

# CHAPTER 8

## PILOTING

### DEFINITION AND PURPOSE

#### 800. Introduction

Piloting involves navigating a vessel through restricted waters. As in all other phases of navigation, proper preparation and strict attention to detail are very important. This chapter will dis-

cuss a piloting methodology designed to ensure the procedure is carried out safely and efficiently. These procedures will vary from vessel to vessel according to the skill and composition of the piloting team. It is the responsibility of the navigator to choose the procedures applicable to his own situation.

### PREPARATION

#### 801. Chart Preparation

- **Assemble Required Publications:** These publications should include *Coast Pilots*, *Sailing Directions*, *Light Lists*, *Lists of Lights*, *Tide Tables*, *Tidal Current Tables*, *Notice to Mariners*, and *Local Notice to Mariners*. Often, for military vessels, a port will be under the operational direction of a particular squadron; obtain that squadron's port Operation Order. Civilian vessels should obtain the port's harbor regulations. These publications will cover local regulations such as speed limits and bridge-to-bridge radio frequency monitoring requirements. Assemble the broadcast Notice to Mariners file.
- **Select and Correct Charts:** Choose the largest scale chart available for the approach. Often, the harbor approach will be too long to be represented on only one chart. For example, three charts are required to cover the waters from the Naval Station in Norfolk to the entrance of the Chesapeake Bay. Therefore, obtain all the charts required to cover the entire passage. Verify using the Notice to Mariners that the charts in use have been corrected through the latest change. Make any required changes prior to using the chart. Check the *Local Notice to Mariners* and the *Broadcast Notice to Mariners* file to ensure the chart is fully corrected and up to date. Annotate on the chart or a chart correction card all the corrections that have been made; this will make it easier to verify the chart's correction status prior to its next use. Naval ships will normally prepare three sets of charts. One set is for the primary plot, the second set is for the secondary plot, and the third set is for the conning officer and captain.

- **Mark the Minimum Depth Contour:** Determine the minimum depth of water in which the vessel can safely operate and outline that depth contour on the chart. Do this step before doing any other harbor piloting planning. Make this outline in a bright color so that it clearly stands out. Carefully examine the area inside the contour and mark the isolated shoals less than the minimum depth which fall inside the marked contour. Determine the minimum depth in which the vessel can operate as follows:

$$\text{Minimum Depth} = \text{Ship's Draft} - \text{Height of Tide} + \text{Safety Margin} + \text{Squat. (See section 802 and section 819.)}$$

Remember that often the fathometer's transducer is not located at the section of the hull that extends the furthest below the waterline. Therefore, the indicated depth of water below the fathometer transducer, not the depth of water below the vessel's deepest draft.

- **Highlight Selected Visual Navigation Aids (NAVAIDS):** Circle, highlight, and label all NAVAIDS on the chart. Consult the applicable *Coast Pilot* or *Sailing Directions* to determine a port's best NAVAIDS if the piloting team has not visited the port previously. These aids can be lighthouses, piers, shore features, or tanks; any prominent feature that is displayed on the chart can be used as a NAVAID. Label critical buoys, such as those marking a harbor entrance or a traffic separation scheme. Verify charted lights against the *Light List* or the *List of Lights* to confirm the charted information is correct. This becomes most critical when attempting to identify a light at night. Label NAVAIDS succinctly and clearly. Ensure everyone in the navigation team re-

fers to a NAVAID using the same terminology. This will reduce confusion between the bearing taker, the bearing recorder, and plotter.

- **Highlight Selected Radar NAVAIDS:** Highlight radar NAVAIDS with a triangle instead of a circle. If the NAVAID is suitable for either visual or radar piloting, it can be highlighted with either a circle or a triangle.
- **Plot the Departure/Approach Track:** This process is critical for ensuring safe pilotage. Consult the *Fleet Guide* and *Sailing Directions* for recommendations on the best track to use. Look for any information or regulations published by the local harbor authority. Lacking any of this information, locate a channel or safe route delineated on the chart and plot the vessel's track through the channel. Most U.S. ports have well-defined channels marked with buoys. Carefully check the intended track to ensure a sufficient depth of water under the keel will exist for the entire passage. If the scale of the chart permits, lay the track out to the starboard side of the channel to allow for any vessel traffic proceeding in the opposite direction. Many channels are marked by natural or man-made **ranges**. A range consists of two NAVAIDS in line with the center of a navigable channel. The navigator can determine his position relative to the track by evaluating the alignment of the NAVAIDS forming the range. These ranges should be measured to the nearest  $0.1^\circ$ , and this value should be marked on the chart. Not only are ranges useful in keeping a vessel on track, they are invaluable for determining gyro error. See section 808.
- **Label the Departure/Approach Track:** Label the track course to the nearest  $0.5^\circ$ . Similarly, label the distance of each track leg. Place these labels well off the track so they do not interfere with subsequent plotting. Highlight the track courses for easy reference while piloting. There is nothing more frustrating than approaching a turn and not being able to determine the next course from the chart quickly. Often a navigator might plan two separate tracks. One track would be for use during good visibility and the other for poor visibility. Considerations might include concern for the number of turns (fewer turns for poor visibility) or proximity to shoal water (smaller margin for error might be acceptable in good visibility). In this case, label both tracks as above and appropriately mark when to use each track. If two separate tracks are provided, the navigator must decide which one to use *before* the ship enters restricted waters. Never change tracks in the middle of the transit.
- **Use Advance and Transfer to Determine Turning Points:** The track determined above does not take into account **advance** and **transfer** for determining turning points. See Figure 801a. The distance the vessel moves

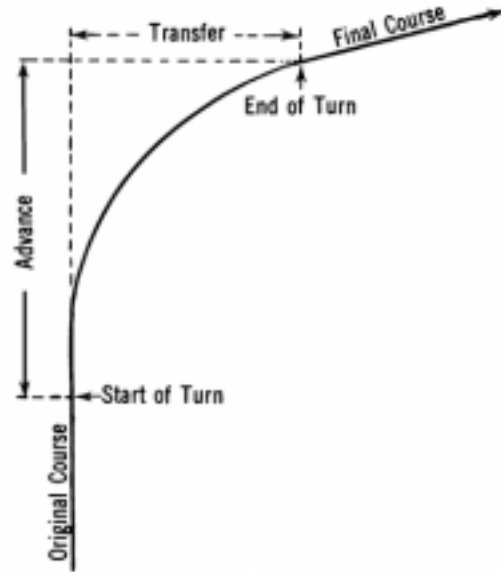


Figure 801a. Advance and transfer.

in the direction of the original course from when the rudder is put over until the new course is reached is called advance. The distance the vessel moves perpendicular to the original course during the turn is called transfer. Use the advance and transfer characteristics of the vessel to determine when the vessel must put its rudder over to gain the next course. From that point, fair in a curve between the original course and the new course. Mark the point on the original course where the vessel must put its rudder over as the **turning point**. See Figure 801b.

- **Plot Turn Bearings:** A **turn bearing** is a predetermined bearing to a charted object from the track point at which the rudder must be put over in order to make a desired turn. Follow two rules when selecting NAVAIDS to be used as turn bearing sources: (1) The NAVAID should be as close to the beam as possible at the turn point; and (2) The aid should be on the inside elbow of the turn. This ensures the largest rate of bearing change at the turning point, thus marking the turning point more accurately. Plot the turn bearing to the selected NAVAID from the point on the track at which the vessel must put its rudder over to gain the new course. Label the bearing to the nearest  $0.1^\circ$ .

**Example:** Figure 801b illustrates using advance and transfer to determine a turn bearing. A ship proceeding on course  $100^\circ$  is to turn  $60^\circ$  to the left to come on a range which will guide it up a channel. For a  $60^\circ$  turn and the amount of rudder used, the advance is 920 yards and the transfer is 350 yards.

**Required:** The bearing of flagpole "FP." when the rudder is put over.

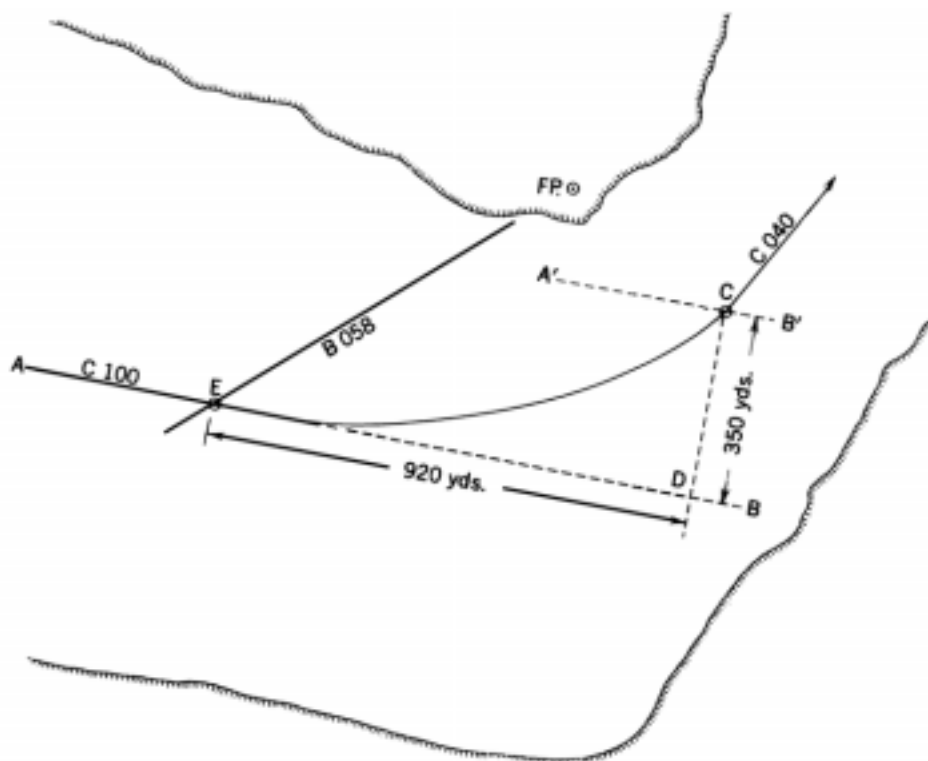


Figure 801b. Allowing for advance and transfer.

**Solution:**

1. Extend the original course line, AB.
2. At a perpendicular distance of 350 yards, the transfer, draw a line A'B' parallel to the original course line AB. The point of intersection, C, of A'B' with the new course line is the place at which the turn is to be completed.
3. From C draw a perpendicular, CD, to the original course line, intersecting at D.
4. From D measure the advance, 920 yards, back along the original course line. This locates E, the point at which the turn should be started.
5. The direction of "FP." from E, 058°, is the bearing when the turn should be started.

**Answer:** Bearing 058°.

- **Plot a Slide Bar for Every Turn Bearing:** To assist the navigator in quickly revising a turn bearing if the ship finds itself off track immediately prior to a turn, use a plotting technique known as the **slide bar**. See Figure 801c. Draw the slide bar parallel to the new course through the turning point on the original course. The navigator can quickly determine a new turn bearing by dead reckoning ahead from the vessel's last fix position to where the DR intersects the slide bar. The revised turn bearing is simply the bearing from that intersection point to the turn bearing NAVAID.

Draw the slide bar with a different color from that

used to lay down the track. The chart gets cluttered around a turn, and the navigator must be able to see the slide bar clearly.

- **Label Distance to Go From Each Turn Point:** At each turning point, label the distance to go until either the ship moors (inbound) or the ship clears the harbor (outbound). For an inbound transit, a vessel's captain is more concerned about *time* of arrival, so assume a speed of advance and label each turn point with time to go until mooring.
- **Plot Danger Bearings:** Danger bearings warn a navigator he may be approaching a navigation hazard too closely. See Figure 801d. Vector AB indicates a vessel's intended track. This track passes close to the indicated shoal. Draw a line from the NAVAID H tangent to the shoal. The bearing of that tangent line measured from the ship's track is 074.0°T. In other words, as long as NAVAID H bears *less than* 074°T as the vessel proceeds down its track, the vessel will not ground on the shoal. Hatch the side of the bearing line on the side of the hazard and label the danger bearing NMT (no more than) 074.0°T. For an added margin of safety, the line does not have to be drawn exactly tangent to the shoal. Perhaps, in this case, the navigator might want to set an error margin and draw the danger bearing at 065°T from NAVAID H. Lay down a danger

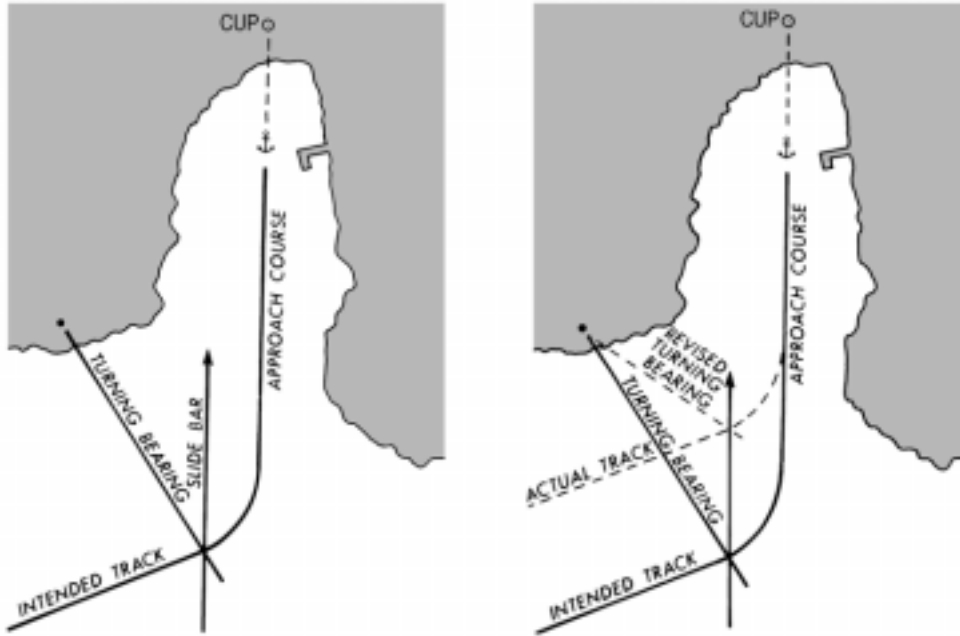


Figure 801c. The slide bar technique.

bearing from any appropriate NAVAID in the vicinity of any hazard to navigation. Ensure the track does not cross any danger bearing.

- **Plot Danger Ranges:** The danger range is analogous to the danger bearing. It is a standoff range from an object to prevent the vessel from approaching a hazard too closely.
- **Label Warning and Danger Soundings:** To determine the danger sounding, examine the vessel's proposed track and note the minimum expected sounding. The minimum expected sounding is the difference between

the shallowest water expected on the transit and the vessel's maximum draft. Set 90% of this difference as the warning sounding and 80% of this difference as the danger sounding. This is not an inflexible rule. There may be peculiarities about the local conditions that will cause the navigator to choose another method of determining his warning and danger soundings. Use the above method if no other means is more suitable. For example: A vessel draws a maximum of 20 feet, and it is entering a channel dredged to a minimum depth of 50 feet. Set the warning and danger soundings at  $0.9 (50\text{ft.} - 20\text{ft.}) = 27\text{ft}$  and  $0.8 (50\text{ft.} - 20\text{ft.}) = 24\text{ft.}$ , respectively. Re-evaluate these soundings at different intervals along the track when the

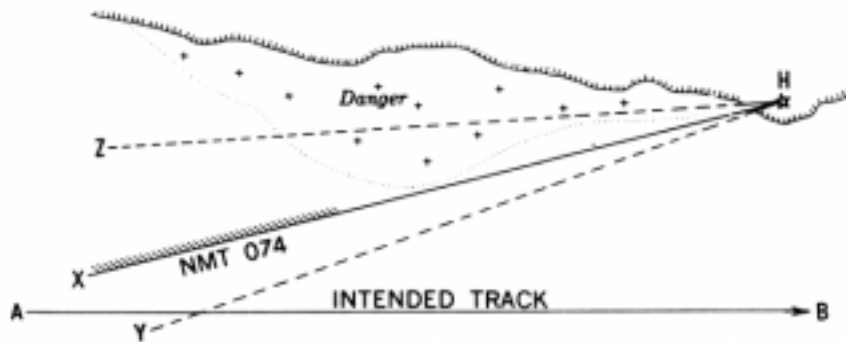


Figure 801d. A danger bearing, hatched on the dangerous side and labeled with the appropriate bearing.

minimum expected sounding may change. Carefully label the points along the track between which these warning and danger soundings apply.

- **Label Demarcation Line:** Clearly label the point on the ship's track at which the Inland and International Rules of the Road apply. This is applicable only when piloting in U.S. ports.
- **Mark Speed Limits Where Applicable:** Often a harbor will have a local speed limit in the vicinity of piers, other vessels, or shore facilities. Mark these speed limits and the points between which they are applicable on the chart.
- **Mark the Point of Pilot Embarkation:** Some ports require vessels over a certain size to embark a pilot. If this is the case, mark the point on the chart where the pilot is to embark.
- **Mark the Tugboat Rendezvous Point:** If the vessel requires a tug to moor, mark the tug rendezvous point on the chart.
- **Mark the Chart Shift Point:** If more than one chart will be required to complete the passage, mark the track point where the navigator should shift to the next chart.
- **Harbor Communications:** Mark the point on the chart where the vessel must contact harbor control. Also mark the point where a vessel must contact its parent squadron to make an arrival report (military vessels only).
- **Tides and Currents:** Mark the points on the chart for which the tides and currents were calculated.

### 802. Tides And Currents

Determining the tidal and current conditions of the port which you are entering is crucial. Determining tides and currents is covered in Chapter 9. Plot a graph of the tidal range at the appropriate port for a 24-hour period for the day of your scheduled arrival or departure. Plotting the curve for the 24-hour period will cover those contingencies that delay your arrival or departure. Depending on a vessel's draft and the harbor's depth, some vessels may be able to transit only at high tide. If this is this case, it is critically important to determine the time and range of the tide correctly.

The magnitude and direction of the current will give the navigator some idea of the **set and drift** the vessel will experience during the transit. This will allow him to plan in advance for any potential current effects in the vicinity of navigation hazards.

### 803. Weather

The navigator should obtain a weather report covering the route which he intends to transit. This will allow him to prepare for any heavy weather by stationing extra lookouts, adjusting his speed for poor visibility, and preparing for radar navigation. If the weather is thick, he may want to consider standing off the harbor until it clears.

The navigator can receive weather information any number of ways. Military vessels receive weather reports from their parent squadrons prior to coming into port. Marine band radio carries continuous weather reports. Some vessels are equipped with weather facsimile machines. Some navigators carry cellular phones to reach shoreside personnel and harbor control; these can be used to get weather reports. However he obtains the information, the navigator should have a good idea of the weather where he will be piloting.

### 804. The Piloting Brief

Assemble the entire navigation team for a piloting brief prior to entering or leaving port. The vessel's captain and navigator should conduct the briefing. All navigation and bridge personnel should attend. The pilot, if he is already on board, should also attend. If the pilot is not onboard when the ship's company is briefed, the navigator should immediately brief him when he embarks. The pilot must know the ship's maneuvering characteristics before entering restricted waters. The briefing should cover, as a minimum, the following:

- **Detailed Coverage of the Track Plan:** Go over the planned route in detail. Use the prepared and approved chart as part of this brief. Concentrate especially on all the NAVAIDS and soundings which are being used to indicate danger. Cover the buoyage system in use and the port's major NAVAIDS. Point out the radar NAVAIDS for the radar operator. Often, a *Fleet Guide* or *Sailing Directions* will have pictures of a port's NAVAIDS. This is especially important for the piloting party that has never transited this particular port before. If no pictures are available, consider stationing a photographer to take some for submission to DMAHTC.
- **Harbor Communications:** Discuss the bridge-to-bridge radio frequencies used to raise harbor control. Discuss what channel the vessel is supposed to monitor on its passage into port and the port's communication protocol.
- **Duties and Responsibilities:** Each member of the piloting team must have a thorough understanding of his duties and responsibilities. He must also understand how his part fits into the scheme of the whole.

The radar plotter, for example, must know if radar will be the primary or secondary source of fix information. The bearing recorder must know what fix interval the navigator is planning to use. Each person must be thoroughly briefed on his job; there is little time for questions once the vessel enters the channel.

### 805. Voyage Planning To The Harbor Entrance (Inbound Vessel Only)

The vessel's planned estimated time of arrival (ETA) at its moorings determines the vessel's course and speed to the harbor entrance. Arriving at the mooring site on time may be important in a busy port which operates its port services on a tight schedule. Therefore, it is important to conduct harbor approach voyage planning accurately. Take the ETA at the mooring and subtract from that the time it will take to navigate the harbor to the pier. The resulting time is when you must arrive at the harbor entrance. Next, measure the distance between the vessel's present location and the harbor entrance. Determine the speed of advance (SOA) the vessel will use to make the transit to the harbor. Use the distance to the harbor and the SOA to calculate what time to leave the present position to make the mooring ETA.

Consider these factors which might affect this decision:

- **Weather:** This is the single most important factor in harbor approach planning because it directly affects the

vessel's SOA. The thicker the weather, the more slowly the vessel must proceed. Therefore, if heavy fog or rain is in the forecast, the navigator must advance the time he was planning to leave for the harbor entrance.

- **Mooring Procedures:** The navigator must take more than distance into account when calculating how long it will take him to pilot to his mooring. If the vessel needs a tug, that will significantly increase the time allotted to piloting. Similarly, picking up (inbound) or dropping off (outbound) a pilot adds time to the transit. It is better to allow a margin for error when trying to add up all the time delays caused by these procedures. It is always easier to avoid arriving early by slowing down than it is to make up lost time by speeding up.
- **Time to Find the Harbor Entrance:** Depending on the sophistication of his vessel's navigation suite, a navigator may require some time to find the harbor entrance. This is seldom a problem with warships and large merchant vessels, both of which carry sophisticated electronic navigation suites. However, it may be a consideration for the yachtsman relying solely on dead reckoning and celestial navigation.
- **Shipping Density:** Generally, the higher the shipping density entering and exiting the harbor, the longer it will take to proceed into the harbor entrance safely.

## TRANSITION TO PILOTING

### 806. Stationing The Piloting Team

Approximately one hour prior to leaving port or entering restricted waters, station the piloting team. The number and type of personnel available for the piloting team depend on the vessel. A Navy warship, for example, has more people available for piloting than does a merchantman. Therefore, more than one of the jobs listed below may have to be filled by a single person. The piloting team should consist of:

- **The Captain:** The captain is ultimately responsible for the safe navigation of his vessel. His judgment regarding navigation is final. The piloting team acts to support the captain, advising him so he can make informed decisions on handling his vessel.
- **The Pilot:** The pilot is usually the only member of the piloting team not normally a member of the ship's company. Many ports require a pilot, a federal or state licensed navigator who possesses extensive local knowledge of the harbor, to be on board as the vessel makes its harbor passage. The piloting team must un-

derstand the relationship between the pilot and the captain. The pilot is perhaps the captain's most important navigation advisor; often, the captain will defer to his recommendations when navigating an unfamiliar harbor. The pilot, too, bears some responsibility for the safe passage of the vessel; he can be censured for errors of judgment which cause accidents. However, the presence of a pilot in no way relieves the captain of his ultimate responsibility for safe navigation. The piloting team works to support and advise the vessel's *captain*.

- **The Officer of the Deck (Conning Officer):** In Navy piloting teams, neither the pilot or the captain usually has the **conn**. The officer having the conn directs the ship's movements by rudder and engine orders. Another officer of the ship's company usually fulfills this function. The captain can take the conn immediately simply by issuing an order to the helm should an emergency arise. The conning officer of a merchant vessel can be either the pilot, the captain, or another watch officer. In any event, the officer having the conn must be clearly indicated in the ship's deck log at all times. Of-

ten a single officer will have the deck and the conn. However, sometimes a junior officer will take the conn for training. In this case, different officers will have the deck and the conn. The officer who retains the deck retains the responsibility for the vessel's safe navigation.

- The Navigator:** The vessel's navigator is the officer directly responsible to the ship's captain for the safe navigation of the ship. He is the captain's principal navigation advisor. The piloting party works for him. He channels the required information developed by the piloting party to the ship's conning officer on recommended courses, speeds, and turns. He also carefully looks ahead for potential navigation hazards and makes appropriate recommendations. He is the most senior officer who devotes his effort exclusively to monitoring the navigation picture. The captain and the conning officer are concerned with all aspects of the passage, including contact avoidance and other necessary ship evolutions (making up tugs, maneuvering alongside a small boat for personnel transfers, engineering evolutions, and coordinating with harbor control via radio, for example). The navigator, on the other hand, focuses solely on safe navigation. It is his job to anticipate danger and keep himself apprised of the navigation situation at all times.
- Bearing Plotting Team:** This team consists, ideally, of three persons. The first person measures the bearings. The second person records the bearings in an official record book. The third person plots the bearings. The more quickly and accurately this process is completed, the sooner the navigator has an accurate picture of the ship's position. The bearing taker should be an experienced individual who has traversed the port before and who is familiar with the NAVAIDS. He should take his round of bearings as quickly as possible, minimizing any time delay errors in the resulting fix. The plotter should also be an experienced individual who can quickly and accurately lay down the required bearings. The bearing recorder can be one of the junior members of the piloting team.
- The Radar Operator:** The radar operator has one of the more difficult jobs of the team. The radar is as important for collision avoidance as it is for navigation. Therefore, this operator must "time share" the radar between these two functions. Determining the amount of time spent on these functions falls within the judgment of the captain and the navigator. If the day is clear and the traffic heavy, the captain may want to use the radar mostly for collision avoidance. As the weather worsens, obscuring visual NAVAIDS, the importance of radar for safe navigation increases. The radar operator must be given clear guidance on how the captain and navigator want the radar to be operated.
- Plot Supervisors:** Ideally, the piloting team should consist of two plots: the primary plot and the secondary plot. The navigator should designate the type of navigation that will be employed on the primary plot. All other fix sources should be plotted on the secondary plot. For example, if the navigator designates visual piloting as the primary fix method, lay down only visual bearings on the primary plot. Lay down all other fix sources (radar, electronic, or satellite) on the secondary plot. The navigator can function as the primary plot supervisor. A senior, experienced individual should be employed as a secondary plot supervisor. The navigator should frequently compare the positions plotted on both plots as a check on the primary plot.

There are three major reasons for maintaining a primary and secondary plot. First, as mentioned above, the secondary fix sources provide a good check on the accuracy of visual piloting. Large discrepancies between visual and radar positions may point out a problem with the visual fixes that the navigator might not otherwise suspect. Secondly, the navigator often must change the primary means of navigation during the transit. He may initially designate visual bearings as the primary fix method only to have a sudden storm or fog obscure the visual NAVAIDS. If he shifts the primary fix means to radar, he has a track history of the correlation between radar and visual fixes. Finally, the piloting team often must shift charts several times during the transit. When the old chart is taken off the plotting table and before the new chart is secured, there is a period of time when no chart is in use. Maintaining a secondary plot eliminates this complication. Ensure the secondary plot is not shifted prior to getting the new primary plot chart down on the chart table. In this case, there will always be a chart available on which to pilot. Do not consider the primary chart shifted until the new chart is properly secured and the plotter has transferred the last fix from the original chart onto the new chart.
- Satellite Navigation Operator:** This operator normally works for the secondary plot supervisor. GPS absolute accuracy with SA operational is not sufficient for most piloting applications. However, the secondary plot should keep track of GPS fixes. If the teams loses visual bearings in the channel and no radar NAVAIDS are available, GPS may be the most accurate fix source available. The navigator must have some data on the comparison between satellite positions and visual positions over the history of the passage to use satellite positions effectively. The only way to obtain this data is to plot satellite positions and compare these positions to visual positions throughout the harbor passage.
- Fathometer Operator:** Run the fathometer continuously and station an operator to monitor it. Do not rely on audible alarms to key your attention to this critically important piloting tool. The fathometer operator must

know the warning and danger soundings for the area the vessel is transiting. Most fathometers can display either total depth of water or depth under the keel. Set the fathometer to display depth under the keel. The navigator must check the sounding at each fix and compare that value to the charted sounding. A discrepancy between these values is cause for immediate action to take another fix and check the ship's position.

### 807. Plot Setup

Once the piloting team is on station, ensure the primary and secondary plot have the following instruments:

- **Dividers:** Dividers are used to measure distances between points on the chart.
- **Compasses:** Compasses are used to plot range arcs for radar LOP's. **Beam compasses** are used when the range arc exceeds the spread of a conventional compass. Both should be available at both plots.
- **Bearing Measuring Devices:** Several types of bearing measuring devices are available. The preferred device is the parallel motion plotter (PMP) used in conjunction with a drafting table. Otherwise, use parallel rulers or rolling rulers with the chart's compass rose. Finally, the plotter can use a one arm protractor. The plotter should use the device with which he can work the most quickly and accurately.
- **Sharpened Pencils and Erasers:** Ensure an adequate supply of pencils is available. There is generally not time to sharpen one if it breaks in the middle of the transit, so have several sharpened pencils available at the plot.
- **Three Arm Protractor:** This protractor is used to plot relative bearings and sextant horizontal angles should the true bearing source fail during the transit.
- **Fischer Radar Plotting Templates:** Fischer plotting is covered in Chapter 13. The plotting templates for this technique should be stacked near the radar repeater.
- **Time-Speed-Distance Calculator:** Given two of the three unknowns (between time, speed, and distance), this calculator allows for rapid computation of the third.
- **Tide and Current Graphs:** Post the tide and current graphs near the primary plot for easy reference during the transit. Give a copy of the graphs to the conning officer and the captain.

Once the navigator verifies the above equipment is in place, he tapes down the charts on the chart table. If more than one chart is required for the transit, tape the charts in a stack such that the plotter works from the top to the bottom of the stack. This minimizes the time required to shift the chart during the transit. If the plotter is using a PMP, align the arm of the PMP with any meridian of longitude on the chart. While holding the PMP arm stationary, adjust the PMP to read 000.0°T. This procedure calibrates the PMP to the chart in use. Perform this alignment every time the piloting team shifts charts.

Be careful not to fold under any important information when folding the chart on the chart table. Ensure the chart's distance scale, the entire track, and all important warning information are visible.

Energize and test all electronic navigation equipment, if not already in operation. This includes the radar and the GPS receiver. Energize and test the fathometer. Ensure the entire electronic navigation suite is operating properly prior to entering restricted waters.

### 808. Evolutions Prior To Piloting

The navigator should always accomplish the following evolutions prior to piloting:

- **Testing the Shaft on the Main Engines in the Astern Direction:** This ensures that the ship can answer a backing bell. If the ship is entering port, no special precautions are required prior to this test. If the ship is tied up at the pier preparing to get underway, exercise extreme caution to ensure no way is placed on the ship while testing the main engines.
- **Making the Anchor Ready for Letting Go:** Make the anchor ready for letting go and station a watchstander in direct communications with the bridge at the anchor windlass. Be prepared to drop anchor immediately when piloting if required to keep from drifting too close to a navigation hazard.
- **Calculate Gyro Error:** An error of greater than 1.0° T indicates a gyro problem which should be investigated prior to piloting. There are several ways to determine gyro error:
  1. Compare the gyro reading with a known accurate heading reference such as an inertial navigator. The difference in the readings is the gyro error.
  2. Mark the bearing of a charted range as the range NAVAID's come into line and compare the gyro bearing with the charted bearing. The difference is the gyro error.
  3. Prior to getting underway, plot a dockside fix using



at least three lines of position. The three LOP's should intersect at a point. Their intersecting in a "cocked hat" indicates a gyro error. Incrementally adjust each visual bearing by the same amount and in the same direction until the fix plots as a pinpoint. The total correction required to eliminate the cocked hat is the gyro error.

4. Measure a celestial body's azimuth, a celestial body's amplitude, or Polaris' azimuth with the gyro, and then compare the measured value with a value computed from the *Sight Reduction* tables or the *Nautical Almanac*. These methods are covered in detail in Chapter 17.

Report the magnitude and direction of the gyro error to the navigator and captain. The direction of the error is determined by the relative magnitude of the gyro reading and the value against which it is compared. When the compass is *least*, the error is *east*. Conversely, when the compass is *best*, the error is *west*.

### 809. Records

Ensure the following records are assembled and personnel assigned to complete them prior to piloting:

- **Bearing Record Book:** The bearing recorders for the primary and secondary plots should record all the bearings used on their plot during the entire transit. The books should clearly list what NAVAIDS are being used and what method of navigation was being used on their plot. In practice, the primary bearing book will contain mostly visual bearings and the secondary bearing book will contain mostly radar ranges and bearings.
- **Fathometer Log:** In restricted waters, monitor soundings continuously and record soundings every five

minutes in the fathometer log. Record all fathometer settings that could affect the sounding display.

- **Deck Log:** This log is the legal record of the passage. Record all ordered course and speed changes. Record all the navigator's recommendations and whether the navigator concurs with the actions of the conning officer. Record all buoys passed, and the shift between different Rules of the Road. Record the name and embarkation of any pilot. Record who has the conn at all times. Record any casualty or important event. The deck log combined with the bearing log should constitute a complete record of the passage.

### 810. Harbor Approach (Inbound Vessels Only)

The piloting team must make the transition from coastal navigation to piloting smoothly as the vessel approaches restricted waters. There is no rigid demarcation between coastal navigation and piloting. Often visual NAVAIDS are visible miles from shore where hyperbolic and satellite navigation provides sufficient absolute accuracy to ensure ship safety. The navigator should take advantage of this overlap when approaching the harbor. Plot hyperbolic, satellite, and visual fixes concurrently on the primary plot, ensuring the piloting team has correctly identified NAVAIDS and is comfortably settling into a piloting routine. Once the vessel is close enough to the shore such that sufficient NAVAIDS (at least three with sufficient bearing spread) become visible, the navigator should order visual bearings only for the primary plot and shift plotting all other fixes to the secondary plot.

Take advantage of the coastal navigation and piloting overlap to shorten the fix interval gradually. The navigator must use his judgment in adjusting these transition fix intervals. If the ship is steaming inbound directly towards the shore, set a fix interval such that two fix intervals lie between the vessel and the nearest danger. Prior to entering into restricted waters, the piloting team should be plotting visual fixes at three minute intervals.

## FIXING A VESSEL'S POSITION WHILE PILOTING

The navigator now has his charts prepared; his team briefed, equipped, and on station; his equipment tested; and his record books distributed. He is now ready to begin piloting.

Safe navigation while piloting requires frequent fixing of the ship's position. The next sections will discuss the three major methodologies used to fix a ship's position when piloting: crossing lines of position, copying satellite or Loran data, or advancing a single line of position. Using one method does not exclude using other methods. The navigator must obtain as much information as possible and employ as many of these methods as practical while piloting.

### 811. Fixing The Ship's Position By Two Or More Lines Of Position

The intersection of at least two LOP's constitutes a **fix**. However, always use three LOP's if three are available. Some of the most commonly used methods of obtaining LOP's are discussed below:

- **Fix by Two Bearing Lines:** The plotter lays down two or more bearing lines from charted NAVAIDS. This is the most common and often the most accurate way to fix a vessel's position. The plotter can also lay down



Figure 811a. A fix by two bearing lines.

bearings to a NAVAID and a bearing to the tangent of a body of land. See Figure 811a. The intersection of these lines constitutes a fix. Plotting bearing lines from charted buoys is the least preferred method of fixing by two bearing lines because the buoy's charted position is only approximate. Tangent LOPs to land areas must be taken carefully to get an accurate line, particularly at long ranges; charted NAVAIDS are preferred.



Figure 811b. A fix by two radar ranges.

- **Fix by Two Ranges:** The navigator can plot a fix consisting of the intersection of two range arcs from charted objects. He can obtain an object's range in several ways:

1. **Radar Ranges:** See Figure 811b. The plotter lays down a range arc from a small island and a range arc from a prominent point on shore. The intersection of the range arcs constitutes a fix. The navigator can plot ranges from any point on the radar scope which he can correlate on his chart. This is the most convenient and accurate way to obtain an object's range. If a choice is available between fixed radar NAVAIDS and low lying land, choose the fixed NAVAID. This will minimize errors caused by using low lying land subject to large tidal ranges.

2. **Stadimeter Ranges:** Given a known height of a NAVAID, use a stadimeter to determine the range. Though most often used to determine the distance to a surface contact, a stadimeter can be used to determine an object's range. See Figure 811c for a representation of the geometry involved. Generally, stadimeters contain a height scale on which is set the height of the object. The observer then directs his line of sight through the stadimeter to the base of the object being observed. Finally, he adjusts the stadimeter's range index until the object's top reflection is "brought down" to the visible horizon. Read the object's range off of the stadimeter's range index.

3. **Sextant Vertical Angles:** Measure the vertical angle from the top of the NAVAID to the waterline below the NAVAID. Enter Table 16 to determine the distance of the NAVAID. The navigator must

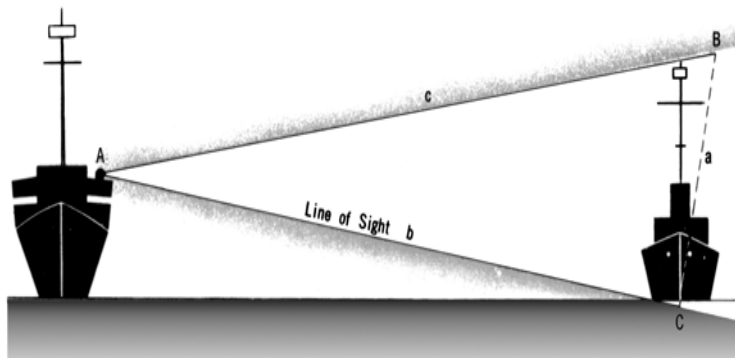


Figure 811c. Principle of stadimeter operation.

know the height of the NAVAID above sea level to use this table; it can be found in the light list.

- 4. Sonar Ranges:** If the vessel is equipped with a sonar suite, the navigator can use sonar echoes to determine ranges to charted underwater objects. It may take some trial and error to set the active signal strength at a value that will give a enough strong return and still not cause excessive reverberation. Check local harbor restrictions on energizing active sonar. Avoid active sonar transmissions in the vicinity of divers.

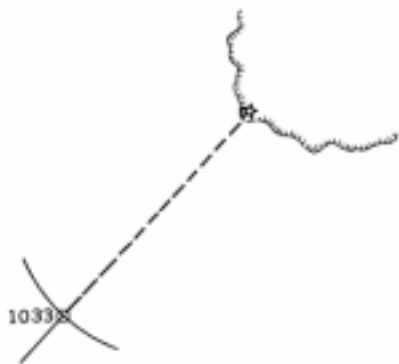


Figure 811d. A fix by range and bearing of a single object.

- **Fix at Intersection of Bearing Line and Range:** This is a hybrid fix of LOP's from a bearing and range to a single object. The radar is the only instrument that can give simultaneous range and bearing information to the same object. (A sonar system can also provide bearing

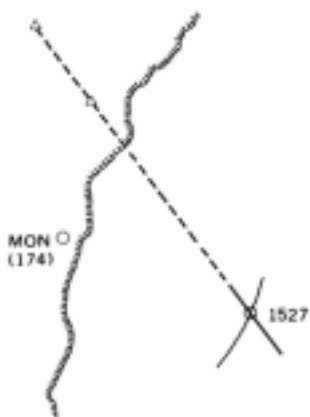


Figure 811e. A fix by a range and distance.

and range information, but sonar bearings are far too inaccurate to use in piloting.) Therefore, with the radar, the navigator can obtain an instantaneous fix from only one NAVAID. This unique fix is shown in Figure 811d. This makes the radar an extremely useful tool for the piloting team. The radar's characteristics make it much more accurate determining range than determining bearing; therefore, two radar ranges are preferable to a radar range and bearing.

- **Fix by Range and Distance:** When the vessel comes in line with a range, plot the bearing to the range and cross this LOP with a distance from another NAVAID. Figure 811e shows this fix.

## 812. Fixing The Ship's Position By Electronics

The stated absolute accuracy of GPS subjected to SA is insufficient to ensure ship's safety while piloting. However, the navigator should not ignore satellite positions. If the vessel is a U.S. Navy warship, the navigator will have access to the Precise Positioning Service (PPS). Even if the navigator does not have access to the PPS, routinely comparing visual and satellite positions provides the navigator some information to use in case he loses both radar and visual piloting. When poor visibility precludes using visual NAVAID's and the area is not suitable for radar piloting, having a satellite position and some idea of how it has related to previous visual fixes is important. The satellite positions should be plotted periodically on the secondary plot.

If the navigator has access to Differential GPS, the absolute accuracy of his satellite positions may be high enough to provide an even more meaningful backup to visual and radar piloting.

Loran C, while generally not suitable for piloting in terms of absolute accuracy, is often accurate enough in terms of repeatable accuracy. Therefore Loran readings should be monitored in case other systems fail.

## 813. The Running Fix

When only one NAVAID is available from which to obtain bearings, use a technique known as the **running fix**. Use the following methodology:

1. Plot a bearing to a NAVAID (LOP 1).
2. Plot a second bearing to a NAVAID (either the same NAVAID or a different one) at a later time (LOP 2).
3. Advance LOP 1 to the time when LOP 2 was taken.
4. The intersection of LOP 2 and the advanced LOP 1 constitute the running fix.

Figure 813a represents a ship proceeding on course  $020^\circ$ , speed 15 knots. At 1505, the plotter plots an LOP to a lighthouse bearing  $310^\circ$ . The ship can be at any point on this 1505 LOP. Some possible points are represented



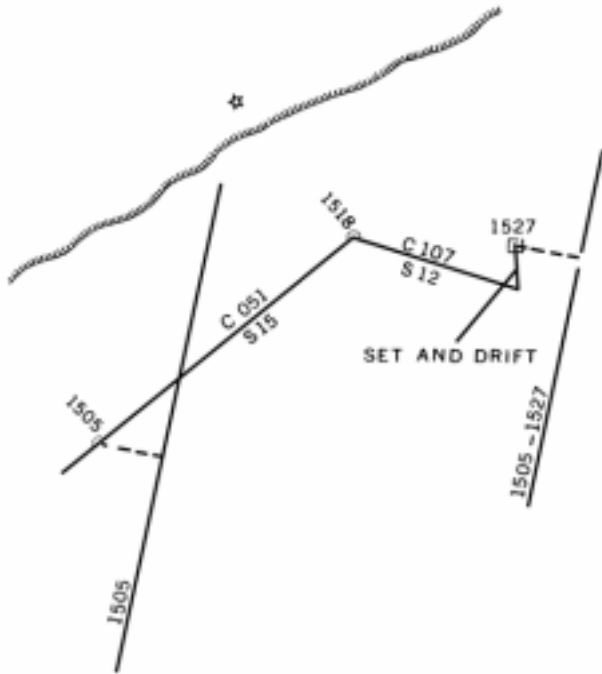


Figure 813d. Advancing a line of position by its relation to the dead reckoning.

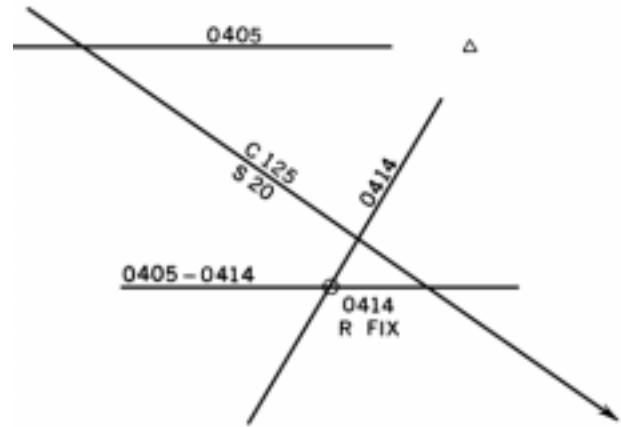


Figure 813e. A running fix by two bearings on the same object.

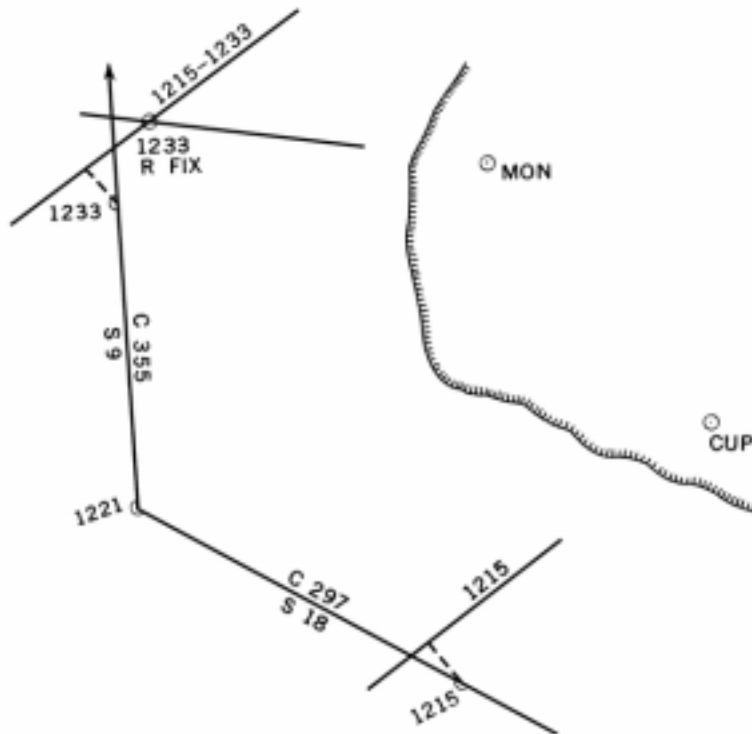


Figure 813f. A running fix with a change of course and speed between observations on separate landmarks.

**Method 3:** See Figure 813d. To advance the 1505 LOP to 1527, first draw a correction line from the 1505 DR position to the 1505 LOP. Next, apply a set and drift correction to the 1527 DR position. This results in a 1527 estimated position (EP). Then, draw from the 1527 EP a correction line of the same length and direction as the one drawn from the 1505 DR to the 1505 LOP. Finally, parallel the 1505 bearing to the end of the correction line as shown.

Label an advanced line of position with both the time of observation and the time to which the line is adjusted.

Figure 813e through Figure 813g demonstrate three separate running fixes. Figure 813e illustrates the case of obtaining a running fix with no change in course or speed between taking two bearings on the same NAVAID. Figure 813f illustrates a running fix with changes in a vessel's course and speed between its taking two bearings on two different objects. Finally, Figure 813g illustrates a running fix obtained by advancing range circles of position using the second method discussed above.

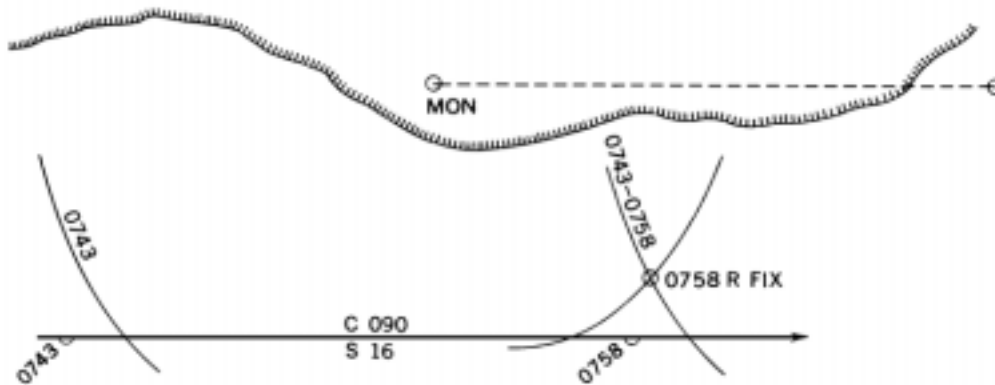


Figure 813g. A running fix by two circles of position.

## PILOTING PROCEDURES

The previous section discussed the methods for fixing the ship's position. This section discusses integrating the fix methods discussed above and the use of the fathometer into a piloting procedure. The navigator must develop his piloting procedure to meet several requirements. He must obtain all available information from as many sources as possible. He must plot and evaluate this information. Finally, he must relay his evaluations and recommendations to the vessel's conning officer. This section examines some considerations to ensure the navigator accomplishes all these requirements quickly and effectively.

### 814. Fix Type And Fix Interval

The preferred piloting fix type is visual bearings from charted shore-based NAVAIDS. Plot visual bearings on the primary plot and plot all other fixes on the secondary plot. If poor visibility obscures visual NAVAIDS, shift to radar piloting on the primary plot. If neither visual or radar piloting is available, consider standing off until the visibility improves.

The interval between fixes in restricted waters should not exceed three minutes. Setting the fix interval at three minutes optimizes the navigator's ability to assimilate and evaluate all

available information. A navigator must not only receive and plot positioning information, but he must also evaluate the information. He must relate it to charted navigation hazards and to his vessel's intended track. It should take a well trained plotting team no more than 30 seconds to measure, record, and plot three bearings to three separate NAVAIDS. The navigator should spend the majority of the fix interval time interpreting the information, evaluating the navigation situation, and making recommendations to the conning officer.

If three minutes goes by without a fix, inform the captain and try to plot a fix as soon as possible. If the delay was caused by a loss of visibility, shift to radar piloting. If the delay was caused by plotting error, take another fix. If the navigator cannot get a fix down on the plot for several more minutes, consider slowing or stopping the ship until its position can be fixed. Never continue a passage through restricted waters if the vessel's position is uncertain.

The secondary plot supervisor should maintain the same fix interval as the primary plot. Usually, this means he should plot a radar fix every three minutes. He should plot other fix sources (sonar ranges and satellite fixes, for example) at an interval sufficient for making meaningful comparisons between fix sources. Every third fix interval,

he should pass a radar fix to the primary plot for comparison with the visual fix. He should inform the navigator how well all the fix sources plotted on the secondary plot are tracking.

### 815. The Cyclic Routine

Following the cyclic routine ensures the timely and efficient processing of data. It yields the basic information which the navigator needs to make informed recommendations to the conning officer and captain.

Repeat this cyclic routine at each fix interval beginning when the ship gets underway until it clears the harbor (outbound) or when the ship enters the harbor until it is moored (inbound).

The cyclic routine consists of the following steps, modified as discussed below for approaching a turn:

1. Plotting the fix.
2. Labeling the fix.
3. Dead Reckoning two fix intervals ahead of the fix.
4. Calculating the set and drift from the DR and fix.

- **Plotting the Fix:** This involves coordination between the bearing taker, recorder, and plotter. The bearing taker must measure his bearings as quickly as possible. As quickly as he takes them, however, there will be a finite amount of time between the first and last bearing measured. The navigator should advance the first and second LOP's to the time of the last bearing taken and label the last bearings time as the fix time. Try to have the fix completed on the even minute to allow for meaningful comparison with the DR.
- **Labeling the Fix:** The plotter should clearly mark a visual fix with a circle or an electronic fix with a triangle. Clearly label the time of each fix. A visual running fix should be circled, marked "R Fix" and labeled with the time of the second LOP. Maintain the chart neat and uncluttered when labeling fixes.
- **Dead Reckoning Two Fix Intervals Ahead:** After labeling the fix, the plotter should dead reckon the fix position ahead two fix intervals. The navigator should carefully check the area marked by this DR for any navigation hazards. If the ship is approaching a turn, update the turn bearing as discussed in section 801.
- **Calculate Set and Drift at Every Fix:** Calculating set and drift is covered in Chapter 7. Calculate these values at every fix and inform the captain and conning officer. Compare the actual values of set and drift with the predicted values from the current graph discussed in section 802 above. Evaluate how the current is affecting the vessel's position in relation to the track and recommend courses and speeds to regain the planned track. Because the navigator can determine set and drift

only when comparing fixes and DR's plotted for the same time, ensure that fixes are taken at the times for which a DR has been plotted. Repeat this cyclic routine at each fix interval beginning when the ship gets underway until it clears the harbor (outbound) or when the ship enters the harbor until she is moored (inbound)

- **Cyclic Routine When Turning:** Modify the cyclic routine slightly when approaching a turn. Adjust the fix interval so that the plotting team has a fix plotted approximately one minute before a scheduled turn. This gives the navigator sufficient time to evaluate the position in relation to the planned track, DR ahead to the slide bar to determine a new turn bearing, relay the new turn bearing to the conning officer, and then monitor the turn bearing to mark the turn.

Approximately 30 seconds before the time to turn, train the bearing measurement instrument on the turn bearing NAVAID. The navigator should watch the bearing of the NAVAID approach the turn bearing. Approximately 1° away from the turn bearing, announce to the conning officer: "Stand by to turn." Slightly before the turn bearing is indicated, report to the conning officer: "Mark the turn." Make this report slightly before the bearing is reached because it takes the conning officer a finite amount of time to acknowledge the report and order the helmsman to put over the rudder. Additionally, it takes a finite amount of time for the helmsman to turn the rudder and for the ship to start to turn. If the navigator waits until the turn bearing is indicated to report the turn, the ship will turn too late.

Once the ship is steady on the new course, immediately take another fix to evaluate the vessel's position in relation to the track. If the ship is not on the track after the turn, recommend a course to the conning officer to regain track.

### 816. Using The Fathometer

Use the fathometer to determine whether the depth of water under the keel is sufficient to prevent the ship from grounding and to check the actual water depth with the charted water depth at the fix position. The navigator must compare the charted sounding at every fix position with the fathometer reading and report to the captain any discrepancies. Continuous soundings in pilot waters are mandatory.

See the discussion of calculating the warning and danger soundings in section 801. If the warning sounding is received, then slow the ship, fix the ship's position more frequently, and proceed with extreme caution. Ascertain immediately where the ship is in the channel; if the minimum expected sounding was noted correctly, the warning sounding indicates the vessel may be leaving the channel and standing into shoal water. Notify the vessel's captain and conning officer immediately.

If the danger sounding is received, take immediate action to get the vessel back to deep water. Reverse the engines and stop the vessel's forward movement. Turn in the direction of

the deepest water before the vessel loses steerageway. Consider dropping the anchor to prevent the ship from drifting aground. The danger sounding indicates that the ship has left the channel and is standing into immediate danger. It requires immediate corrective action by the ship's conning officer, navigator, and captain to avoid disaster.

Many underwater features are poorly surveyed. If a fathometer trace of a distinct underwater feature can be obtained along with accurate position information, send the fathometer trace and related navigation data to the Defense Mapping Agency for entry into the Digital Bathymetric Data Base. See Chapter 30 for details on recording and reporting procedures.

## ANCHORING PROCEDURES

### 817. Anchoring

If a vessel is to anchor at a predetermined point, such as in an assigned berth, follow an established procedure to ensure an accurate positioning of the anchor. The following procedure is representative. See Figure 817.

Locate the selected anchoring position on the chart. Consider limitations of land, current, shoals, other vessels when determining the direction of approach. Where conditions permit, make the approach heading into the current. Close observation of any other anchored vessels will provide clues as to which way the ship will lie to her anchor. If wind and current are strong and from different directions,

ships will lie to their anchors according to the balance between these two forces and the draft and trim of each ship. Different ships may lie at different headings in the same anchorage depending on the balance of forces affecting them.

Approach from a direction with a prominent NAVAID, preferably a range, available dead ahead to serve as a steering guide. If practicable, use a straight approach of at least 1200 yards to permit the vessel to steady on the required course. Draw in the approach track, allowing for advance and transfer during any turns. In Figure 817, the chimney was selected as this steering bearing.

Next, draw a circle with the selected position of the anchor as the center, and with a radius equal to the distance

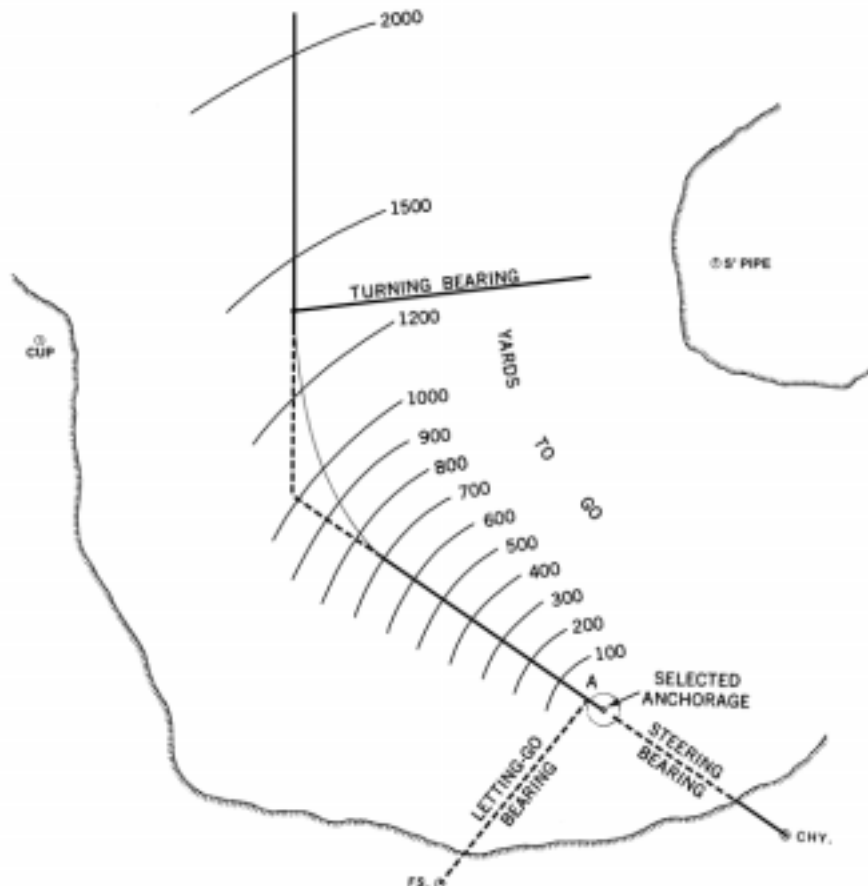


Figure 817. Anchoring.



between the hawsepipe and pelorus, alidade, or periscope used for measuring bearings. This circle is marked "A" in Figure 817. The intersection of this circle and the approach track is the position of the vessel's bearing-measuring instrument at the moment of letting the anchor go. Select a NAVAID which will be on the beam when the vessel is at the point of letting go the anchor. This NAVAID is marked "FS" in Figure 817. Determine what the bearing to that object will be when the ship is at the drop point and measure this bearing to the nearest 0.1°T. Label this bearing as the letting go bearing.

During the approach to the anchorage, plot fixes at frequent intervals. The navigator must advise the conning officer of any tendency of the vessel to drift from the desired track. The navigator must frequently report the conning officer of the distance to go, permitting adjustment of the speed so that the vessel will be dead in the water or have very slight sternway when the anchor is let go. To aid in determining the distance to the drop point, draw and label a number of range arcs as shown in Figure 817 representing distances to go to the drop point.

At the moment of letting the anchor go, take a fix and plot the vessel's exact position on the chart. This is important in the construction of the swing and drag circles discussed below. To draw these circles accurately, determine the position of the vessel at the time of letting go the anchor as accurately as possible.

Veer the anchor chain to a length equal to five to seven times the depth of water at the anchorage. The exact amount to veer is a function of both vessel type and severity of weather expected at the anchorage. When calculating the scope of anchor chain to veer, take into account the maximum height of tide.

Once the ship is anchored, construct two separate circles around the ship's position when the anchor was dropped. These circles are called the **swing circle** and the **drag circle**. Use the swing circle to check for navigation hazards and use the drag circle to ensure the anchor is holding.

The swing circle's radius is equal to the sum of the ship's length and the scope of the anchor chain released. This represents the maximum arc through which a ship can swing while riding at anchor if the anchor holds. Examine this swing circle carefully for navigation hazards, interfering contacts, and other anchored shipping. Use the lowest height of tide expected during the anchoring period when checking inside the swing circle for shoal water.

The drag circle's radius equals the sum of the hawsepipe to pelorus distance and the scope of the chain released. Any bearing taken to check on the position of the ship should, if the anchor is holding, fall within the drag circle. If a fix falls outside of that circle, then the anchor is dragging.

In some cases, the difference between the radii of the

swing and drag circles will be so small that, for a given chart scale, there will be no difference between the circles when plotted. If that is the case, plot only the swing circle and treat that circle as both a swing and a drag circle. On the other hand, if there is an appreciable difference in radii between the circles when plotted, plot both on the chart. Which method to use falls within the sound judgment of the navigator.

When determining if the anchor is holding or dragging, the most crucial period is immediately after anchoring. Fixes should be taken frequently, at least every three minutes, for the first thirty minutes after anchoring. The navigator should carefully evaluate each fix to determine if the anchor is holding. If the anchor is holding, the navigator can then increase the fix interval. What interval to set falls within the judgment of the navigator, but the interval should not exceed 30 minutes.

### 818. Choosing An Anchorage

Most U.S. Navy vessels receive instructions in their movement orders regarding the choice of anchorage. Merchant ships are often directed to specific anchorages by harbor authorities. However, lacking specific guidance, the mariner should choose his anchoring positions using the following criteria:

- **Depth of Water:** Choose an area that will provide sufficient depth of water through an entire range of tides. Water too shallow will cause the ship to go aground, and water too deep will allow the anchor to drag.
- **Type of Bottom:** Choose the bottom that will best hold the anchor. Avoid rocky bottoms and select sandy or muddy bottoms if they are available.
- **Proximity to Navigation Hazards:** Choose an anchorage as far away as possible from known navigation hazards.
- **Proximity to Adjacent Ships:** Try to anchor as far away as possible from adjacent vessels.
- **Proximity to Harbor Traffic Lanes:** Do not anchor in a traffic lane.
- **Weather:** Choose the area with the weakest winds and currents.
- **Availability of NAVAIDS:** Choose an anchorage with several NAVAIDS available for monitoring the ship's position when anchored.

## NAVIGATIONAL ASPECTS OF SHIP HANDLING

### 819. Effects Of Banks, Channels, And Shallow Water

A ship moving through shallow water experiences pronounced effects from the proximity of the nearby bottom. Similarly, a ship in a channel will be affected by the proximity of the sides of the channel. These effects can easily cause errors in piloting which lead to grounding. The effects are known as **squat**, **bank cushion**, and **bank suction**. They are more fully explained in texts on shiphandling, but certain navigational aspects are discussed below.

**Squat** is caused by the interaction of the hull of the ship, the bottom, and the water between. As a ship moves through shallow water, some of the water it displaces rushes under the vessel to rise again at the stern. This causes a venturi effect, decreasing upward pressure on the hull. Squat makes the ship sink deeper in the water than normal and slows the vessel. The faster the ship moves through shallow water, the greater is this effect; groundings on both charted and uncharted shoals and rocks have occurred because of this phenomenon, when at reduced speed the ship could have safely cleared the dangers. When navigating in shallow water, the navigator must reduce speed to avoid squat. If bow and stern waves nearly perpendicular the direction of travel are noticed, and the vessel slows with no change in

shaft speed, squat is occurring. Immediately slow the ship to counter it. Squatting occurs in deep water also, but is more pronounced and dangerous in shoal water. The large waves generated by a squatting ship also endanger shore facilities and other craft.

**Bank cushion** is the effect on a ship approaching a steep underwater bank at an oblique angle. As water is forced into the narrowing gap between the ship's bow and the shore, it tends to rise or pile up on the landward side, causing the ship to sheer away from the bank.

**Bank suction** occurs at the stern of a ship in a narrow channel. Water rushing past the ship on the landward side exerts less force than water on the opposite or open water side. This effect can actually be seen as a difference in draft readings from one side of the vessel to the other. The stern of the ship is forced toward the bank. If the ship gets too close to the bank, it can be forced sideways into it. The same effect occurs between two vessels passing close to each other.

These effects increase as speed increases. Therefore, in shallow water and narrow channels, navigators should decrease speed to minimize these effects. Skilled pilots may use these effects to advantage in particular situations, but the average mariner's best choice is slow speed and careful attention to piloting.

## ADVANCED PILOTING TECHNIQUES

### 820. Assuming Current Values To Set Safety Margins When Using Running Fixes

Current affects the accuracy of a running fix. Consider, for example, the situation of an unknown head current. In Figure 820a, a ship is proceeding along a coast, on course 250° speed 12 knots. At 0920 light A bears 190°, and at 0930 it bears 143°. If the earlier bearing line is advanced a distance of 2 miles (10 minutes at 12 knots) in the direction of the course, the running fix is as shown by the solid lines. However, if there is a head current of 2 knots, the ship is making good a speed of only 10 knots, and in 10 minutes will travel a distance of only  $1\frac{2}{3}$  miles. If the first bearing line is advanced this distance, as shown by the broken line, the actual position of the ship is at B. This actual position is nearer the NAVAID than the running fix actually plotted. A following current, conversely, would show a position too far from the NAVAID from which the bearing was measured.

If the navigator assumes a following current when advancing his LOP, the resulting running fix will plot further from the NAVAID than the vessel's actual position. Conversely, if he assumes a head current, the running fix will plot closer to the NAVAID than the vessel's actual position. To ensure a margin of safety when plotting running fix bear-

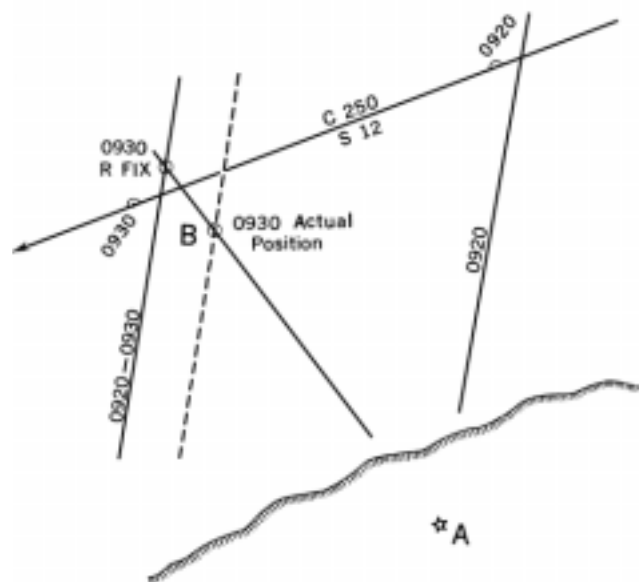


Figure 820a. Effect of a head current on a running fix.



Figure 820b. A number of running fixes with a following current.

ings to a NAVAID on shore, always assume the current slows a vessel's speed over ground. This will cause the running fix to plot closer to the shore than the ship's actual position.

When taking the second running fix bearing from a different object, maximize the speed estimate if the second object is on the same side and farther forward, or on the opposite side and farther aft, than the first object was when observed.

All of these situations assume that danger is on the same side as the object observed first. If there is either a head or following current, a series of running fixes based upon a number of bearings of the same object will plot in a straight line parallel to the course line, as shown in Figure 820b. The plotted line will be too close to the object observed if there is a head current and too far out if there is a following current. The existence of the current will not be apparent unless the actual speed over the ground is known. The position of the plotted line relative to the dead reckoning course line is not a reliable guide.

### 821. Determining Track Made Good By Plotting Running Fixes

A current oblique to a vessel's course will also result in an incorrect running fix position. An oblique current can be detected by observing and plotting several bearings of the same object. The running fix obtained by advancing one

bearing line to the time of the next one will not agree with the running fix obtained by advancing an earlier line. See Figure 821a. If bearings A, B, and C are observed at five-minute intervals, the running fix obtained by advancing B to the time of C will not be the same as that obtained by advancing A to the time of C, as shown in Figure 821a.

Whatever the current, the navigator can determine the direction of the track made good (assuming constant current and constant course and speed). Observe and plot three bearings of a charted object O. See Figure 821b. Through O draw XY in any direction. Using a convenient scale, determine points A and B so that OA and OB are proportional to the time intervals between the first and second bearings and the second and third bearings, respectively. From A and B draw lines parallel to the second bearing line, intersecting the first and third bearing lines at C and D, respectively. The direction of the line from C and D is the track made good.

The distance of the line CD in Figure 821b from the track is in error by an amount proportional to the ratio of the speed made good to the speed assumed for the solution. If a good fix (not a running fix) is obtained at some time before the first bearing for the running fix, and the current has not changed, the track can be determined by drawing a line from the fix, in the direction of the track made good. The intersection of the track with any of the bearing lines is an actual position.

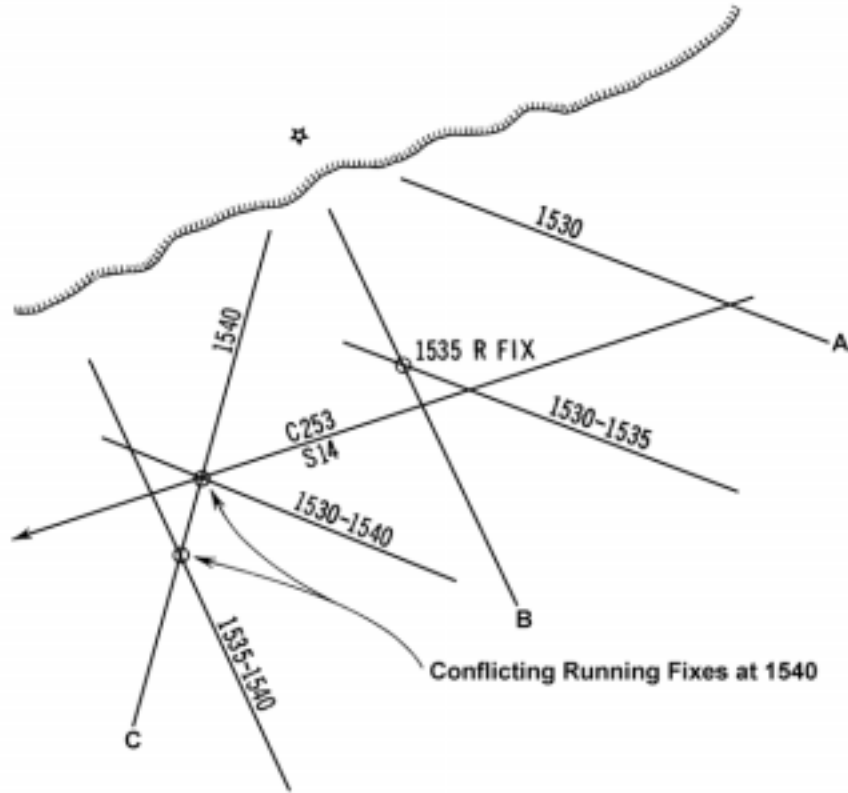


Figure 821a. Detecting the existence of an oblique current, by a series of running fixes.

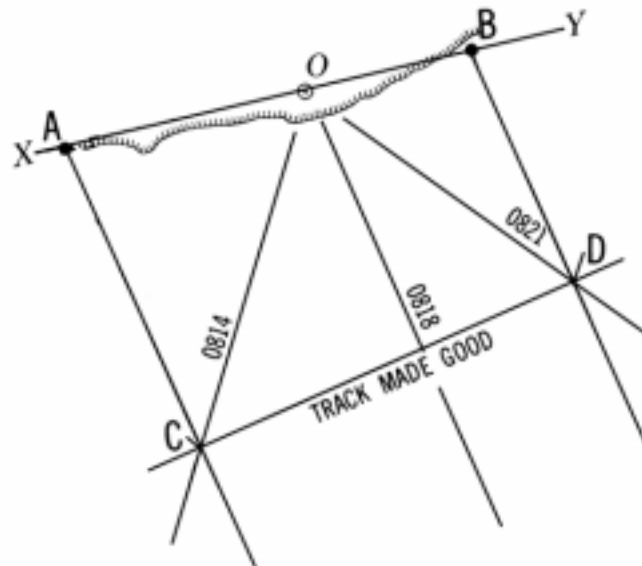


Figure 821b. Determining the track made good.

**822. A Fix By The Distance Of An Object By Two Bearings (Table 18)**

Geometrical relationships can define a running fix. In Figure 822, the navigator takes a bearing on NAVAID D. Express the bearing as degrees right or left of course. Later, at B, take a second bearing to D; similarly, take a bearing at C, when the landmark is broad on the beam. The navigator knows the angles at A, B, and C and the distance run between points. The various triangles can be solved using Table 18. From this table, the navigator can calculate the lengths of segments AD, BD, and CD. He knows the range and bearing; he can then plot an LOP. He can then advance these LOP's to the time of taking the CD bearing to plot a running fix.

Enter the table with the difference between the course and first bearing (angle BAD in Figure 822) along the top of the table and the difference between the course and second bearing (angle CBD) at the left of the table. For each pair of angles listed, two numbers are given. To find the distance from the landmark at the time of the second bearing (BD), multiply the distance run between bearings (in nautical miles) by the first number from Table 18. To find the distance when the object is abeam (CD), multiply the distance run between A and B by the second number from the table. If the run between bearings is exactly 1 mile, the tabulated values are the distances sought.

**Example:** A ship is steaming on course 050°, speed 15 knots. At 1130 a lighthouse bears 024°, and at 1140 it bears 359°.

**Required:**

- (1) Distance from the light at 1140.
- (2) Distance from the light when it is broad on the port beam.

**Solution:**

- (1) The difference between the course and the first bearing (050° - 24°) is 26°, and the difference between the course and the second bearing (050° + 360° - 359°) is 51°.
- (2) From Table 18, the two numbers (factors) are 1.04 and 0.81, found by interpolation.

- (3) The distance run between bearings is 2.5 miles (10 minutes at 15 knots).
- (4) The distance from the lighthouse at the time of the second bearing is  $2.5 \times 1.04 = 2.6$  miles.
- (5) The distance from the lighthouse when it is broad on the beam is  $2.5 \times 0.81 = 2.0$  miles.

**Answer:** (1) D 2.6 mi., (2) D 2.0 mi.

This method yields accurate results only if the helmsman has steered a steady course and the navigator uses the vessel's speed over ground.

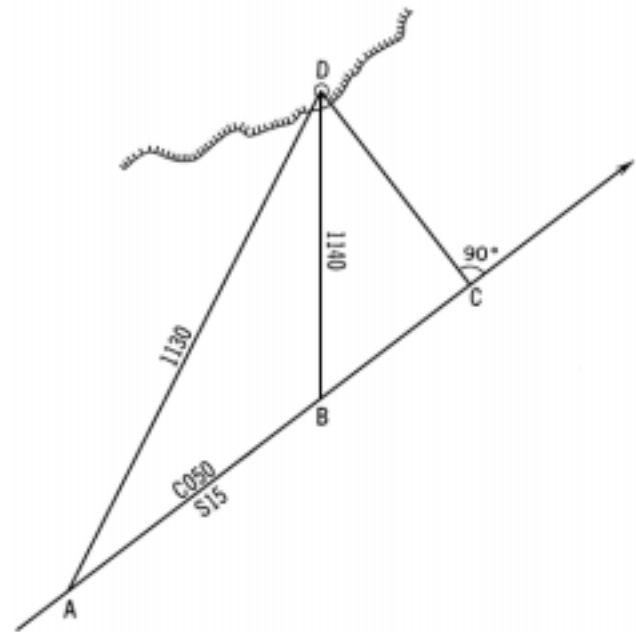


Figure 822. Triangles involved in a Table 18 running fix.

**MINIMIZING ERRORS IN PILOTING**

**823. Common Errors**

Piloting requires a thorough familiarity with principles involved, constant alertness, and judgment. A study of groundings reveals that the cause of most is a failure to use or interpret available information. Among the more common errors are:

1. Failure to obtain or evaluate soundings.
2. Mis-identification of aids to navigation.
3. Failure to use available navigational aids effectively.
4. Failure to correct charts.
5. Failure to adjust a magnetic compass or keep a table of corrections.

6. Failure to apply deviation.
7. Failure to apply variation.
8. Failure to check gyro and magnetic compass readings regularly.
9. Failure to keep a dead reckoning plot.
10. Failure to plot new information.
11. Failure to properly evaluate information.
12. Poor judgment.
13. Failure to use information in charts and navigation publications.
14. Poor navigation team organization.
15. Failure to "keep ahead of the vessel."
16. Failure to have backup navigation methods in place.

Some of the errors listed above are mechanical and some are matters of judgment. Conscientiously applying the principles and procedures of this chapter will go a long way towards eliminating many of the mechanical errors. However, the navigator must guard against the feeling that in following a checklist he has eliminated all sources of error. A navigator's judgment is just as important as his checklists.

**824. Minimizing Errors With A Two Bearing Plot**

When measuring bearings from two NAVAIDS, the fix error resulting from an error held constant for both observations is minimized if the angle of intersection of the bearings is 90°.

If the observer in Figure 824a is located at point T and the bearings of a beacon and cupola are observed and plotted without error, the intersection of the bearing lines lies on the circumference of a circle passing through the beacon, cupola, and the observer. With constant error, the angular difference of the bearings of the beacon and the cupola is not affected. Thus, the angle formed at point F by the bearing lines plotted with constant error is equal to the angle formed at point T by the bearing lines plotted without error. From geometry it is known that angles having their apexes on the circumference of a circle and that are subtended by the same chord are equal. Since the angles at points T and F are equal and the angles are subtended by the same chord, the intersection at point F lies on the circumference of a circle passing through the beacon, cupola, and the observer.

Assuming only constant error in the plot, the direction of displacement of the two-bearing fix from the position of the observer is in accordance with the sign (or direction) of the constant error. However, a third bearing is required to determine the direction of the constant error.

Assuming only constant error in the plot, the two-bearing fix lies on the circumference of the circle passing

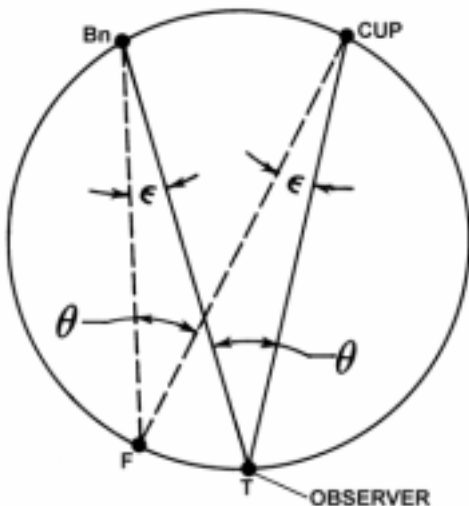


Figure 824a. Two-bearing plot.

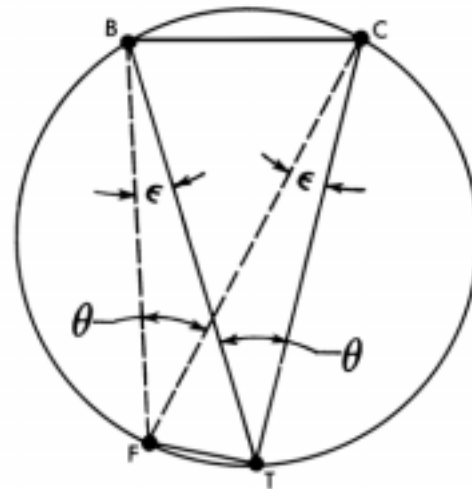


Figure 824b. Two-bearing plot with constant error.

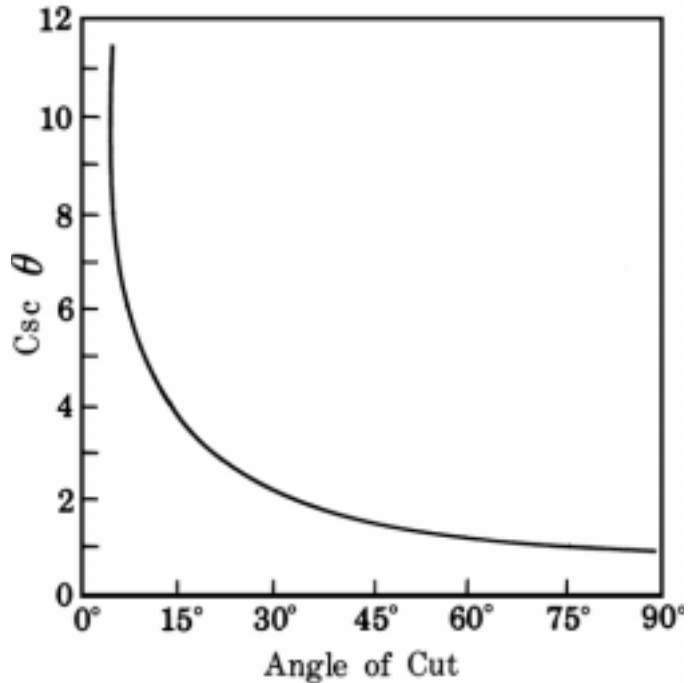


Figure 824c. Error of two-bearing plot.

through the two charted objects observed and the observer. The fix error, the length of the chord FT in Figure 824b, depends on the magnitude of the constant error  $\epsilon$ , the distance between the charted objects, and the cosecant of the angle of cut, angle  $\theta$ . In Figure 824b,

$$\text{The fix error} = FT = \frac{\epsilon BC \csc \theta}{2}$$

where  $\epsilon$  is the magnitude of the constant error, BC is the length of the chord BC, and  $\theta$  is the angle of the LOP's intersection.

Since the fix error is a function of the cosecant of the angle of intersection, it is least when the angle of intersec-

tion is  $90^\circ$ . As illustrated in Figure 824c, the error increases in accordance with the cosecant function as the angle of intersection decreases. The increase in the error becomes quite rapid after the angle of intersection has decreased to below about  $30^\circ$ . With an angle of intersection of  $30^\circ$ , the fix error is about twice that at  $90^\circ$ .

### 825. Adjusting A Fix For Constant Error By The Trial And Error Technique

If several fixes obtained by bearings on three objects produce triangles of error of about the same size, suspect a constant error in observing or plotting the bearings. If ap-

plying of a constant error to all bearings results in a point, or near-point, fix, apply such a correction to all subsequent fixes. Figure 825 illustrates this technique. The solid lines indicate the original plot, and the broken lines indicate each line of position moved  $3^\circ$  in a clockwise direction.

Employ this procedure carefully. Attempt to find and eliminate the error source. The error may be in the gyrocompass, the repeater, or the bearing transmission system. Compare the resulting fix positions with a satellite position, a radar position, or the charted sounding. A high degree of correlation between these three independent positioning systems and an "adjusted" visual fix is further confirmation of a constant bearing error.

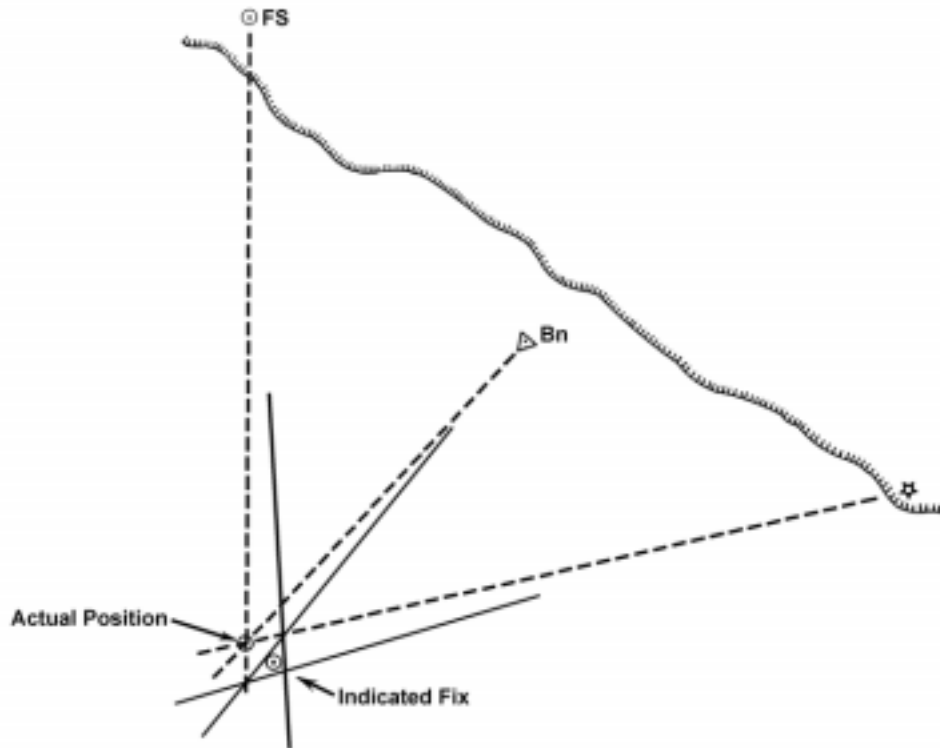


Figure 825. Adjusting a fix for constant error.

## TRAINING

### 826. Piloting Simulators

Civilian piloting training has traditionally been a function of both maritime academies and on-the-job experience. The latter is usually more valuable, because there is no substitute for experience in developing judgment. Military piloting training consists of advanced correspondence courses and for-

mal classroom instruction combined with duties on the bridge. U.S. Navy Quartermasters frequently attend Ship's Piloting and Navigation (SPAN) trainers as a routine segment of shoreside training. Military vessels in general have a much clearer definition of responsibilities, as well as more people to carry them out, than civilian ships.

Computer technology has made possible the develop-

ment of computerized **ship simulators**, which allow piloting experience to be gained without risking accidents at sea and without incurring underway expense. Simulators range from simple micro-computer-based software to a completely equipped ship's bridge with radar, engine controls, 360° horizon views, programmable sea motions, and the capability to simulate almost any navigational situation.

A different type of simulator consists of scale models of ships in a pond. The models, actually small craft of about 20-30 feet, have hull forms and power-to-weight ratios similar to various types of ships, primarily supertankers, and the operator pilots the vessel from a position such that his view is from the craft's "bridge." These are primarily used in training pilots and masters in docking maneuvers with exceptionally large vessels.

The first computer ship simulators came into use in the late 1970s. Several years later the U.S. Coast Guard began accepting a limited amount of simulator time as "sea time" for licensing purposes. The most sophisticated simulators have a full 360° horizon, visible from a completely equipped wheelhouse, which can be programmed for movement, noise, and vibration. They can simulate virtually any conditions encountered at sea or in piloting waters, including land, aids to navigation ice, wind, fog, snow, rain, and lightning. The system can also be programmed to simulate hydrodynamic effects such as shallow water, passing ves-

sels, current, and tugs.

Virtually any type of vessel can be simulated, including tankers, bulkers, container ships, tugs and barges, yachts, and military vessels. Similarly, any given navigational situation can be modeled, including passage through any chosen harbor, river, or passage, convoy operations, meeting and passing situations at sea and in harbors.

Simulators are used not only to train mariners, but also to test feasibility of port and harbor plans and visual aids to navigation system designs. This allows pilots to "navigate" simulated ships through simulated harbors before construction begins to test the adequacy of channels, turning basins, aids to navigation, and other factors.

A full-capability simulator consists of a ship's bridge which may have motion and noise/vibration inputs, a programmable visual display system which projects a simulated picture of the area surrounding the vessel in both daylight and night modes, image generators for the various inputs to the scenario such as video images and radar, a central data processor, a human factors monitoring system which may record and videotape bridge activities for later analysis, and a control station where instructors control the entire scenario.

Some simulators are part-task in nature, providing specific training in only one aspect of navigation such as radar navigation, collision avoidance, or night navigation.