendix A).

2. These control networks consist of stable, identifiable points tied together by extremely accurate observations. From these observations, datum values (coordinates or gravity) are computed and published. These datum values provide the common basis that is so important to surveying and mapping activities.

3. As stated, the United States maintains three control networks. A horizontal network provides geodetic latitudes and longitudes in the North American Datum reference system; a vertical network furnishes elevations in the National Geodetic Vertical Datum reference system; and a gravity network supplies gravity values in the U.S. absolute gravity reference system. A given station may be a control point in one, two, or all three control networks.

4. It is not feasible for all points in the control networks to be of the highest possible accuracy. Different levels of accuracy are referred to as the "order" of a point. Orders are often subdivided further by a "class" designation. Datum values for a station are assigned an order (and class) based upon the appropriate classification standard for each of the three control networks.

5. Clearly, the control networks would be of little use if the datum values were not published. The section entitled "Information" describes the various products and formats of available geodetic data.

C. Corrective Measures for Aids with Unsatisfactory Position Tolerances. The following action should be considered to improve the positioning for aids that can't be positioned to their desired tolerances.

1. Recovering Benchmarks. In areas that lack landmarks for sextant angles, the district may research locations of benchmarks from NGS data. Benchmarks are marked by brass disks cemented into the ground, and have been surveyed and tied to the national network of horizontal control. The district can provide descriptions for locating the benchmarks so that units can locate and temporarily mark the point for use in positioning.

2. Surveying Landmarks. Some areas may have many objects visible from the aid, but few accurately known positions. Districts may take steps to have these points surveyed so that they may be used as reference objects for positioning aids. Where landmarks and horizontal control are scarce, districts may consider erecting structures to survey as a reference object.

3. Conversion to Fixed Aids. If a buoy is consistently reported or found o[t station, the feasibility of converting the station to a fixed aid should be considered by the district. The fixed aid, once built, can be surveyed and used to strengthen the horizontal control for positioning other aids in the vicinity.

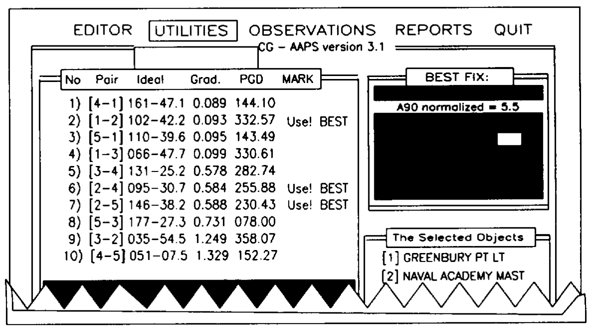
The Positioning Grid

Definition

The Positioning Grid (also called an Offset Grid) is a maneuvering tool that assists the unit in finding the Assigned Position (AP) when using horizontal sextant angles to position aids. The Center of the Grid represents the AP.

Determine The Best Fix

Run a Best Fix in AAPS. Turn on the printer and press [PRT SCR] (print screen) key on the computer to obtain a print out of the objects, ideal angles, positive gradient directions (PGD's), and gradients. The print out will look similiar to the one pictured below. This training aid will use LOP no 2 (Pair [1-2]) below in all examples.

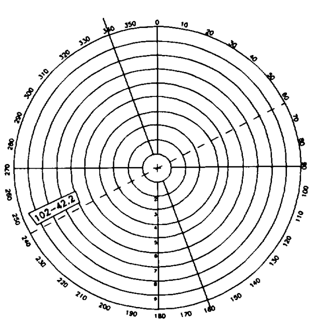


Instructions

Complete the following steps for each angle to be used. Each angle should be drawn in a different color. Red should be avoided in case the Grid must be used under red lights on the bridge.

Plot the Ideal Angle

Draw a dashed line through center of the grid <u>perpendicular</u> to the PGD and label it with the ideal angle for the angle.



PGD = 332.57°T

continued on next page

The Positioning Grid, continued

Determine Minimum LOP Spacing

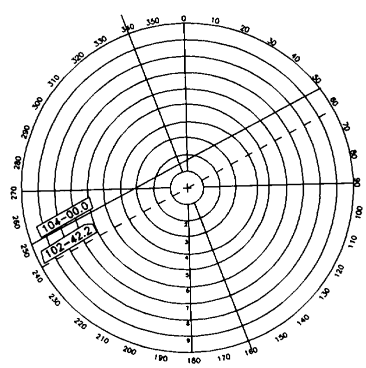
If your lines are drawn too close together the Grid will be difficult to use. For a 50 yard grid, line spacing should not be less than 10 yards (for a 100 yard grid 20 yards, etc.). To determine the spacing first look at the gradient for the angle listed on the Best Fix printout. Divide the desired line spacing by the gradient.

EXAMPLE: For a gradient of 0.093 yds/min. the line spacing would be 2 degrees. 10 divided by 0.093 is 107.5. 107.5 is how many minutes of arc are in 10 yards. Since it is easier to work with even numbers, round to 2 degrees (120 minutes). {The Line Spacing should be in units that can be easily interpolated between, i.e. 5, 10, 20, or 30 minutes, or whole degrees.}

Determine Offset for the Adjacent Angle

The adjacent angles to each ideal are drawn parallel to the ideal. The adjacent angles are offset from the ideal to obtain the desired line spacing in whole units.

EXAMPLE: For a desired line spacing of 2 deg. (120 min), and an ideal angle of 102 42.2', the adjacent line is 104 00.0'. Next determine the difference between the ideal and adjacent angles (104 00.0' - 102 42.2' = 77.8'). Multiply the difference by the gradient to determine the offset (77.8' X 0.093 = 7.2 yds). Go **TOWARDS** the PGD distance for the offset and draw a line parallel to the ideal angle. Label the line with it's angle (104-00.0).



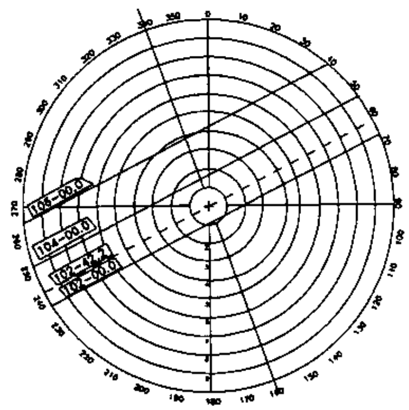
continued on next page

The Positioning Grid, continued

Compute the Remaining Lines

Multiply the desired LOP spacing by the gradient.

EXAMPLE: For a desired LOP spacing of 2 degrees and a gradient of 0.093 (120 X 0.093 = 11.2 yards). Draw the remaining lines parallel to the 104-00 line and spaced 11.2 yards apart. Make sure to measure the lines from the first offset line (our 104 00.0 line) and not the ideal. Label the lines. For our example, the next line towards the PGD would be 106 00.0 and the first line drawn away from the PGD would be 102-00.0. Continue to space the line in this method to the edge of the grid.



Plot the Other Angles

Repeat these steps for the remaing angles from the best fix. Remember to use a different color for each of the remaining angles.

Label the Grid

The Grid should be labeled with the following information:

1) Radius used (i.e. 50 Yards)

2) Name and Assigned Position (AP) of the aid

3) Date the Grid was drawn

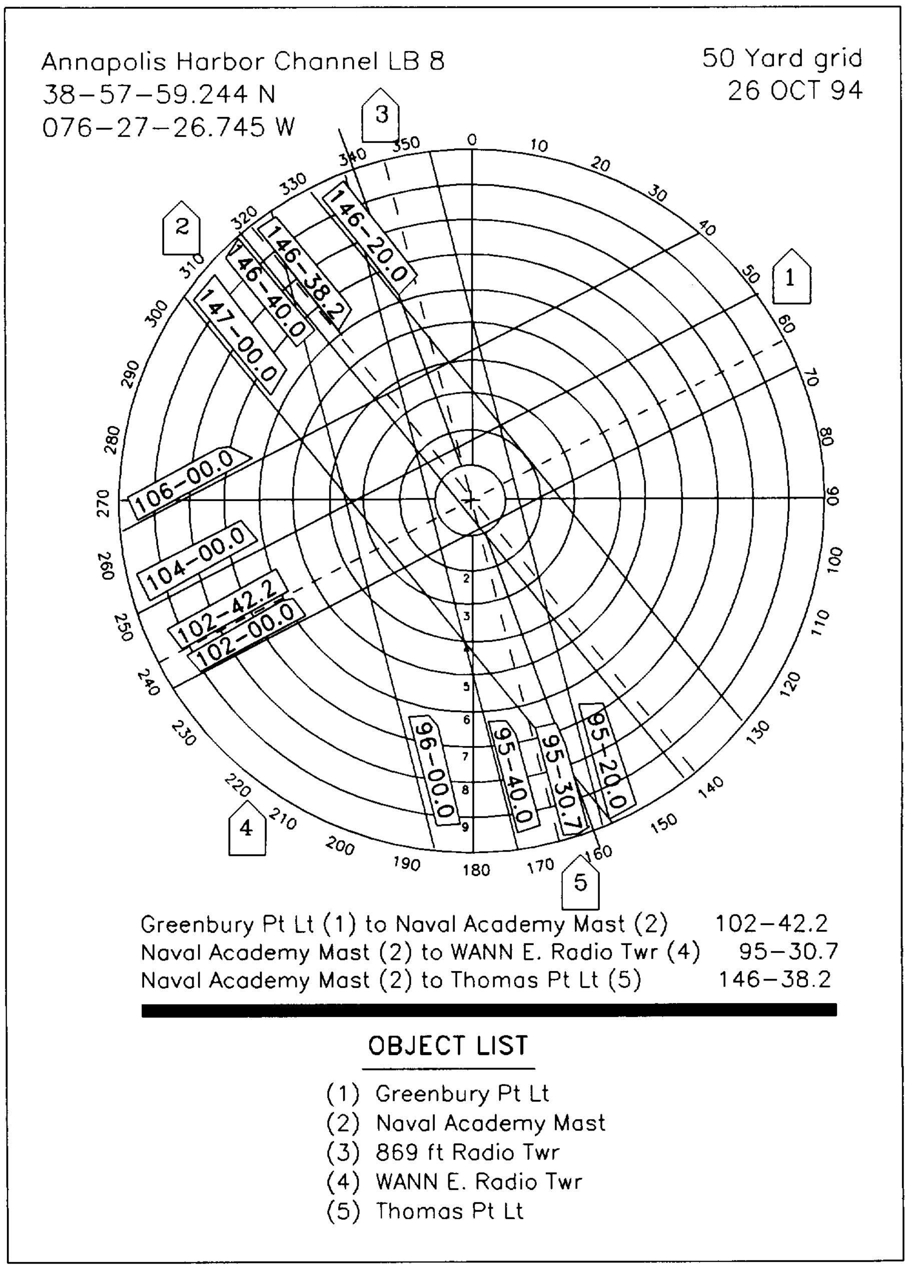
4) List the objects used in each angle and the ideal angle in the same color that the angle is drawn with.

5) Place a symbol outside the last ring of the grid at the true bearing for each object used. Label the objects.

continued on next page

The Positioning Grid, continued

Example Here is an example of a grid with a 50 yard radius. For clarity, only the ideal angles, the first offset line, and 2 other lines are drawn.



DGPS RTCM Broadcast

A. General. The Coast Guard's DGPS system broadcasts corrections in the RTCM SC-104 (Version 2.1) format. The RTCM has defined data messages for use in the transmission of DGPS corrections, ancillary information, and integrity information. RTCM format allows flexibility in its implementation and use. The U.S. Coast Guard's Broadcast Standard further defines the use of this format along with specifying the various broadcast parameters. For more information on DGPS message types see COMDTINST M16577.1.

B. Data Message Types.

Type 1 Differential GPS Corrections. The Type 1 Message is not used due to the advantages of the Type 9 Message. If Selective Availability were permanently discontinued, use of the Type 1 Message might be revisited as it is able to utilize a less expensive frequency source, hence user equipment should retain the ability to process it. The Type 9 Message will serve as the exclusive message for the broadcast of pseudorange corrections.

Type 3 Reference Station Parameters. The NAD 83 coordinates of the reference station with a resolution of 0.01 meter are found here. This message will nominally be broadcast twice per hour. User derived atmospheric corrections may be aided through use of this message type.

Type 5 Constellation Health. The main use of this message type will be to notify the user equipment suite that a satellite which is deemed unhealthy by its current navigation message is unusable for DGPS navigation.

Type 7 Radiobeacon Almanac. This message provides location, frequency, service range, and health information for adjacent broadcast transmitters as well as the radiobeacon from which the message is broadcast. When broadcast from a given radiobeacon, it can be used to acquire the next transmitter when in transit down the coast. This message will nominally be sent every 10 minutes.

Type 9 Differential GPS Corrections. The Type 9 Message has been selected for broadcast of DGPS corrections over the Type 1 Message for the following reasons: 1) greater impulse noise immunity; 2) lower latency (when broadcast in groups of three); 3) less susceptibility to SA on one or more satellites; 4) a more timely alarm capability. Unlike the Type 1 message, partial Type 9 messages can be used in accordance with the RTCM and IALA standards.

Type 16 Special Message. This is an ASCII message up to 90 characters long. It can be sent by service providers to broadcast warning information, such as scheduled outages. User equipment should have the ability to display this information to the navigator, with audible warning of receipt.

C. <u>Application of Type 9 corrections</u>. Recent tests have demonstrated the substantial advantage gained through this use of the Type 9 Message. Pseudorange corrections (PRC) and range rate corrections (RRC) are broadcast for up to nine satellites which are above a 7.5 degree mask angle. The message indicates the nominal time (shown as below t0) for which this data was valid. The current differential correction is computed as follows:

$PRC(t) = PRC(t_0) + RRC \cdot t-t_0),$

where PRC(t0) is the PRC value in the PRC message. The PRC is then applied by adding it to the pseudorange measurement. The RRC is included in an attempt to extend the life of the PRC, as the RRC is a "rate" term which is used to propagate PRCs in time. Type 9 Messages will contain the corrections for up to three satellites in each message. For example, if the corrections for eight satellites are broadcast the corrections will consist of three Type 9 Messages, two with the corrections for three satellites and one with the correction for two satellites. Because of the possibility of sudden pseudorange accelerations it was decided that basing the Type 9 generation method on pseudorange velocity or acceleration would prove to be overly cumbersome and of considerable operational risk. A combination of a low drift frequency source (rubidium or a high grade crystal) and proper drift modeling is required. This is because the user will be mixing corrections which are generated at different epochs, and in periods of high noise the corrections received for a given satellite may be up to 30 seconds apart. Though a rubidium source is not necessarily required for Type 9 message generation, its low phase noise may improve the achievable accuracy to the user by 30-40 cm due to the superior range rate correction which can be generated through its use. Velocity accuracy is enhanced as well. Additionally, a rubidium source allows the reference station clock to achieve a greater degree of isolation from GPS anomalies since the derived GPS constellation time can be smoothed and checked over a longer period of time.

D. GGA - Global Positioning System Fix Data. The GGA NMEA 0183 data message is used to transmit time, position, and fix related data to AAPS. The sections are described below.

```
Differential reference station ID, 0000-1023
Age of DGPS data
Units of geoidal separation (meters)
Geoidal separation
Units of antenna altitude (meters)
Antenna altitude (above geoid)
HDOP

$GPGGA,hhmmss.ss,llll.ll,a,yyyyy.yy,a,x,xx,x.x,x.x,M,x.x,M,x.x,xxx

# of satellites in use
GPS quality indicator
(see below for meaning)
Longitude,E/W
Latitude,N/S
UTC of fix
```

GPS Quality Indicator: 0=No fix
1=GPS SPS fix
2=DGPS fix
3=GPS PPS fix

E. GRS - GPS Range Residuals. Range residuals applied to the satellites to determine the DGPS position. The sections are described below.

```
$GPGRS,hhmmss.ss,x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x,x.x

Range residuals for satellites used
Mode, 0=residuals used to calculate position
UTC of fix
```

F. GSA - GPS DOP and Active Satellites. GPS receiver operating mode, DOP (dilution of precision) values, and satellites used. The sections are described below.

```
$GPGSA,a,x,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,xx,x.x,x.x,x.x

VDOP
HDOP
PDOP
PRN numbers of satellites used
Mode:  1=no fix; 2=2 dimensional fix; 3=3 dimensional fix
Mode:  M=Manual (rcvr forced to operate in 2d or 3d mode)
            A=Automatic (rcvr allowed to select 2d or 3d)
```

G. <u>GST - GPS Pseudorange Noise (PRN) statistics</u>. Pseudorange measurement noise statistics can be used to give statistical measures of the quality of the position. The sections are described below.

```
$GPGST,hhmmss.ss,x.x,x.x,x.x,x.x,x.x,x.x,x.x
```

- standard deviation of altitude error (meters)
- standard deviation of longitude error (meters)
- standard deviation of latitude error (meters)
- orientation of semi-major axis of error ellipse (degrees from 000T)
- standard deviation of semi-minor axis of error ellipse (meters)
- standard deviation of semi-major axis of error ellipse (meters)
- RMS value of the standard deviation of the range inputs. Range inputs include DGPS corrections and pseudoranges.
- UTC of fix

United States Coast Guard DGPS Site Information

Atlantic and Gulf Coasts

Broadcast Site	Frequency (Khz)	Trans Rate (BPS)	Latitude (N)	Longitude (W)	Range (NM)	Ref Sta A ID	Ref Sta B ID	Radiobeacon ID
NSA Brunswick, ME	316	100	43 53 42	69 56.17	115	000	001	800
Portsmouth Harbor, NH	288	100	43 04 15	70 42 37	100	002	003	801
Chatham, MA	325	200	41 40 17	69 57 02	95	004	005	802
Montauk Point, NY	293	100	41 04 02	71 51 38	130	006	007	803
Sandy Hook, NJ	286	200	40 28 17	74 00 42	100	008	009	804
Cape Henlopen, DE	298	200	38 46 36	75 05 16	180	010	011	805
Cape Henry, VA	289	100	36 55 38	76 00 24	130	012	013	806
Fort Macon, NC	294	100	34 41 52	76 40 59	130	014	015	807
Charleston, SC	298	100	32 45 28	79 50 35	150	016	017	808
Cape Canaveral, FL	289	100	28 27 35	80 32 35	250	018	019	809
Miami, FL	322	100	25 43 56	80 09 38	75	020	021	810
Key West, FL	286	100	24	82	110	022	023	811
Egmont Key, FL	312	200	27 36 16	82 45 40	210	024	025	812
Puerto Rico	295	100	18 27.7	66 04.0	125	034	035	817
Mobile Point, AL	300	100	30 13 38	88 01 24	170	026	027	813
English Turn, LA	293	200	29 52 44	89 56 31	170	028	029	814
Galveston, TX	296	100	29 19 45	94 44 10	180	030	031	815
Aransas Pass, TX	304	100	27 50 18	97 03 33	180	032	033	816

Great Lakes Region *

Broadcast Site	Frequency (Khz)	Trans Rate (BPS)	Latitude (N)	Longitude (W)	Range (NM)	Ref Sta A ID	Ref Sta B ID	Radiobeacon ID
Wisconsin Point, WI	296	100	46 42 16	92 01 01	40	100	101	830
Upper Keweenaw, WI	298	100	47 13 21	88 37 18	130	102	103	831
Sturgeon Bay, WI	322	100	44 47 40	87 18 49	110	104	105	832
Milwaukee, WI	297	100	43 00 06	87 53 18	140	106	107	833
Whitefish Point, MI	318	100	46 46 17	84 57 29	80	108	109	834
Neebish Island, MI	309	200	46 19 17	84 09 02	60	110	111	835
Cheboygan, MI	292	200	45 39 10	84 28 00	110	112	113	836
Saginaw Bay, MI	301	100	43 37 43	83 50 17	85	114	115	837
Detroit, MI	319	200	42 17 49	83 05 41	100	116	117	838
Youngstown, NY	322	100	43 14 10	79 01 03	150	118	119	839

Inland Rivers Region **

Broadcast Site	Frequency (Khz)	Trans Rate (BPS)	Latitude (N)	Longitude (W)	Range (NM)	Ref Sta A ID	Ref Sta B ID	Radiobeacon ID
Vicksburg, MS	313	200	32 19 53	90 55 11	115	150	151	860
Memphis, TN	310	200	35 27 56	90 12 21	115	152	153	861
St Loius, MO	322	200	38 36 41	89 45 31	115	154	155	862
Rock Island, IA	311	200	42 00 30	90 14 00	150	156	157	863
St. Paul, MN	317	200	44 18 15	91 54 14	150	158	159	864
Millers Ferry, AL	320	200	32 05 24	87 23 44	150	160	161	865

* Great Lakes and Western Rivers DGPS sites indicate radiobeacon ranges in statute miles, all others are in nautical miles.
** Future Plans are to add an additional eight sites to the Inland Rivers Region.

Alaska, Pacific Coast, and Hawaii

Broadcast Site	Frequency (Khz)	Trans Rate (BPS)	Latitude (N)	Longitude (W)	Range (NM)	Ref Sta A ID	Ref Sta B ID	Radiobeacon ID
Cold Bay, AK	289	100	55 15 25	162 46 05	180	296	297	898
Kodiak, AK	313	100	57 37 08	152 11 21	180	294	295	897
Kenai, AK	310	100	60 35 50	150 13 01	170	292	293	896
Potato Point, AK	298	100	61 03 24	146 41 48	100	290	291	895
Cape Hinchinbrook, AK	292	100	60 14 18	146 38 48	120	288	289	894
Gustavus, AK	288	100	58 25 20	135 42 10	170	284	285	892
Annette Island, AK	323	100	55 04 11	131 35 52	170	278	279	889
Whidbey Island, WA	302	100	48 18 46	122 41 46	90	276	277	888
Robinson Point, WA	323	200	47 23 15	122 22 29	60	274	275	887
Fort Stevens, OR	287	100	46 12 18	123 57 21	180	272	273	886
Cape Mendocino, CA	292	100	40 26 29	124 23 56	180	270	271	885
Point Blunt, CA	310	200	37 51 12	122 25 04	60	268	269	884
Pigeon Point, CA	287	100	37 10 55	122 23 35	180	266	267	883
Point Arguello, CA	321	100	34 34 39	120 38 38	180	264	265	882
Point Loma, CA	302	100	32 39 54	117 14 33	180	262	263	881
Kokole Point, HI	300	200	22 03 30	159 46 34	300	260	261	880
Upolu Point, HI	285	100	20 14 48	155 53 12	170	258	259	879

DGPS EQUIPMENT VERIFICATION PROCEDURES

A. REFERENCE CHECK GUIDELINES. This enclosure provides guidance when the Commanding Officer/Officer in Charge/Coxswain questions the integrity and/or performance of the DGPS/GPS equipment, or when there has been an onboard equipment configuration change. This includes initial installation, replacement or relocation of the receiver or antennae. Daily reference checks previously required are no longer mandatory; rather, COs/OinCs/coxswains must ensure that the receiver is operating properly prior to position (similar guidance may be found in COMDTINST 3530.2, Cutter Navigation Standards).

1. The check is completed by comparing a fixed location to a DGPS/GPS position. The fixed location must have been determined previously using an approved survey method.

   (a) If using DGPS, the DGPS fix must have a 2DRMS less than or equal to 10.94 yards. The comparison must show the DGPS position to be 10.94 yards or less from the fixed position.

   (b) If using GPS, the GPS fix must have a 2DRMS less than or equal to 110 yards. The comparison must show the GPS position to be 110 yards or less from the fixed position.

2. The reference check may also be completed by comparing the DGPS/GPS fix to a horizontal sextant angle fix taken simultaneously.

   (a) If using DGPS, the DGPS fix must have a 2DRMS less than or equal to 10.94 yards. The comparison must show the DGPS position to be 10.94 yards or less from the horizontal sextant angle position. The horizontal sextant angle fix must have an A90 of 10 yards or less.

   (b) If using GPS, the GPS fix must have a 2DRMS less than or equal to 110 yards. The comparison must show the GPS position to be 110 yards or less from the horizontal sextant angle position. The horizontal sextant angle fix must have an A90 of 10 yards or less.

3. If the DGPS/GPS comparison is mandatory due to an onboard equipment (hardware) change, a comparison APR must be created. The APR shall be created in accordance with the procedures in chapter 7. If the DGPS or GPS position does not meet the above standards, the receiver shall not be used for positioning until the cause of the error is determined.

GLOSSARY

Accuracy Classification - The area that forms a circle around an aid's assigned position within which the aid is considered on station.

Achievable Buoy Station Dimension (aBSD) - The area around an aid's Assigned Position where statistics say the aid can be expected to be. aBSD is only used to determine the Accuracy Classification.

Achievable Error Ellipse (AEE) - An estimate of the fix error (A90) that can be expected for an aid's AP.

Aid Position Record (APR) - A legal document produced each time a floating aid is visited or a fixed aid is rebuilt. All information used to position the aid is listed so the aid's position can be recreated at a later time.

Aid to Navigation Information System (ATONIS) - A computer program that contains the hardware information (lighting equipment, hull size, etc.) for the aid.

A90 - The semi-major axis of the error ellipse. This is the length from the center to the farthest point of the error ellipse.

A90 Normalized - The estimated A90 for an aid based on a fix with an s of one. A90 normalized is used to determine AEE.

Assigned Position (AP) - The specific geographic position (latitude and longitude) where an aid should be located. The AP for aids to navigation are listed to one thousandth of a second.

Automated Aid Positioning System (AAPS) - A MSDOS based computer program used to determine the position of an aid. AAPS is sometimes called LAAPS (Laptop Automated Aid Positioning System).

Best Fix - The combination of three angles that produces the smallest A90 normalized and meets the following criteria: LOPs for the angles must be separated by a minimum of 15 degrees and use a minimum of four objects.

B90 - The semi-minor axis of the error ellipse. This is the length from the center to the nearest point of the error ellipse.

Buoy Station Dimension - The radius of a circle centered on the error ellipse (MPP or CWC) where the aid is expected to be. BSD is computed using the fix error (2drms or A90) and WCR.

CAPII - Computer Aided Positioning program, version 2. This was the standard positioning program prior to AAPS.

Cartographer's Tolerance - The amount a cartographer may move an object on a chart to make it look correct. The cartographer's tolerance is 1/30th of an inch for charts with a scale of 1:20,000 and larger, and 1/50th of an inch for chart scales smaller than 1:20,000.

Center of Watch Circle (CWC) - The estimated position of the sinker for an aid positioned not at short stay. CWC is the center of the area that the buoy hull can travel around the sinker (watch circle). The error ellipse is offset from MPP by the distance and reciprocal of the bearing of excursion to determine CWC.

Datum, Geographic - A reference upon which to base horizontal (latitude and longitude) positions. Most aid positions are based on NAD-83 or WGS-84.

Datum, Sounding - Low water.

Desired Positioning Tolerance (DPT) - The radius of a circle that describes the maximum desired error for positioning an aid. DPT is based on the service the aid provides, and the navigational needs of the mariner in a specific location.

Differential Global Positioning System (DGPS) - An enhancement of DOD's NAVSTAR GPS service. Corrections for individual satellites are broadcast, increasing the accuracy of the GPS satellite system from approximately 110 yards to less than 11 yards.

Ellipse Orientation - The direction, in degrees true, at which the major axis of the error ellipse is inclined.

Ephemeris Data - Data relating to the positions of astronomical bodies and artificial satellites. For NAVSTAR GPS, ephemeris data is used by GPS receivers to determine pseudoranges.

Error Ellipse - The area that has a 90% confidence level for a fix with three or more LOPs. The center of the error ellipse is called MPP if the aid is at short stay and CWC when the aid is not at short stay.

Excursion - The direction and distance that the buoy hull is being forced away from the sinker.

Found Fix - The initial position where the buoy is found after arriving onscene. The found fix is either the first fix obtained after arriving onscene utilizing excursion (if necessary), or a fix obtained after the aid has been pulled to short stay.

Geographic Datum - See Datum, Geographic

Global Positioning System (GPS) - See NAVSTAR Global Positioning System.

Gradient - A ratio of the distance that must be traveled to change a LOP by a given amount. For sextant angles gradient is expressed as a ratio of yards per minute.

Horizontal Control - The relationship between an aid and the objects that are visible to position it. Aids that have few objects available for positioning, or when those objects are grouped together or a great distance away, are often said to have a lack of horizontal control.

Horizontal Dilution of Precision (HDOP) - HDOP describes the satellite geometry's effect on position errors. HDOP is based solely on satellite geometry.

Ideal Angle - The horizontal sextant angle that would be measured at an aid's assigned position, assuming there are no errors in the positions of the reference objects or the observation.

Laptop Automated Aid Positioning System (LAAPS) - See Automated Aid Positioning System.

Line of Position (LOP) - A line on which you are located. LOPs may be straight or curved. For aid positioning, we often assume straight line approximations of curved LOPs.

Most Probable Position (MPP) - The position of the sinker for an aid positioned at short stay, or the position of the buoy hull for an aid positioned not at short stay.

North American Datum (NAD) - A reference system used to determine the position of latitude and longitude lines in North America.

NADCON - A MSDOS based computer program used to convert positions from one geodetic datum to another.

NAD-27 - The North American Datum of 1927. NAD-27 used Meades Ranch, Kansas as its origin (basis for positions).

NAD-83 - The North American Datum of 1983. The current geodetic datum of North America, NAD-83 uses the center of the earth as its origin. NAD-83 is functionally equivalent to the World Geodetic System.

NAVCEN - The U.S. Coast Guard's Navigation Center located in Alexandria, VA. NAVCEN controls and can provide information on the DGPS, LORAN-C, and OMEGA systems.

NAVSTAR Global Positioning System (GPS) - A space based system used to obtain accurate position, time, and velocity information. NAVSTAR GPS is operated by the U.S. Department of Defense and consists of 24 satellites.

Off Station - The determination that an aid to navigation is not located where it can best serve the purpose for which it is intended. AAPS makes this determination based on mathematical equations and does not take into account any additional factors. The Commanding Officer ultimately determines if the aid is Off Station.

On Station - The determination that an aid to navigation is located where it can best serve the purpose for which it is intended. AAPS makes this determination based on mathematical equations and does not take into account any additional factors. The Commanding Officer ultimately determines if the aid is On Station.

Orient - See ellipse orientation.

Position Approximate (PA) - An inexact position. Fixed aids are considered PA when they do not meet the cartographer's tolerance listed in Table IV. These aids are charted with the "open circle" chart symbol and labeled PA.

Position Known - An exact position. Fixed aids are considered position known when they meet the cartographer's tolerance listed in Table IV. These aids are charted with the "closed circle" chart symbol.

Positive Gradient Direction - The direction you must travel from an aid's assigned position to make a horizontal sextant angle increase. PGD is always perpendicular to the LOP direction.

Pseudorange - The distance between a GPS receiver and a GPS satellite, adjusted for user clock bias.

Pseudorange Correction (PRC) - The correction applied to a pseudorange to obtain a more accurate fix. PRCs are determined and broadcast by DGPS reference stations for up to nine satellites.

Set Fix - The fix taken when an aid is set. The set fix represents the location where the aid is left, and is normally taken when the sinker is let go.

Short Stay - The horizontal position of the buoy hull and the sinker are the same (chain is "up and down" and all excess chain is on deck).

Sounding - The measured depth water. Vessel draft and tide correction are be applied, usually in AAPS, to determine Datum.

Stadimeter - An mechanical instrument used to determine distance from an object of known height.

Standard Deviation of Residuals (s) - The random error inherent to the fix. s indicates the consistency of the observers and is expressed in minutes of arc for a sextant angle fix.

Target Area - Used to determine accuracy classification, Target Area is the DPT or AEE, whichever is larger. For an aid to be positioned with DGPS the DPT is used as the Target Area.

Tolerance Radius - The radius of a circle drawn around the aid's AP where the aid is considered to be On Station.

Two Distance Root Mean Squared (2DRMS) - The radius of a circle within which 95% of all possible solutions fall.

Watch Circle Radius - The maximum horizontal distance the buoy hull can travel from the sinker.

World Geodetic System (WGS) - A worldwide system used to determine latitude and longitude. Unlike previous systems (i.e. the North American Datum) that were based on a single point of origin, the WGS is based on many positions. The result is an ellipsoid that closely fits the surface of the earth.

WGS-72 - The World Geodetic System of 1972.

WGS-84 - The World Geodetic System of 1984. WGS-84 is a refined version of WGS-72 and is used to position aids in some areas of the world.

INDEX

A

B

C

D

D

E

F

G

H

I

L

M

N

O

O

P

Q

R

S

T

V

W