CHAPTER 10

PLOTTING

LEARNING OBJECTIVES

After you finish this chapter , you should be able to do the following:

1. Discuss basic plotting definitions and plotting terminology.
2. Discuss the various types of surface plots and the associated reports sent to the bridge.
3. Discuss the various types of air plots.
4. Discuss the procedures for ASW plotting and how to use the Halifax plot under emergency conditions.
5. Discuss the contact information reports sent to the bridge.

INTRODUCTION

One of the most important functions of CIC is to display information. To perform this function, CIC receives and processes raw information into useable forms. Figure 10-1 shows an example of how information flows to, from, and within a typical CIC. To perform their duties effectively, key personnel such as the evaluator/TAO, CIC officer, and CIC watch officer and air controllers and command personnel depend on Operations Specialists to keep the information accurate, up-to-date, and in an easy-to-read form. This means that to perform your job properly, you must learn the techniques, symbols and abbreviations, equipment, and types of displays used in CIC well enough to produce the desired display accuracy for every situation.

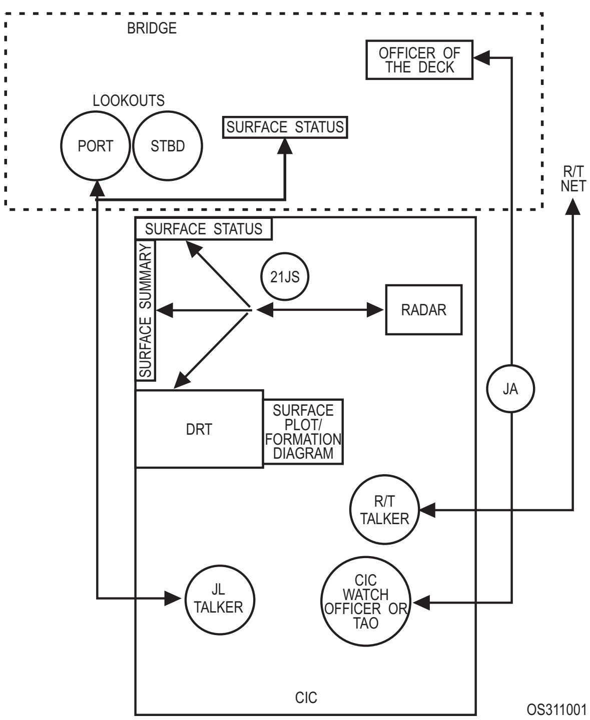


Figure 10-1.—Example of the flow of information within CIC.

In chapter 2, we discussed the various plots and status boards used to display both tactical and strategic information. Recall that plots provide a visual reference of the positions of friendly and enemy units and forces. Some plots are static in nature; others show movement. Some plots cover large areas and show both friendly and enemy forces; others depict only own units within a small area. Many of the displays used in CIC today are automated or are maintained and displayed in some type of electronic format. Still, basic plot characteristics, plotting procedures, and plotting abbreviations and symbols remain the same.

We discussed geographic (DRT/DDRT) plots in chapter 9. In this chapter, we will deal primarily with the surface and air summary plots (and related status boards) and the procedures for ASW (anti-submarine warfare) and TMA (target motion analysis) that present a relative picture of the surface and air situation around own ship.

BASIC PLOTTING DEFINITIONS AND TERMINOLOGY

To develop and maintain plots properly, Operations Specialists must be thoroughly familiar with basic bearing terminology. Suppose CIC receives the following request from the captain: "What course will take me to a position 2,000 yards west of the contact, and how long will it take to get there at a speed of 30 knots?" The surface plotter must solve this problem and give the captain the correct answers, quickly and accurately. There is no excuse for an incorrect solution. When the captain requests a course to a certain position, he must have the information in a matter of seconds—not minutes. You may use various methods to solve such a problem (the DRT/DDRT, the surface plot, or the face of the scope), but you will normally use the surface plot or a separate maneuvering board.

In the example above, the captain might have requested the information in the following manner: "I want a course to take our ship to a position 2,000 yards from the target at a target angle of 300°. We will use a speed of 30 knots to make the maneuver."

Or he might have said: "I want a course to take our ship to a position 2,000 yards bearing 270° true from the contact."

The three bearings the captain requested were *true bearings*. But he could just as easily have asked for *relative bearings*. Therefore, you must know the exact meaning of both true and relative bearings and must also have a thorough understanding of how to convert true bearings to relative bearings, and vice versa. In this section, we will discuss both types of bearings and how to determine them.

BEARINGS

A *bearing* is simply a direction to a target (or object). The principal bearings used in CIC are *true* and *relative*. Each type serves a useful purpose at one time or another. Other types of bearings are *reciprocal* and *target angle*. Figure 10-2 illustrates all of these types of bearings. All bearings are measured clockwise from their reference point.

Line of bearing: The line connecting the positions of two objects.

True bearing: The angular measurement between true north and the line of bearing to the object. Unless stated otherwise, all bearings used in CIC are true.

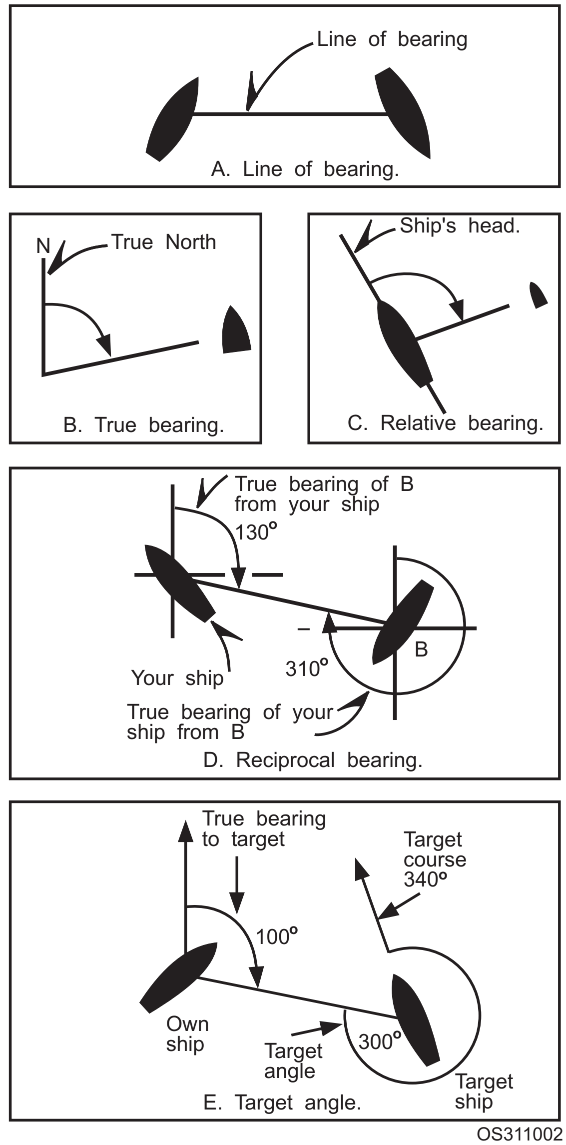


Figure 10-2.—Types of bearings.

Relative bearing: The angular measurement between own ship's head (own course) and the line of bearing to the object.

Reciprocal bearing: A bearing that is 180°, plus or minus, from any given bearing. Look at view D of figure10-2. Ship B bears 130° true from own ship. The reciprocal of 130° is 310°. Therefore, own ship bears 310° **from** ship B.

Target angle: The relative bearing of own ship from a target ship. It is the angular measurement from the target's head clockwise to the relative bearing of own ship.

By using the following formulas, you can determine a true or relative bearing arithmetically by using a given bearing and own ship's head.

1. The true bearing of an object equals the object's relative bearing plus ship's head (TB = RB + SH). When the answer exceeds 360°, subtract 360°.
2. The relative bearing of an object equals the object's true bearing minus ship's head (RB = TB - SH). When SH exceeds TB, add 360°to TB before you subtract SH.

To determine the target angle, use the following formula:

> Target angle equals the true bearing of the target from own ship, plus or minus 180°, minus the course of the target (TA = TB ± 180° -TCO). For example, assume that the true bearing of a target on a course of 340° is 100°. Add this bearing to 180°. Now subtract the target's course (340°). Because you cannot subtract 340° from 280°, add 360° to the target's true bearing before you subtract the target's course. The target angle is 300°.

RELATIVE PLOT

Relative movement is the movement of one object in relation to another—the movement that takes place between two objects when one or both are moving independently. Likewise, the distance moved and the speed of the movement are relative values.

A *relative plot* is a drawing to scale showing the position of one moving object relative to other objects. Special plotting sheets, called *maneuvering boards*, are printed with polar coordinates for plotting bearings, and with concentric circles for plotting distances.

In CIC, relative plots are maintained on maneuvering boards and on vertical plotting boards called *summary plots*. (Maneuvering board plotting is discussed in chapter 11.)

Q1. What is a reciprocal bearing?

Q2. What is a target angle?

SURFACE PLOTTING

During the course of a watch, an Operations Specialist may be rotated at 30- to 60-minute intervals between such positions as surface search radar operator, DRT plotter, surface plotter, S/P telephone and radiotelephone operator, surface summary plotter, tote board keeper, and surface status board keeper.

In the next few sections, we will discuss some of the plots and status boards of primary importance to the surface picture, and the information found on them. We will not attempt to prescribe physical requirements for the format of the plots and status boards, since their layout, size, and location are greatly influenced by the mission of the ship, available space, CIC doctrine, and the arrangement of equipment in CICs.

We introduced the primary surface plots and status boards in earlier chapters. In this chapter, we will discuss their functions in connection with plotting and will point out how each status board works in conjunction with a plot to develop a complete picture. The following plots pertain to the surface picture:

1. Geographic plot
2. Surface plot
3. Formation diagram
4. Surface status board
5. Strategic plot
6. Nuclear detonation

GEOGRAPHIC PLOT

The geographic plot (also called the navigation plot) shows the true movement of surface, subsurface, and certain air contacts. The geographic plot is maintained on the dead-reckoning tracer (DRT) (refer to chapter 9).

The geographic plot consists of a piece of tracing paper over the DRT. When the ship is engaged in shore bombardment or radar piloting in restricted waters, a chart of the area is put on the DRT in place of the tracing paper. A neat and complete track of all contacts should be kept on the geographic plot. The plot can serve as a vital log and should be treated as such for all events requiring a navigational track.

SURFACE PLOT

The surface plot is one of the most important plots maintained in CIC. When properly kept, the surface plot eliminates confusion by providing continuous identification of other vessels.

The surface plot is a comprehensive, relative display of the positions and tracks of friendly, enemy, and unidentified surface and subsurface targets, of geographical points, and of other data required for an understanding of the complete surface picture.

The surface plot is kept in polar coordinates (true ranges and bearings), usually on a maneuvering board. If space permits, a 36-inch edge-lighted vertical plotting board scribed in the same manner as a maneuvering board also is used. The latter is called the *surface summary plot*. Both plots show essentially the same information, with the summary plot being visible to more people. Also, because of its size, the summary plot is less cluttered, making situations easier to evaluate. In our discussion the term *surface plot* applies to both plots, with differences noted as necessary.

When a surface summary plot is kept, the maneuvering board is used mainly for determining a contact's course, speed, and closest point of approach (CPA).

Plotting Symbols and Abbreviations

All surface and air plots use standard symbols and abbreviations to provide the most information without unduly cluttering the plot. Although most information comes from radars, there are other sources that must be identified. For example, "LO" alongside a plot indicates a lookout report; "COM" means a radio report.

Formation symbols are shown in figure 10-3. They are used on all plots to indicate at a glance the positions of various types of units.

Plotting symbols are shown in figure 10-4. Table 10-1 lists plotting abbreviations. Some of the symbols and abbreviations are used only on the geographic plot, some only on the surface plot, and some on the air plot, while some are used on all plots. Whatever your plotting assignment, you must know all the symbols and abbreviations and when and where to use them.

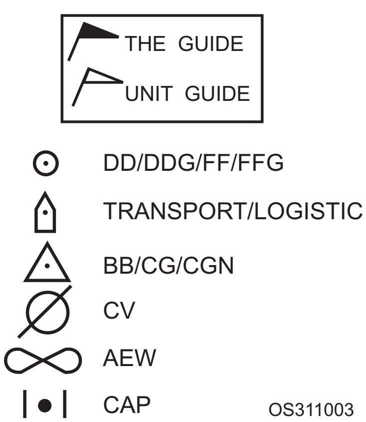


Figure 10-3.—Example of formation symbols.

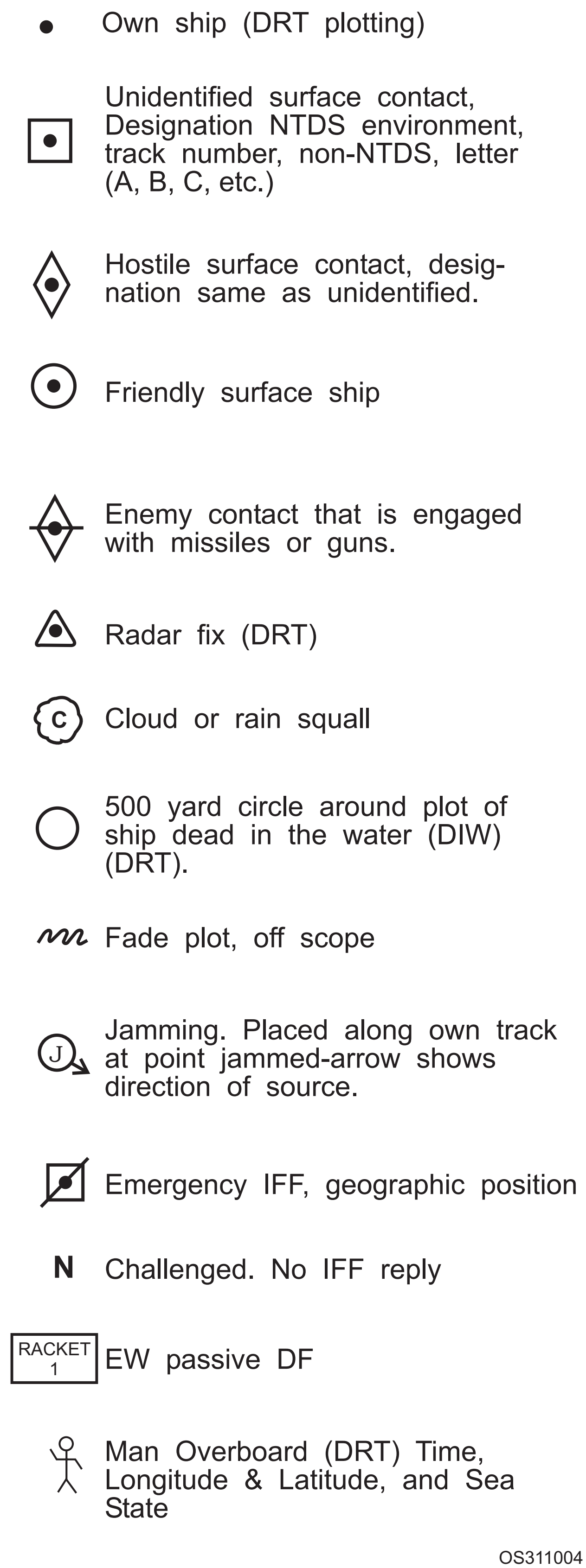


Figure 10-4.—Example of surface plotting symbols.

Table 10-1.—Surface Plotting Abbreviations

L	Large Ship (prefaced by number)
AEW	Airborne Early Warning
S	Small Ship (prefaced by number)
LAT	Latitude
LONG	Longitude
C	Course
S	Speed
C/C	Changed Course
C/S	Changed Speed
DK	Radar Decoy
OF	Opened Fire
CF	Ceased or Checked Fire (add letter to indicate target)
LO	Lookout Report
COM	Radio Report
SON	Sonar Report
PIN	Assumed Friendly Emission
VOL	Enemy Guided Missile Signal
RAK	Intercepted Electronic Transmission
MOB	Man Overboard
MS	Make Smoke

Plotting Procedures

We will now discuss how to develop a surface plot. Our discussion assumes that own ship is part of an AW formation. Figure 10-5 illustrates how the surface summary plot is kept.

On a surface plot, your ship is always in the center. When setting up the plot, always indicate formation type, center, guide, axis, course, and speed. Show the wind force and direction at the outer edge of the plot.

Plot the major units of the formation in relation to own ship, together with their identities, such as station designations or call signs. (You can get bearings and ranges of other ships from the formation diagram, which we will discuss later.) All formation units, their stations, and their call signs are listed on a status board located in CIC. Be sure to show and label the AW axis and sectors. Also show reference points and significant points of land should, along with the scale of the plot.

In figure 10-5, the tactical arrangement is a circular formation (the small circle labeled "AW") with the "Guide" being a cruiser in station 0 (the center of the formation). The formation's center bears approximately 135° and 6,000 yards from the center of the plot. The formation is moving at a speed of 15 knots on an axis and course 000°. The wind is from 350°at 15 knots. The AW sectors originate at the center of the formation, relative to the AW axis (in this case true north) and are described as follows:

Sector Delta	000-120
Sector Echo	120-240
Sector Foxtrot	240-000

The general procedure for plotting a surface contact (Skunk B in figure 10-5) is as follows:

1. At 1803, the surface search radar operator detects a contact and reports it over the 21JS S/P circuit: "Surface contact (or Skunk)—025—24,000—one small."

.2.The plotter immediately notes the time, marks a small "x" at the reported bearing and range, and records the time in four digits. (Subsequent plots use only two digits for minutes. Four digits are used again on the even hour.)

3. The plotter draws the symbol for an unknown surface contact (a square) near the plot and places the raid designation (B) near the symbol. This designation is retained for internal usage. After the contact is reported to the OTC, it will normally be assigned a four-digit track number.

4. The plotter then places the estimated size of the contact in a box near its designation (in this case, "1S").

5. The plotter will usually maintain the track at 1-minute intervals until the contact fades (in this case, time = 1812) or until he receives an order to cease tracking.

6. A minimum of three plots (2 minutes) is necessary to obtain an initial course and speed. A 3-minute plot is better because it gives a better

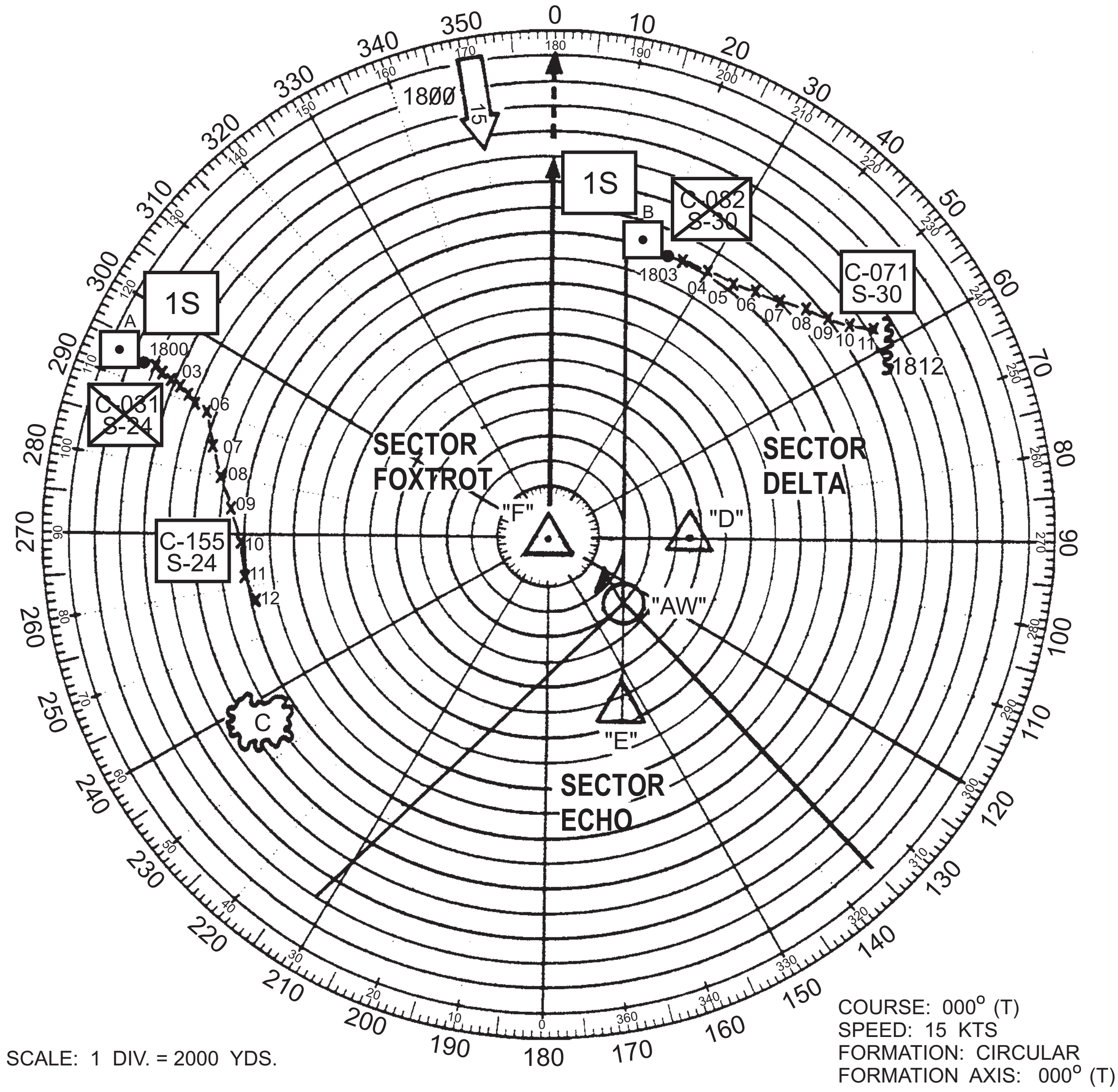


Figure 10-5.—Example of a surface summary plot.

picture of contact movement and enables use of the 3-minute rule for finding speed.

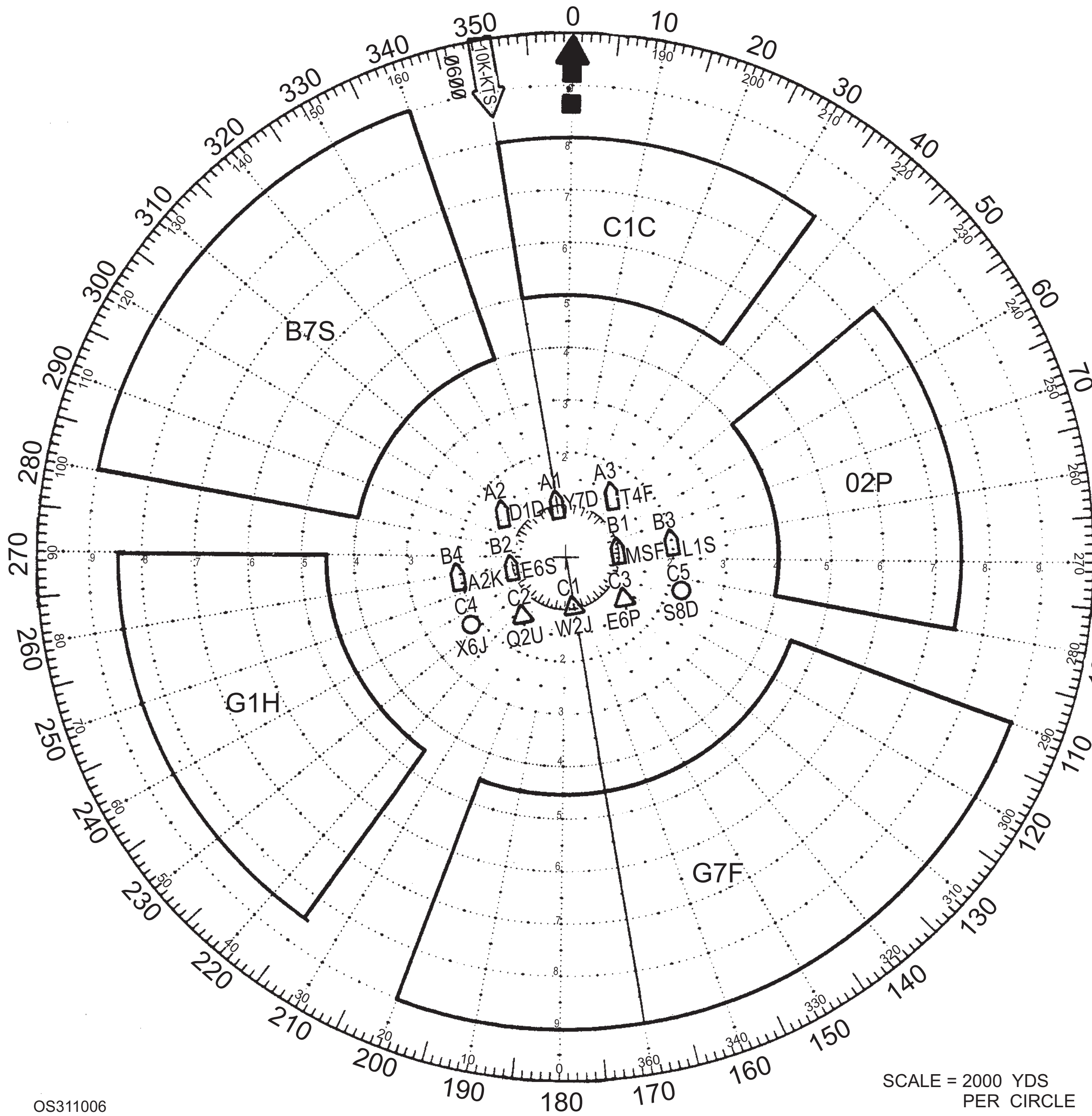
7. Course and speed are usually determined by the geographic plotter, who reports the information to the summary plotter, who then displays it in a box along the track at the appropriate time. When the plotter receives a corrected course and speed, he enters the new information in a box and crosses out the old.

8. The surface plotter (on a maneuvering board) also determines course and speed, and the contact's bearing, range, and time of its CPA to own ship.

The surface plotter also determines, when directed, the course and speed for own ship in order to intercept or avoid a contact, the course to new station, the direction and force of the true wind, and the course and speed to obtain the desired wind. We will discuss these and related subjects in chapter 11.

FORMATION DIAGRAM

A formation diagram shows the station of every ship in the formation. It is kept in polar coordinates relative to the formation's axis and center, with formation's center located at the center of the plot. As with the surface plot, it is desirable to keep the formation diagram on a vertical, edge-lighted board, but space and personnel limitations often require the use of a maneuvering board instead. Figure 10-6 illustrates a formation diagram.



OS311006

Figure 10-6.—Example of a formation diagram.

The main body is shown, with each station number and the call sign of the ship occupying that station. Screen sectors are also shown with the call signs of assigned screen units. Sector boundaries are drawn from two groups of four numerals each, specified in a tactical message. Look at the sector in figure 10-6 occupied by unit “O2P”. In the assigning message, this sector was specified as “0510-0815 DESIG O2P”. The first two numerals of the first group indicate the true bearing in tens of degrees of the left boundary (050°); the second two numerals indicate the right boundary (100°). The second group indicates sector depth. The first two numerals indicate the inner limit (8,000 yards), while the second two numerals indicate the outer limit (15,000 yards) of the sector from the formation or screen center.

Whenever a change in the formation occurs, a new diagram must be plotted and the surface plot corrected accordingly. Any change that affects the relation between own ship and the guide (e.g., a change in own station assignment) must be plotted immediately and the new bearing and range to the guide determined. The surface plotter determines the course to the new station.

Sometimes it is necessary to combine the surface plot and the formation diagram. In this event, two different scales and plotting colors are used. Red is normally used for the surface plot; black for the formation diagram. The two scales MUST be displayed prominently.

SURFACE STATUS BOARD

Surface status boards contain the following data for surface plotters and other CIC personnel: cruising formation; formation axis, course, and speed; position and intended movement (PIM); and own ship bearing and range of the guide. The sector assignments of other ships in the formation may also be included.

The exact form of the surface status board varies from ship to ship. Figure 2-5, chapter 2, shows an example of a typical surface status board.

STRATEGIC PLOT

The strategic plot is a large-area true display showing the position, movement, and strength of own and enemy sea, land, and air forces within a prescribed area of operations. This display is maintained on hydrographic charts of suitable scale. Its information is taken from the operation plans and orders, intelligence data, and reports of reconnaissance missions. The strategic plot is used in planning present and future operations and in making decisions. It should contain the location of own and enemy submarines, own submarine restricted areas, enemy missile-launching sites (including all data on type and numbers), and other strategic data that may affect the tactical situation.

Q3. What surface plot displays a true picture of surface ship movement?

Q4. *What information is contained on the formation diagram?*

AIR PLOTTING

The objective of air plotting is to present a neat, accurate, up-to-the-minute picture of the positions and tracks of all aircraft in the area under surveillance.

Displays and status boards are of primary importance during air warfare operations. As for surface displays, we make no attempt to prescribe their exact format. Their size, location, and specific content are based on each ship's mission, available space, and arrangement of equipment.

In the following topics concerning air plotting, we will discuss procedures for tracking air contacts; standard air plotting symbols and abbreviations; methods for computing courses and speeds; and procedures for designating raids, making raid estimates, and plotting altitudes, fades, and splits.

AIR SUMMARY PLOT

Air plotting is done on the air summary plot, sometimes called the *vertical plot* or just the *air plot*. The air summary plot is a vertical, edge-lighted, 60-inch transparent plastic board scribed in the same manner as the surface summary plot. Depending on the amount of coverage desired, each circle might equal 1, 5, 10, 20, or 50 nautical miles. Normally, the 20-miles-per-circle scale is used so that coverage is out to 200 miles.

Air plotters man the 22JS sound-powered telephone circuit connected to the radar operators. Radar operators read the range and bearing of contacts from the scope and provide information on the contact's altitude, size, IFF code, splits, jamming, and any other data available. If the radar operator does not provide this information, the air plotter must request it, in order to figure the course and speed of contacts.

Air plotters normally work from the back of the board. Hence, you must learn to write and plot backwards so the information you plot can be read and understood easily from the front of the board.

You will use different colored grease pencils in writing on the summary plot's plastic surface. Most ships adopt a color scheme such as:

- Red or orange for hostiles or unknowns;
- Yellow for friendlies; and
- White for picket ships, patrol aircraft, and other ships in the formation.

The air summary plot is used as (1) a visual display for easy evaluation, (2) an aid in controlling aircraft, (3) a tactical picture of the air situation, and (4) a source of information for weapons liaison personnel.

The tracks of friendly combat air patrol, attack, search, observation, rescue, and other aircraft are plotted to assist in the overall evaluation and action required. The display also assists in helping lost planes get home and in establishing the position of a downed aircraft.

Although the air summary plot is basically a picture of the air situation, it also shows surface forces relating to the air picture. Reference points, dangers to air navigation, wind direction and velocity, position of the sun, positions of outlying picket forces, and raid designations are also presented on this board. Figure 10-7 illustrates some of the information shown on an air summary plot.

Information displayed on the air summary plot comes from several sources. The principal source is the ship's air search radar, augmented by the radar of other ships in the force, picket ships, and AEW aircraft. For all CICs to have the same information, data is exchanged over both voice radio and data links.

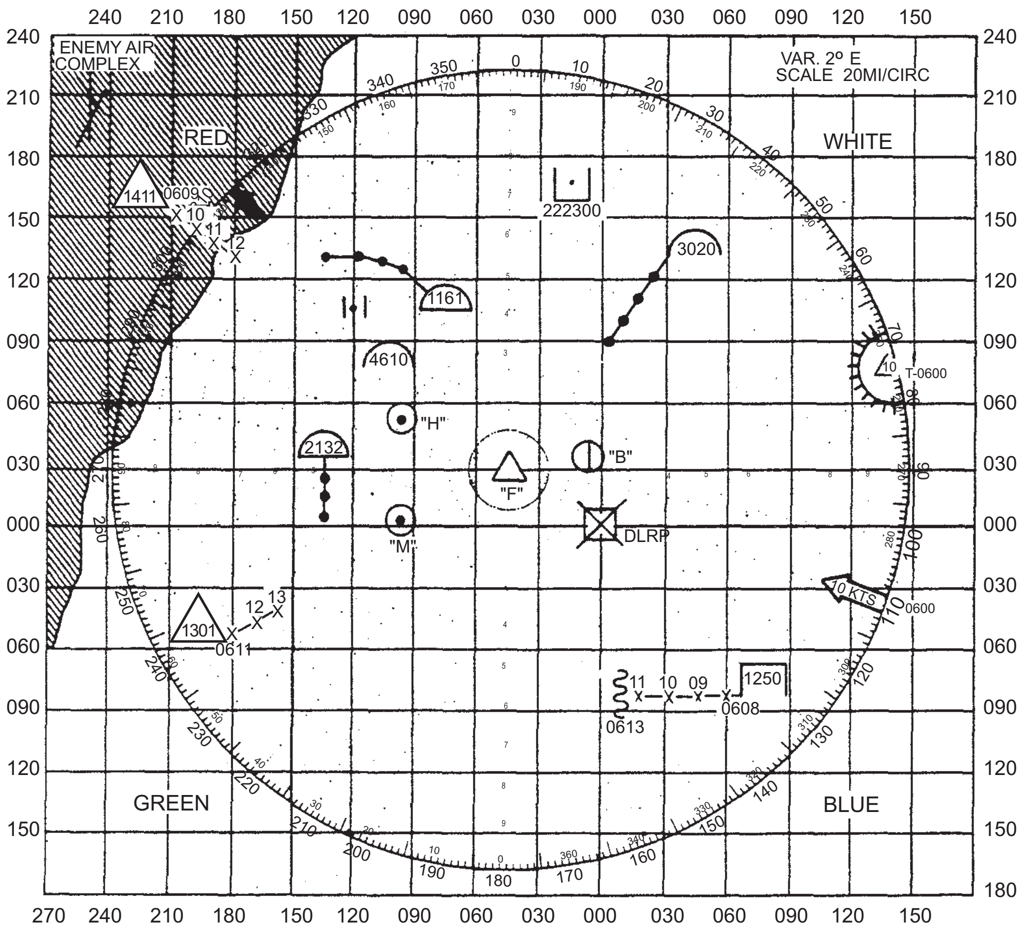
Plotting Symbols and Abbreviations

The primary reason for using plots is to make important tactical information available, at a glance, to personnel who need it. To ensure that such information is presented in the same way every time, Operations Specialists use a set of standard air plotting symbols and abbreviations. The symbology, based on historical use and the Naval Tactical Data System (NTDS), is divided into three fundamental types:

- One based on a *square* to indicate an "unknown" contact,
- One based on a *circle* to indicate a "friendly" contact, and
- One based on a *diamond* to indicate a "hostile" contact

These symbols are divided by track types, with the upper half of the symbol indicating an air contact **(insert "unknown", "friend", and "hostile" air symbols)**, the whole symbol indicating a surface contact **(insert "unknown", "friend", and "hostile" surface symbols)**; and the lower half of the symbol indicating a subsurface contact **(insert "unknown", "friend", and "hostile" sub symbols)**. Thus, the symbols **(insert "friend surface", "hostile air", and "unknown sub" symbols)** indicate a friendly surface contact, a hostile air contact, and an unknown subsurface or submarine contact. Figure 10-8 lists the NTDS symbology most commonly used for manual air plotting.

All symbols written on plots must be large enough to be seen easily by anyone standing 14 or 15 feet from the plot.



OS311007

Figure 10-7.—Example of an air summary plot.

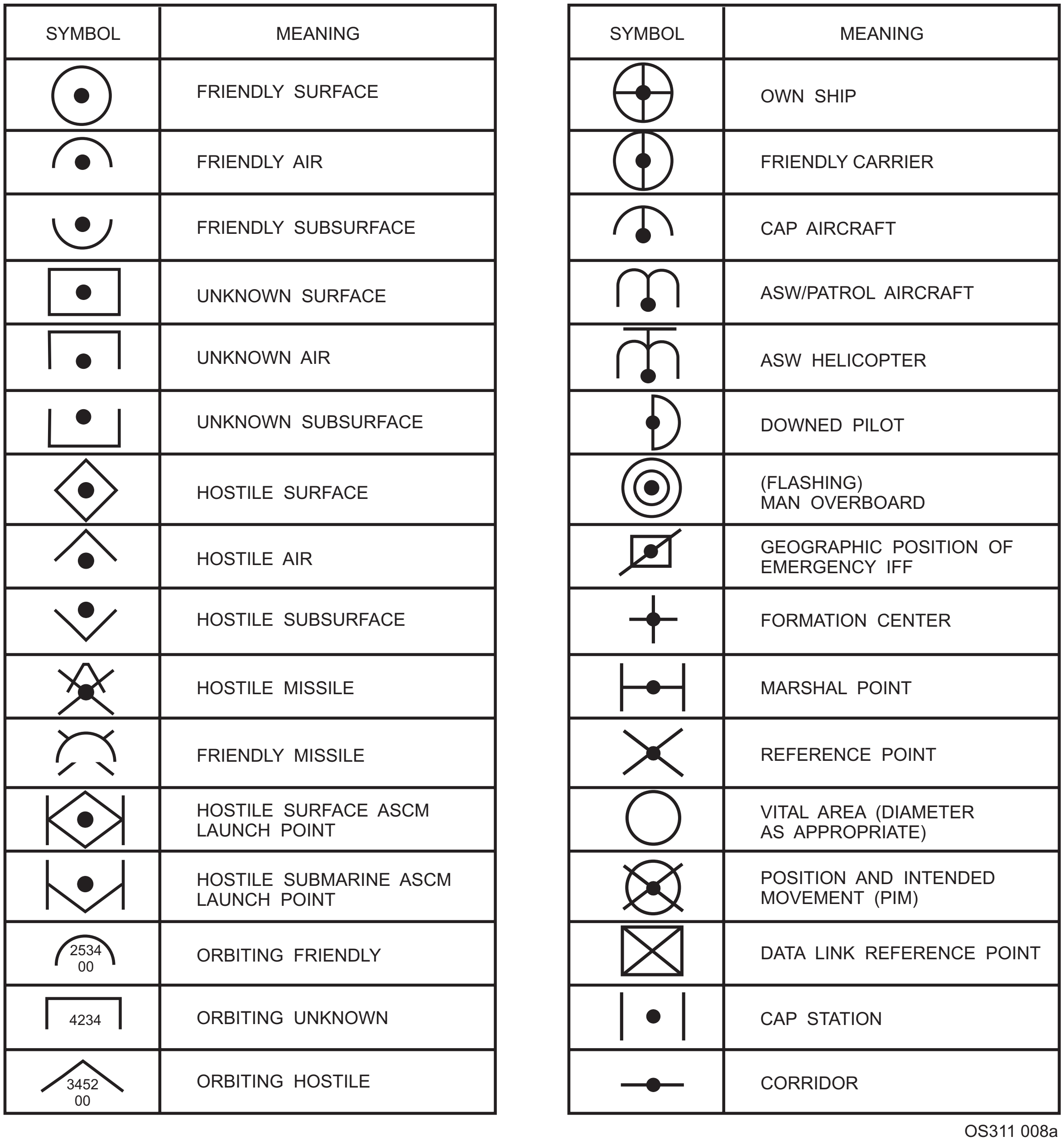


Figure 10-8.—NTDS symbology for use in manual air plotting.

Until an air contact is identified, it is referred to by the term *bogey* and is assumed to be an enemy contact. It is indicated by the "unknown" air symbol and has its position and direction of movement indicated by a series of "X"s. If the bogey is identified as friendly, its "unknown" symbol will be changed to a "friendly" symbol. If it is identified as hostile (positively identified enemy contact), its "unknown" symbol will be changed to a "hostile" symbol. All bogeys are treated as hostile until they are identified.

If the radar operator needs to report a friendly and a bogey at the same position, he will use the term *merged plot*. The symbol for a merged plot is an arrow enclosed in a circle. Merged plots occur most frequently when friendly aircraft intercept an enemy or unidentified raid and begin an air reconnaissance and/or battle.

Plotting Technique

Because of the importance of tactical information, a plotter cannot hesitate in plotting the proper symbol at the correct range and bearing. Thus, to ensure rapid and accurate plotting, you must be completely familiar with the symbols and abbreviations used in air plotting.

Immediately upon receiving a contact report from the radar operator, you should do the following:

1. Place your grease pencil at the correct range and bearing, then quickly plot an X for unknowns

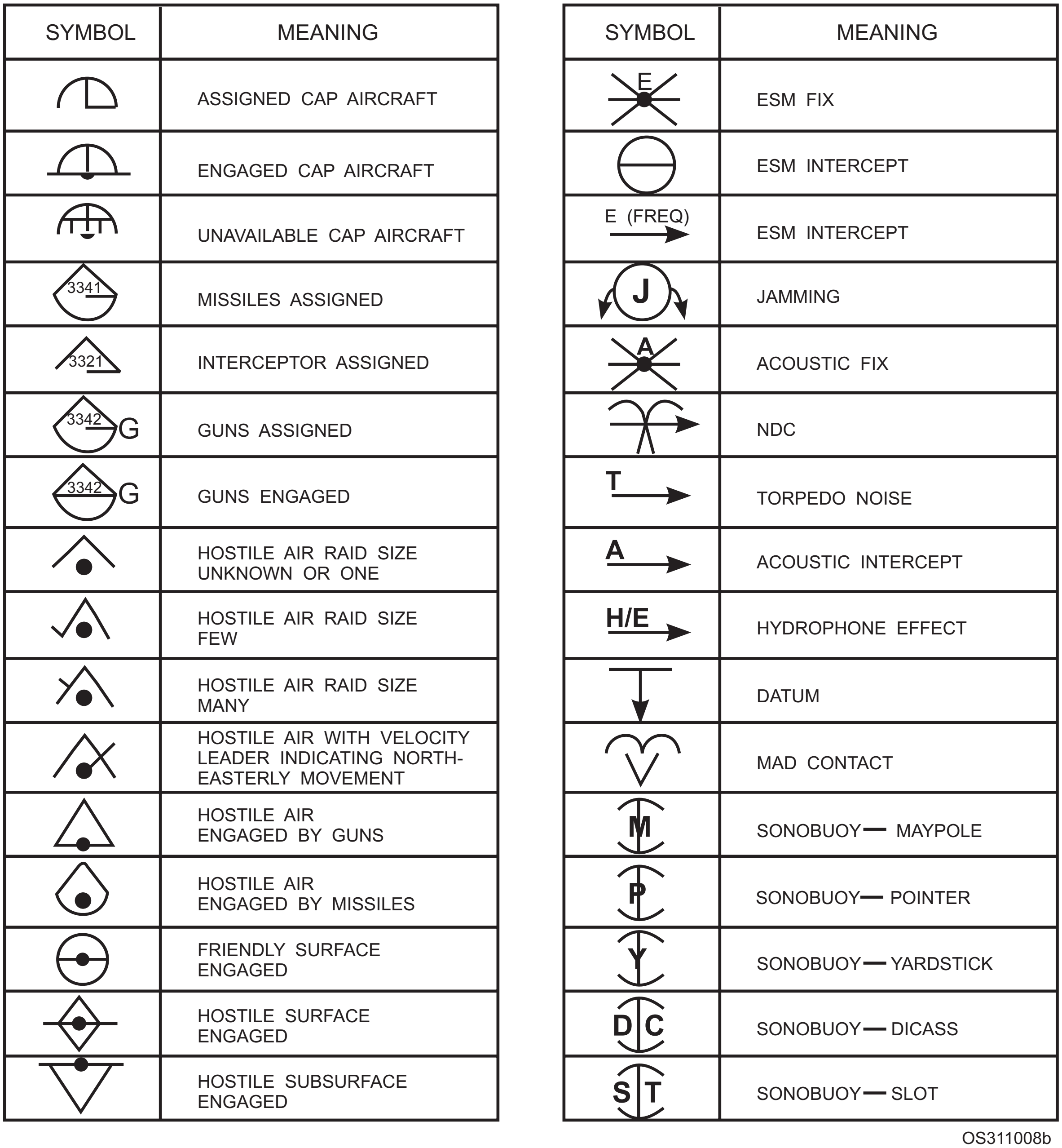


Figure 10-8.—NTDS Symbology for use in manual air plotting (Continued).

and hostiles; use a small dot connected by a line for friendlies.

2. Alongside the plotted position, record the time you received the report. Use a four-digit time (i.e. 0923) for the first mark and marks on the hour; use a two-digit time (to indicate minutes; i.e. 24, 25, 26, etc.) for all other marks.
3. Place the proper symbol at the head of the track to indicate contact's identity.
4. Connect successive plotted positions with a line between the Xs that mark the succeeding positions.

AW units are assigned station letter designators to be used as AW unit call signs. Air raids are designated alphanumerically by the unit making the detection, using the unit's station letter designator followed by numerals commencing with figure 1, as D1, D2, and the like. Bogeys detected by NTDS units will be assigned track numbers. In addition, a designated NTDS unit will assign track numbers to all alphanumerically designated bogeys, and from then on, the bogey will be referred to by track number.

The code words *bogey*, *hostile*, or *friendly*, followed by the alphanumeric designation or track number, will be used to report the raid.

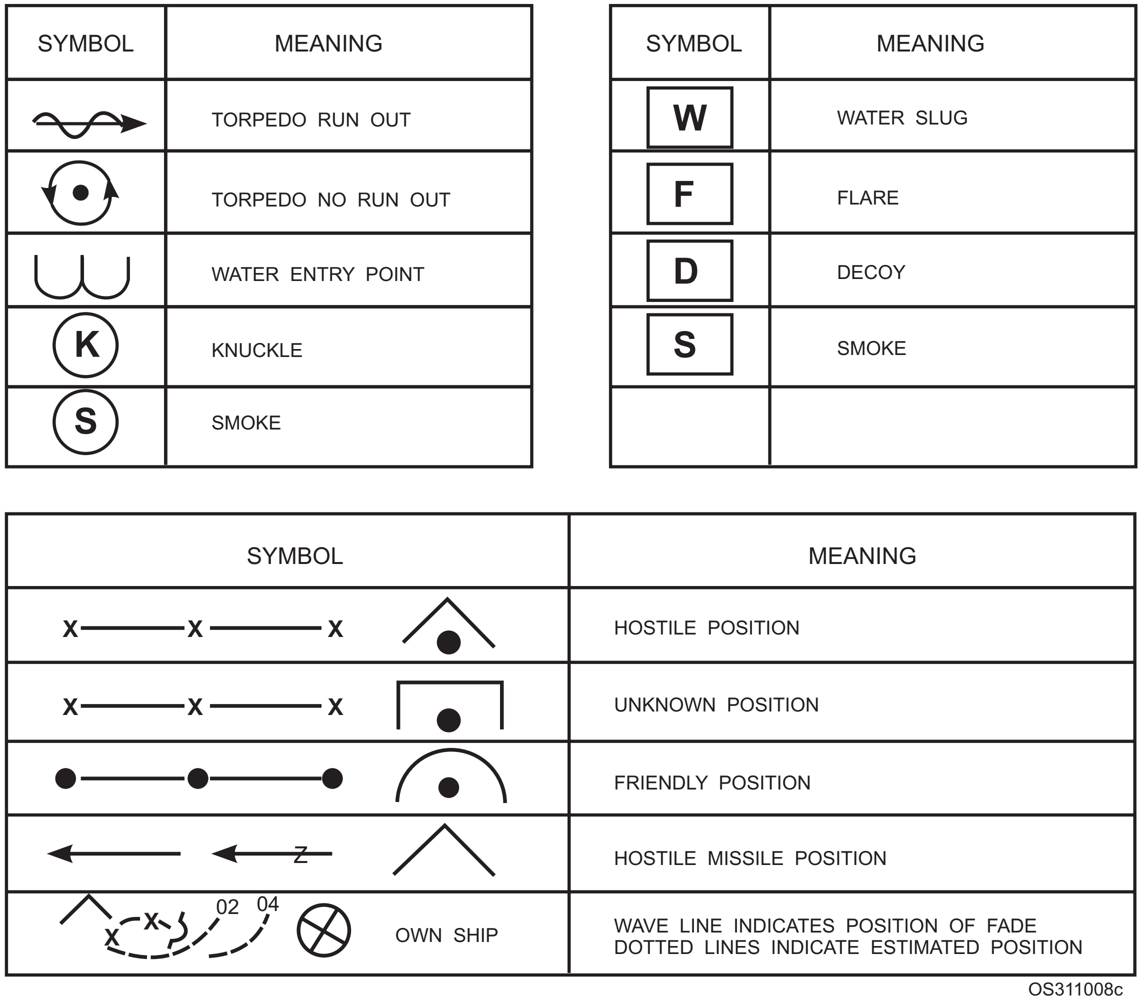


Figure 10-8.—NTDS Symbology for use in manual air plotting (Continued).

To keep a neat plot, you may wish to use a plastic template, especially for drawing raid designation symbols. To obtain a neat symbol, merely place the template against the plotting board and mark through the proper hole with a grease pencil.

Fades

Sometimes a bogey you are tracking will disappear from radar. When this happens, you should plot a *radar fade*. The aim of fade plotting is to present all possible positions at which the bogey might reappear. Because we are interested chiefly in the bogey's advance toward the formation, you should draw the fade plot with this objective in mind.

To plot a radar fade, draw a wavy line about 1-inch long, just beyond the bogey's last plotted position, perpendicular to the direction of the track. When the bogey reappears, place a similar wavy line on the track side of the plot where the bogey reappears. Then join the two plots by a solid line in the usual manner. In some instances, you may need to plot an estimated position (EP) for the bogey.

Splits

If a raid splits, the separate parts of the raid are assigned separate designations by the unit that reports the split. The part of the raid that most nearly maintains course and speed retains the previously assigned designation. The other part (or parts) is assigned the next consecutive alphanumeric designation of that unit. Those reported by TDS units are given track numbers.

Plotting Friendlies

When a contact is picked up by the radar operator, it is designated "unknown." When the contact shows proper IFF, it is re-designated "friendly" and the friendly symbol is placed at the head of the track. This contact is then listed in the appropriate area of the tote board, such as "CAP" or "strike".

When a ship is assigned a combat air patrol (CAP) to control, plotters must ensure that information concerning the CAP is kept up to date. Information displayed on the plot enables the evaluator to provide the anti-air warfare commander and friendly units information required to coordinate defensive weapons.

Computing Course and Speed

Whenever you plot a contact, obtain and plot its course and speed after the first 3 minutes of track and checked them frequently thereafter to ensure that you note any significant changes. Use a minimum of four plots (3 minutes of track) for the initial solution of course and speed. If the contact is beyond a range of 20 miles, use a minimum of three plots (2 minutes of track) to ascertain a change in course and speed. If the contact is within a range of 20 miles, you may use two plots (1 minute of track).

Course is the mean line between a number of plots and normally is computed to even tens of degrees. Figure 10-9 illustrates how to find course and speed. Compute speed as soon and as accurately as possible. Depending upon the contact's range, you can obtain its speed from 1 minute of plot, but of course, this method is not as accurate as a speed determined over longer periods. The longer the track, the more accurate your speed estimate. The most satisfactory compromise is to determine the distance (in miles) the contact covers in 3 minutes of track and then to multiply that distance by 20. (In 3 minutes, the contact will travel 1/20 the distance it will travel in 1 hour.)

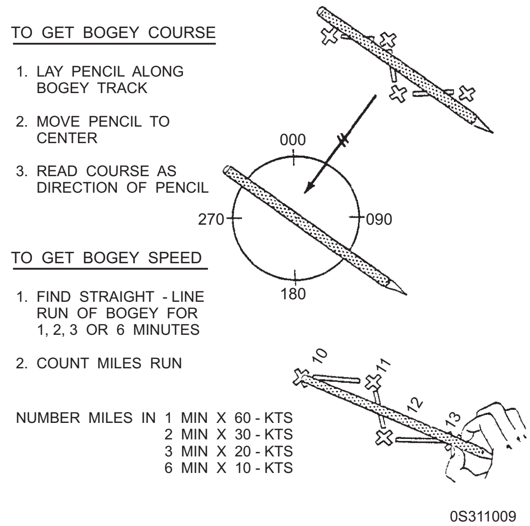


Figure 10-9.—Air contact course and speed.

TOTE BOARD

As the performance characteristics of aircraft increased over the years, the surveillance area around a force had to be expanded to allow defensive forces more time to respond to threats. Today's high-performance aircraft make it necessary to greatly extend the surveillance area. In a high activity situation, many more contacts than in the past may have to be plotted on the air summary plot. If all necessary information about every contact (speed, altitude, composition, etc.) were put on the air summary plot, the display would be so cluttered that it would be of no practical use to the evaluator or to anyone else.

The solution to this problem is to place part of the information on another plot called a *tote board*. The tote board (figure 10-10) contains all of the amplifying information on every air contact plotted on the air summary plot and is maintained by one to four persons, depending on the type of ship and the situation. The tote board contains three sections—bogey, CAP, and other friendlies.

BOGEY	TN	CSE	SPD	ALT	COMP	TIME	WEAPONS ASSIGNED			REMARKS
							CAP	BIRD	GUN	
T4F2	0315	170	350	23	1	1723	✓			BADGER
T4F-3	0320	255	325	30	1	1725	✓			RAK-4

CAP						OTHER FRIENDLIES	
CALL	TN	ANG	STATE	STATION	TIME	TN/CALL	REMARKS
SB201/203	0275	24	160-4-0-2	270ZZ60	1715	0251	TANKER
GS110/107	0261	30	150-4-4-0	000ZZ-60	1715		

OS311010

Figure 10-10.—Example of a tote board.

Ideally, the tote board is located next to the air summary plot. The two boards together form the complete air summary display. The main plotter is located behind the board and plots all of the amplifying data on own ship's radar contacts. He or she usually figures the course and speed of each contact by measuring the distance and direction traveled in a certain period of time on the air summary board, and receives composition and altitude information on sound-powered phones from the radar operator. The main plotter receives other amplifying information from the RCO or the air controller.

One or two plotters, located in front of the board, plot amplifying data on air contacts as it is received from other ships on R/T nets. On ships that have a limited number of personnel, the R/T plotter-talkers who are plotting on the front of the air summary plot may also have to maintain the tote board. If sufficient personnel are available, a second plotter can be placed behind the board to plot data on friendly aircraft. The main plotter can concentrate on only bogey data.

Since the tote board illustrated in figure 10-10 is an example, it can easily be modified to include more friendly information as required. The upper section of the tote board pertains to bogeys and includes alphanumeric designation, track number, course, speed, altitude, composition, time, and weapons assigned. The remainder of the board is devoted to friendly air contacts, such as CAP and strike aircraft. Contained in this section is information on the CAP, for example, the call sign, track number, assigned altitude, state (fuel and weapons on board), station (a number, code word, or bearing and range), and time. For other friendly aircraft, the call sign or track number and mission (under "Remarks") are all that is necessary.

The tote board plotters must actually work on two separate boards—the tote board and the summary plot. In performing their duties, they must do the following:

1. Watch the summary plot and list new bogeys on the tote board under the "Bogey" section.
2. Use their grease pencils to measure the distance the raid traveled in a certain time by contacts on the summary plot, compute speed, and determine course.
3. Receive bogey composition from the radar operator and record it under the "Bogey" section.
4. Record altitude of the raid. (Depending on circumstances, this height figure may come from own radars or from the CAP. If it comes from the CAP, the plotters will receive the data from the air controller via the RCO.)
5. Record any information relayed to them by the R/T net plotter, the link 14 plotter, and the air controller.

CONVERSION PLOTTING

Various methods of making position reports are in use today in anti-air warfare operations. Some of these methods are (1) latitude and longitude; (2) grid systems; and (3) bearing and distance from own ship, another designated ship, or from a specified point. You may have to use any of these three basic methods to report positions. You may also have to convert information in one system to equivalent information in another system. For example, you may have to translate raid positions received in the task group's coordinate system to polar coordinates for weapons target designation. The OTC will normally specify the most suitable reporting method in each situation.

Even when you don't have to convert information from one system to another, you may have to convert information within the same system. For example, you may have to convert range and bearing information of own ship's radar to range and bearing information for another ship in the task group. The simplest and quickest way to do this is the parallelogram method.

Figure 10-11 shows the parallelogram method. Suppose point A represents own ship and point B represents the flagship, bearing 070-30 miles. Own ship picks up and plots bogey X, bearing 010-50. Your task is to report the bearing and range of the bogey from the flagship, B. To solve the problem quickly, place a pencil on the imaginary line that connects B and X. Note the distance from B to X. Now move the pencil parallel to line BX until it lies over point A. Note the point (C) that is located the same distance from point A that point X is located from point B. Read the range and bearing of point C from point A. By the rules of a parallelogram, this is also the range and bearing of point X from point B. In this problem, bogey X bears 333° at a range of 43 miles from the flagship B.

You can also use the parallelogram method to convert a contact position you receive from another ship to own ship reference. Suppose the flagship, B, gave you the range and bearing of bogey X from B. How do you determine the range and bearing of X from own ship? First, plot (or use your pencil to determine) point C from point A using the same range and bearing

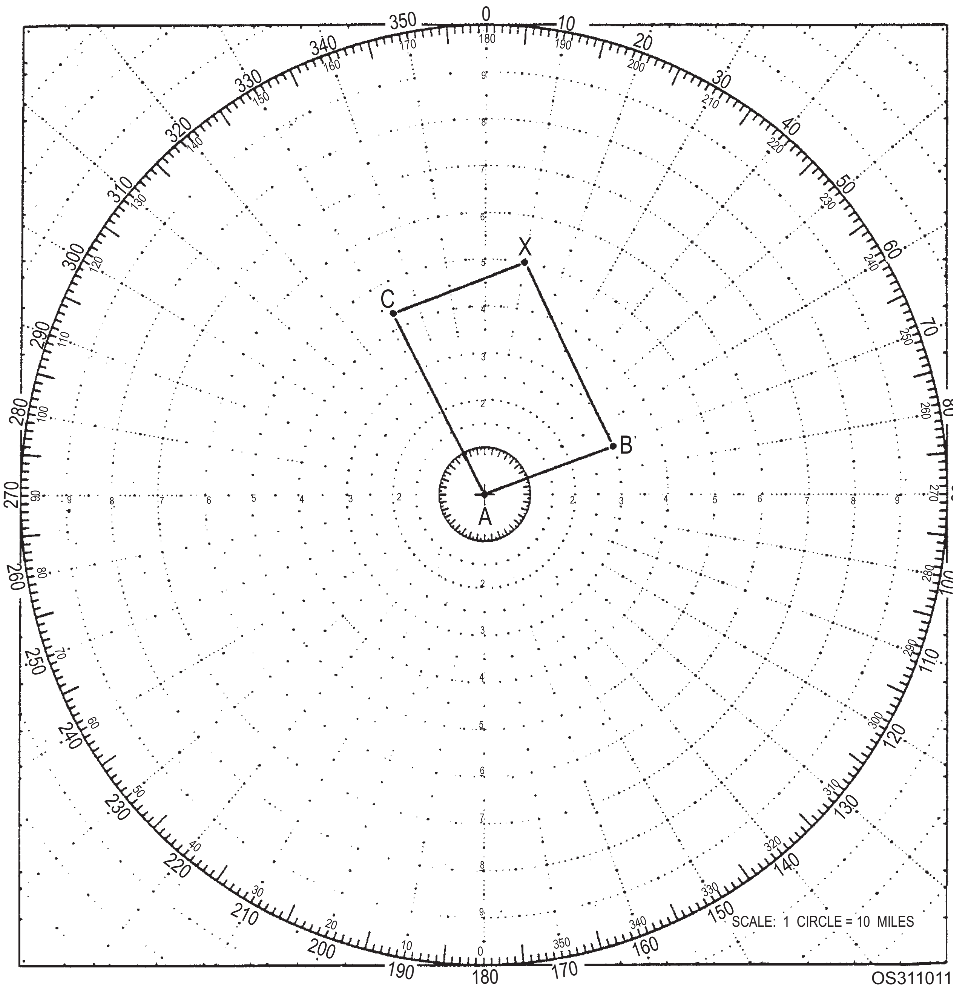


Figure 10-11.—Example of a conversion plot.

information supplied by the flagship. Now move a line equal in length to line AC parallel to AC until the "point A" end of the line coincides with point B. Mark the "point B" end of the line at the new location. This point is the location of bogey X. Finally, determine the range and bearing of X from own ship, A.

Q5. What scale is normally used to set up an air summary plot?

Q6. What information is plotted on a tote board?

ASW PLOTTING

Two of the key figures in maintaining the display of the ASW tactical situation are the DRT plotters. The DRT plot is the heart of ASW operations in CIC. It displays much more than the location of the submarine and the surface ships; it also records other vital information, such as hydrophone effects, weapons launched, and depth indications. The importance of having a permanent and easy-to-read record of this information is that the information often has little significance at the time it is obtained, but when the TAO/evaluator later looks over the entire operation, all of the important details come together as one significant whole. For this reason, the plotters should be highly experienced. Usually, there are two plotters—No. 1 and No. 2. The No. 1 (or south) plotter records own ship's contact and, hence, must wear the 61JS phones. The No. 2 (or north) plotter plots the assisting ship and the assisting ship's contact. He or she, therefore, must wear the 21JS phones over one ear and, at the same time, listen to the TG REPT net speaker for the assisting ship's contact reports.

DRT PLOTTING PROCEDURES

The importance of the DRT in successful ASW operations warrants a close look at the procedures and symbols used in ASW plotting.

Own Ship—Own ship's track is plotted using a circle with a cross inside. By using this symbol to mark the periodic position of the DRT bug and connecting the plots, the plotter can determine the ship's approximate course between the several positions. Own ship's track should be plotted in black, with succeeding positions recorded on the plot at intervals of 1 to 5 minutes, based on the range of the ASW action (long-range or close-in). Occasionally, arrows should be added to show the direction of the ship's movement. Marking arrows on the plot is particularly important when the ship is working over a contact in a limited area. Because plots often crisscross, the arrows enable personnel reviewing the plot later to gain a more comprehensive picture of the ship's actual maneuvers.

Submarine—A submarine's track is plotted using the appropriate submarine symbol. On every report from sonar, a plot must be made of the true position of the submarine. (This plot can be a dot with the symbol plotted at 3- to 4-minute intervals.) The submarine's track should be recorded in either black (friendly) or red (unknown or hostile), with succeeding positions recorded on the plot at intervals necessary to maintain a proper plot (1 to 3 minutes).

Assist Ship—The assist ship is plotted in blue with the surface friendly symbol. Subsequent positions should be plotted as necessary to clarify the plot.

As assist contact reports are received, they are plotted in red, with an X inside the contact symbol indicating that the report came from a ship and a small square indicating that the report came from an aircraft. Assist contact reports are less frequent than own ship's contact reports, so time may be plotted as the reports are received over the radio.

When contact is lost, the plotter dead reckons the contact, and the TAO/evaluator orders search arcs. Dashed lines indicate the DR track.

Other important symbols consist of squares or circles enclosing a letter. One of these symbols is an encircled K, representing a *knuckle*, a sharp turn made by a ship using its engines or heavy rudder. This symbol serves as a reminder in later operations through the same area that sonar may receive echoes from the water disturbance.

Another situation calling for a distinctive symbol is when a submarine emits a water slug, flare, smoke, or decoy that creates sonar echoes. (A slug is ejected air that rises to the surface and can be seen easily because of the resultant discoloring of the surface water.) These items are plotted as a square with the appropriate letter (W, F, S, or D) inside the square.

EMERGENCY PLOTTING

During ASW operations on most ships, if a casualty occurs on the DRT, the plotters should use the Halifax plot described in chapter 9 (see figure 9-8). Before the Halifax plot is used, the DRT paper should first be lightly marked off with parallel north-south and east-west lines about 2 inches apart.

Emergency plotting procedures call for more plotters. An own ship's plotter, using the plotting scale, the ship's tactical data (templates, if possible), and information supplied by the ship's information talker, maintains a plot of own ship's position. The plotter keeps the plotting scale properly oriented underneath the DRT paper, with its center below own ship's position. At the same time, other plotters record information on the submarine and the coordinating ship(s).

The ship's information talker, stationed next to the plotting table, uses a stopwatch to provide *Mark* signals every 15 seconds. At these intervals he also announces the ship's course, speed, and rudder to enable own ship's plotter to maintain the track.

The regular south plotter is responsible only for plotting the submarine at 15-second intervals. The north plotter performs the same functions as in regular plotting except that, instead of using the DRT bug, the north plotter uses the plot of own ship's plotter as a point of reference.

Several variations of the Halifax plotting procedure have been used in the fleet. The procedure described below is one of those, but individual ships may find it necessary to introduce modifications to suit their own needs.

When the TAO/evaluator gives the order "Commence emergency plot," the ship's information talker sets his stopwatch at the start of the next 15-second interval of the CIC direct reading clock. He announces "Mark" and own ship's present course, speed, and rudder. He continues to call "Mark" and gives this information at 15-second intervals.

At the first *Mark*, own ship's plotter, who has the plotting scale correctly oriented under the DRT paper, marks own ship's position. If at all possible, the ship should maintain a speed of 15 knots while emergency plotting is in progress, to support dead reckoning. At this speed, the 1/2-inch circle of the Halifax plot represents the distance traveled in 30 seconds. Turns must be plotted on the basis of the ship's tactical data.

The sonar supervisor receives the initial mark from CIC and starts his stopwatch. With a system of "Stand by—Mark" signals, he ensures that a range and bearing to the submarine are supplied to the north plotter every 15 seconds via the sonar information circuit.

Using red pencil and plotting symbols, the north plotter plots each submarine position.

The south plotter, at each "Stand by—Mark" signal given by the information talker, receives from the radar repeater operator a radar range and bearing to the assist ship. As soon as the north plotter plots the submarine information, the south plotter plots the coordinating ship.

Own ship's plotter then moves the plotting scale to the next 15-second position of own ship.

The surface scope operator must have the radar repeater at the proper range setting for marking the assisting ship, which may be close to own ship at times during the operation. The surface scope operator wears the 21JS sound-powered phones and marks the assisting ship, ships of the SAU (Search-Attack Unit), and helicopters or Skunks for the No. 2 plotter and the maneuvering board operator. During weapon attacks (ASROC), the surface scope operator also marks the water entry point if it is seen on the scope.

Q7. During ASW plotting, what sound-powered phone circuits do the north and south plotters talk on?

Q8. What color and symbol should the plotter use to plot an assist ship on the DRT?

TARGET MOTION ANALYSIS AND PASSIVE LOCALIZATION

Target motion analysis (TMA) is a method of tracking a submarine by using information obtained by passive means. This section presents single-ship TMA procedures and is organized to present a logical flow through the TMA process. We begin with definitions, symbols, acronyms, abbreviations, and a list of the plots used in the TMA process.

Silent search sonar information usually consists of an indication of the contact's bearing and, sometimes, clues to its classification. Several methods have been developed that rely on target bearing information to obtain the contact's range, course, and speed. The process of calculating these values is called target motion analysis (TMA). You must understand the inputs, basic assumptions, and underlying principles of the TMA process and methods to implement these methods effectively and to interpret their results.

Figure 10-12 is a summary of the TMA symbols and parameters (fire control values) that are used in this chapter. A graphic example is provided to assist in visualizing each parameter.

LINE OF SIGHT (SOUND) DEFINITIONS AND SYMBOLS

To develop an understanding of TMA, you must learn the line-of-sight (LOS) diagram. It is an essential tool to help you visualize the motion relationship between own ship and the target. Most TMA techniques break target and own ship motions into various components in and across the line of sight in order to measure or compute various quantities. Figure 10-13 is the basic LOS diagram. It shows the various components of own ship and target motions used in TMA.

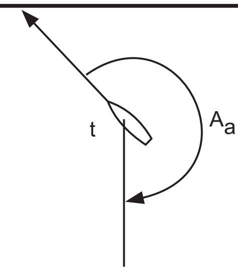
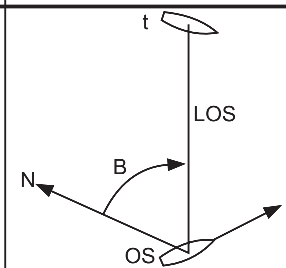
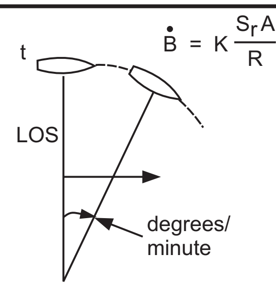
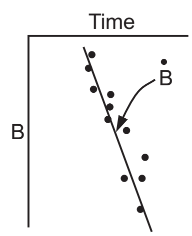
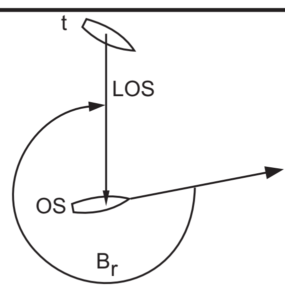
In practice, the LOS diagram is a simple, logical, and orderly method of viewing the relationship of own ship and the target ship during all phases of approach and attack. It is an instantaneous vector picture that shows own ship and the target ship oriented about the LOS common to both ships. Figure 10-14 illustrates components of the line-of-sound diagram.

The LOS (view A) is the line from own ship to the middle of the target. The distance from own ship to the middle of the target (view B) is the range (R). Target course (C_t) vector (view C) extends in either direction through the longitudinal axis of the target and is determined by angle on the bow. Own ship's course (C_o) vector (view D) extends from the engaged axis (the end of own ship pointing toward the target). When the lines representing target course and own ship's course are extended (view E), a target vector and an own ship vector result.

Presented in view E is a complete LOS diagram showing symbols of LOS, C_t, C_o, R, LA, and A_b. Any change in these values results in a corresponding change in the LOS diagram. In conclusion, it can be said that this diagram shows an instantaneous and constantly changing picture of the relative positions of own ship and the target.

ANGLE ON THE BOW

Angle on the bow (A_b) is the relative bearing of own ship from the target, expressed in angles up to 180° port or starboard of the target's bow. Although

SYMBOL	TERM	EXAMPLE	DEFINITION
A_a	ASPECT ANGLE (TARGET ANGLE)		THE ANGLE BETWEEN THE VERTICAL PLANE THROUGH THE TARGET SPEED VECTOR AND THE VERTICAL PLANE THROUGH THE LINE OF SOUND.
B	TRUE TARGET BEARING		THE ANGLE FROM NORTH TO THE LINE OF SIGHT MEASURED CLOCKWISE THROUGH 360°
$\dot{B}$	BEARING RATE INDICATE RIGHT OR LEFT		THE RATE OF CHANGE OF TRUE TARGET BEARING, EX-PRESSED IN DEGREES PER MINUTE, MEASURED RIGHT OR LEFT IN THE SAME DI-RECTION AS S_tA
$\overline{B}$	FAIRED BEARING		A LINE FAIRED THROUGH A SERIES OF RAW BEARINGS. MATHEMATICALLY, A LEAST-SQUARES SOLUTION.
B_r	RELATIVE TARGET BEARING		THE ANGLE FROM OWN SHIP'S COURSE AND SPEED VECTOR TO THE LINE OF SIGHT, MEASURED CLOCKWISE FROM THE BOW THROUGH 360°

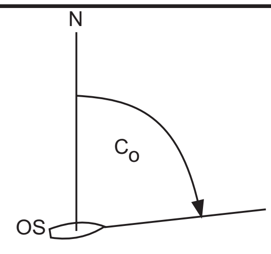
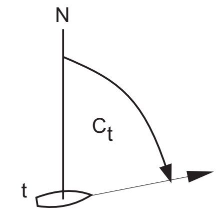
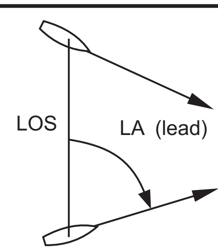
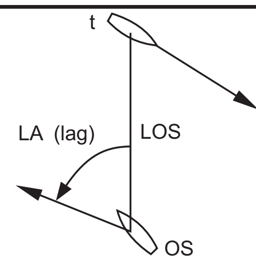
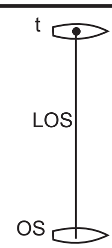
OS311012a

Figure 10-12.—TMA symbology and definitions.

both angle on the bow and target angle are determined by relative bearing of own ship from a target, they differ in this respect: Angle on the bow is measured 0° to 180° port or starboard from target bow, whereas target angle (A_a) is measured clockwise from the target bow in a full 360° circle.

When you know own course and relative target bearing (see figure 10-12), angle on the bow makes it possible to determine the true course of the target.

True target course (C_t) is determined in the following manner: Take the reciprocal of true target bearing (own ship's true bearing from target) and

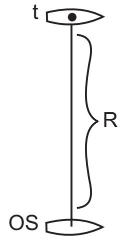
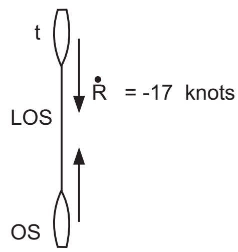
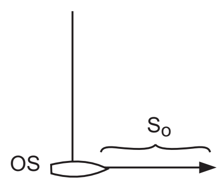
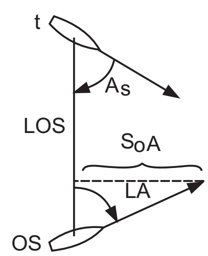
SYMBOL	TERM	EXAMPLE	DEFINITION
C	SPEED OF SOUND	NONE	SPEED OF SOUND IN WATER - EXPRESSED IN FEET PER SECOND
C_o	OWN SHIP COURSE		THE ANGLE FROM NORTH TO OWN SHIP'S TRACK MEASURED CLOCKWISE THROUGH 360^o
C_t	TARGET COURSE		THE ANGLE FROM NORTH TO OWN SHIP'S TARGET TRACK MEASURED CLOCKWISE THROUGH 360^o
LA	LEAD ANGLE		ANGLE MEASURED FROM THE LINE OF SIGHT TO OWN SHIP'S TRACK (0^o TO 180^o)
	LAG ANGLE		WHEN OWN SHIP'S TRACK IS NOT INCLINED IN THE DIRECTION OF TARGET MOTION, IT IS CALLED A LAG ANGLE
LOS	LINE OF SIGHT		A LINE FROM OWN SHIP TO THE TARGET

OS311012b

Figure 10-12.—TMA symbology and definitions (Continued).

subtract the angle on the bow; the difference is true target course. When visual sighting is impossible, angle on the bow can be calculated from estimated target course based on one of the sonar plots (discussed later in this chapter). To obtain angle on the bow by this method, subtract target course from the reciprocal of target bearing ($B_{ts} = B_y + 180° - C_t$).

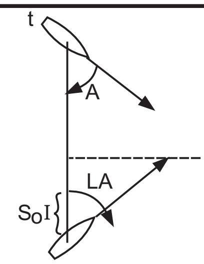
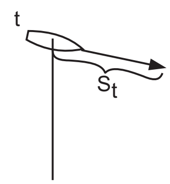
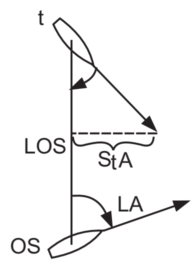
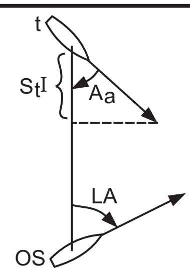
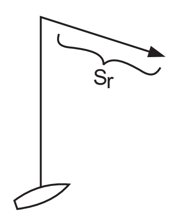
Relative angle on the bow (A_{br}) is defined as the angle measured from the direction-of-relative-motion (DRM) line to the line of sight or sound (LOS). Its use comes into play extensively when you use the time bearing and relative motion plots and the bearing rate computer. You can easily understand relative angle on the bow if you consider a target that is on a collision

SYMBOL	TERM	EXAMPLE	DEFINITION
R	RANGE		THE DISTANCE FROM OWN SHIP TO THE TARGET
$\dot{R}$	RANGE RATE PREFIX: +OPENING -CLOSING		THE ALGEBRAIC SUM OF S_tI AND S_oI EXPRESSED IN KNOTS OR YARDS PER MINUTE. R MUST BE PREFIXED + FOR OPENING RANGE OR - FOR CLOSING RANGE.
S	SPEED		MOVEMENT THROUGH THE WATER EXPRESSED IN KNOTS OR YARDS/MINUTE
S_o	OWN SHIP SPEED		OWN SHIP'S SPEED THROUGH WATER IN KNOTS
S_oA	OWN SPEED ACROSS LOS PREFIX: R RIGHT L LEFT		THE MEASUREMENT (COMPONENT) OF OWN SPEED PERPENDICULAR TO THE LOS, MEASURED RIGHT OR LEFT IN KNOTS $S_oA = S_o \sin LA$

OS311012c

Figure 10-12.—TMA symbology and definitions (Continued).

course with own ship. In this situation, relative angle on the bow is zero. In another example, a target that is at its closest point of approach (CPA) has a relative angle on the bow of 90°. With respect to a target bearing rate, when A_{br} equals 0°, target bearing rate is 0, and no range solution is possible. When A is 90°, bearing rate is a maximum value. Aboard a submarine, target angle is derived by a method known as angle on the bow (A_b). Whereas the ship uses 360° for computing target angle, the submarine uses only 180°, specifying port or starboard side. For example, a destroyer has a submarine bearing 070° relative. Aboard the submarine the target angle would be reported as "Angle on the bow, starboard 70." A relative bearing

SYMBOL	TERM	EXAMPLE	DEFINITION
S_OI	OWN SPEED IN LOS PREFIX: + OPENING - CLOSING		THE MEASUREMENT (COMPONENT) OF OWN SPEED PERPENDICULAR TO THE LOS, MEASURED RIGHT OR LEFT IN KNOTS $S_O I = S_O \sin(90^{o} - LA)$
S_t	TARGET SPEED		TARGET SPEED THROUGH THE WATER IN KNOTS
S_tA	TARGET SPEED ACROSS LOS PREFIX: R RIGHT L LEFT		THE MEASUREMENT (COMPONENT) OF TARGET SPEED PERPENDICULAR TO THE LOS, MEASURED RIGHT OR LEFT IN KNOTS $S_tA = S_t \sin(90^{o} - A_a)$
S_tI	TARGET SPEED IN LOS PREFIX: + OPENING - CLOSING		THE MEASUREMENT (COMPONENT) OF TARGET SPEED IN THE LOS MEASURED OPENING OR CLOSING IN KNOTS $S_tI = S_t \sin(90^{o} - A_a)$
S_r	RELATIVE SPEED PREFIX: R RIGHT L LEFT		THE SPEED RESULTING WHEN OWN SPEED COMPONENTS ARE REMOVED FROM TARGET SPEED COMPONENTS

OS311012d

Figure 10-12.—TMA symbology and definitions (Continued).

of 345° from ship to target is reported on the submarine as "Angle on the bow, port 15."

BEARING RATE

Bearing rate ($\dot{B}$) is change of target bearing, in degrees per minute. It is the algebraic sum of the components of target and own ship motion across the LOS converted into angular measurement in degrees per minute. By definition, right bearing rates are positive (+); however, we use the notation *right* or *left*, not positive or negative. Therefore, all components of speed across the LOS (S_oA, S_tA, and S_rA) must be labeled right or left so that $\dot{B}$ and S_rA are always in the same direction.

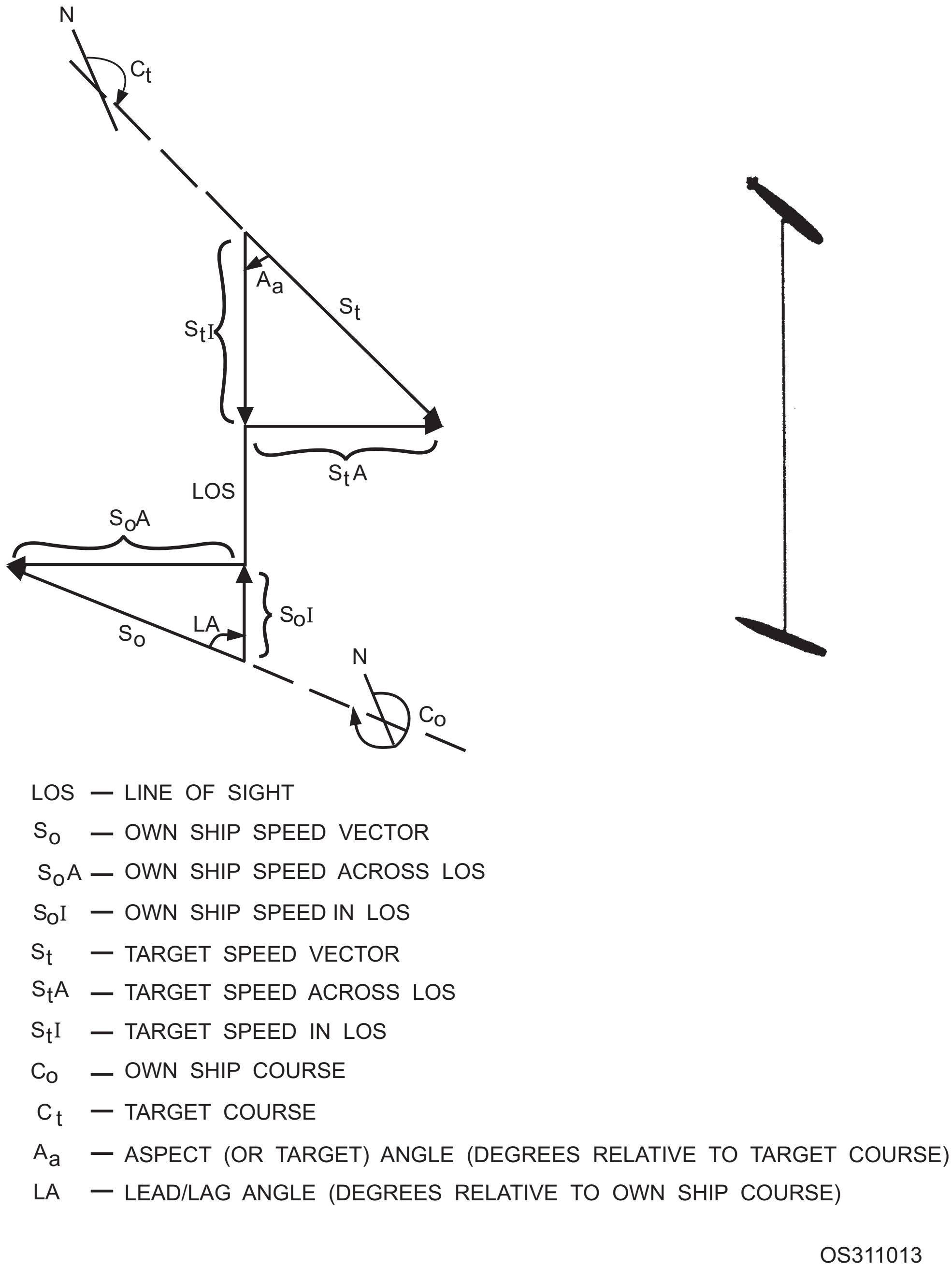


Figure 10-13.—Line of Sight/Sound (LOS) diagram.

ANALYSIS OF TARGET MOTION

Basic elements of target motion analysis are target speed, course, range, bearing, and bearing rate. Bearing rate ($\dot{B}$) is a quantity for use in developing target course, speed, and range.

Establishing Bearing Rate

The primary objective of establishing bearing rate is to calculate target course and speed. If the target cannot be observed visually, true target motion can be learned most readily by hovering or heading directly toward the target. This method is simple and results in no own ship's component across the LOS. The bow normally should be headed toward the target to produce a more aggressive approach and to avoid loss of sonar contact astern. If angle on the bow can be ascertained, direction of true target motion is known.

Once direction of true target motion is known, bearing rate can be determined by using one of the relative plots (discussed later). These plots provide certain data that can serve as known values in calculating many unknown values. These calculations are accomplished by means of a bearing rate computer.

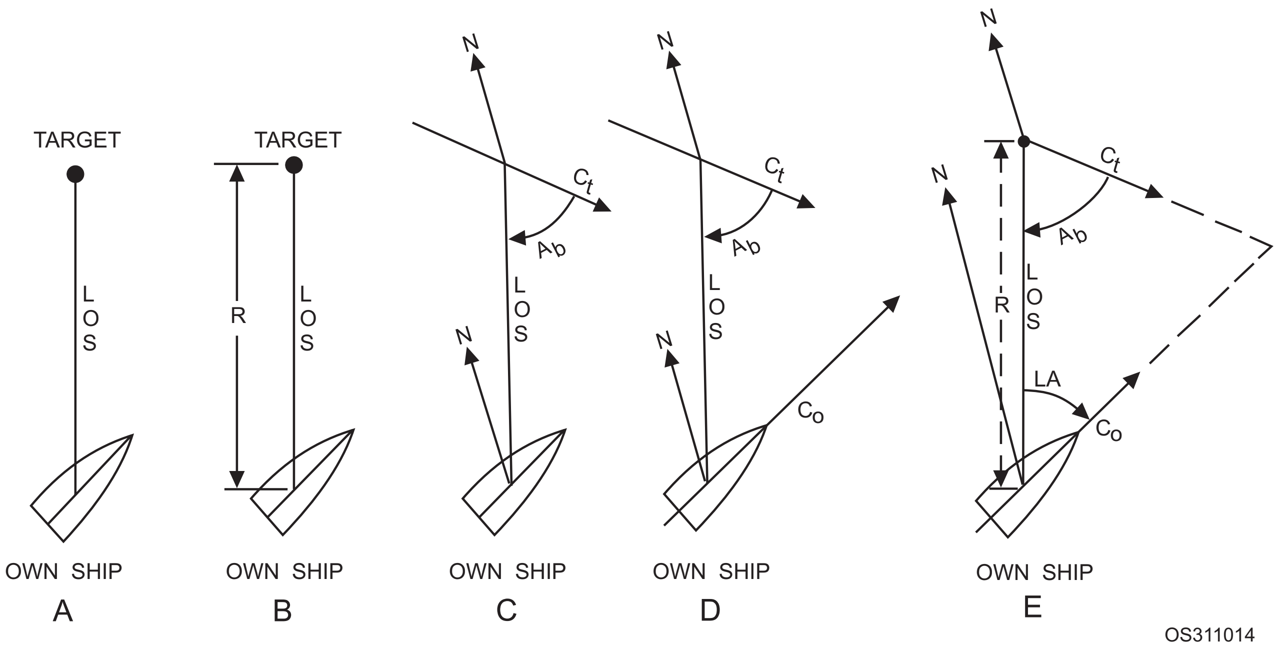


Figure 10-14.—Breakdown of LOS diagram.

Bearing Rate Computer

The bearing rate computer (BRC) is a tool used by ASW plotting personnel aboard surface ships to compute the following values:

1. Own ship's speed across the LOS
2. Target speed across the LOS
3. Target range, using total relative speed across the LOS and the bearing rate
4. Ekelund range, using own ship's speed across the LOS and bearing rate totals for two different legs

The bearing rate computer (also called bearing rate slide rule (BRSR)) is a circular slide rule consisting of two concentric discs, each scribed with two scales and a movable cursor. See figure 10-15. From the outer edge inward, these scales are target speed, bearing rate, range, and angle on the bow. Range and speed scales are inscribed on a fixed element. Bearing rate and angle-on-the-bow scales are inscribed on a movable element attached to the fixed element. For convenience in aligning the slide rule and reading values, a cursor is mounted on top of the fixed and movable scales.

Labeling of the angle-on-the-bow scale permits entering directly an angular value whose sine is desired. This angle-on-the-bow scale can be used for any angle whose sine is needed—whether bow, lead angle, deflection angle, or other angle. The 90° mark on the angle-on-the-bow scale represents the sine of 90° or 1; 30° on the same scale represents the sine of 30° or 1/2.

Time/Bearing Plot

The time/bearing curve or plot is the keystone to almost all TMA techniques. The purpose of the plot is to provide a graphical display of target motion with respect to time, giving insight into critical events as they occur as well as quantitative inputs to other TMA techniques. You can visualize the relationship of the time/bearing plot information by considering a long-range closing contact that maintains constant course and speed. If own ship also maintains course and speed, the bearing changes slowly at first, with the bearing drift (rate of bearing change) increasing gradually as range decreases. As the contact closes to CPA, the bearing rate increases more rapidly, reaching a maximum value at CPA, and then decreases as the contact opens. As the range increases, the bearing rate decreases to near zero. Figure 10-16 shows the time/bearing curve for the target and own ship tracks shown in figure 10-17. The tactically significant features of the time/bearing plot are as follows:

1. If own ship and target maintain constant course and speed, the bearing drift is always in the same direction. As range decreases, the bearing rate increases from near zero to a maximum at CPA, then decreases to zero as the range increases. The rate and direction of bearing drift depend on relative course and speed as well as range. A sharp change in the bearing rate may indicate a

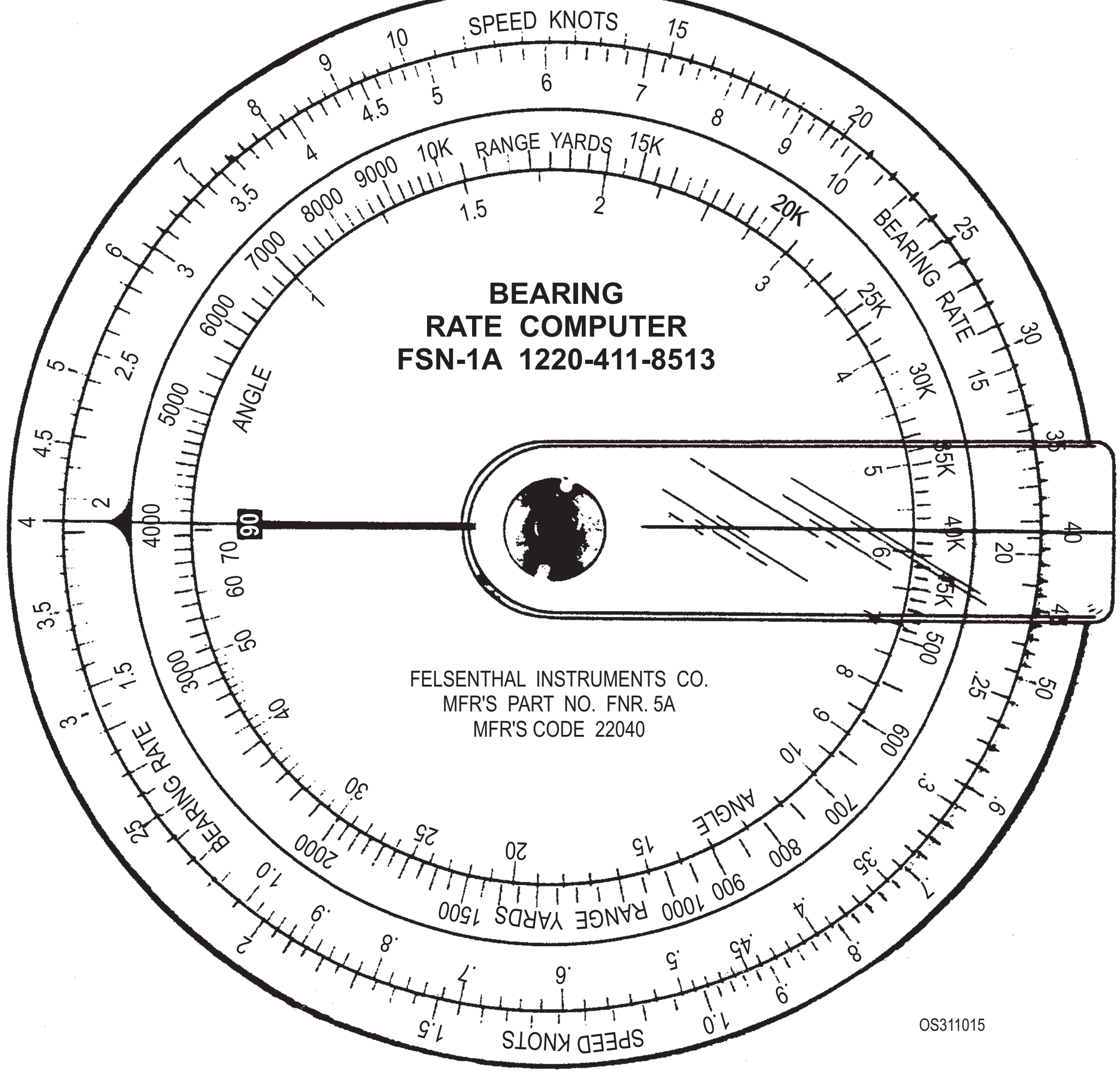


Figure 10-15.—Bearing Rate Computer (bearing slide rule [BRSR]).

target (or own ship) maneuver. A change in the direction of bearing drift, however, always indicates a maneuver.

2. The bearing rate is proportional to relative speed across the LOS and inversely proportional to range. The bearing rate at CPA can be used to estimate either the target range or speed, given an estimate of the other. A bearing rate of about 3° per minute or higher is a strong indication that the target is close enough for the TAO to consider going to an active search. Once the target has closed to active detection range, there is no further advantage to remaining in silent search, as the surface ship is extremely liable to detection by the submarine.

3. While a TMA solution is being developed, own ship should remain at a constant course and speed for 10 to 20 minutes, depending on the particular TMA method being used. Thus, the CIC team is unlikely to observe more than a segment of the total time/bearing curve, shown in figure 10-16. The segment they observe will most likely appear nearly linear, as in figure 10-18. An observable change in bearing rate or a break in the time/bearing plot that is not due to an own ship or target maneuver gives a rough indication of range when the target is near CPA. A rapid change in bearing rate, observed as an abrupt break on the time/bearing plot, indicates that the target is passing close aboard, while a less pronounced break indicates a more distant target. In general, the higher the bearing rate, the

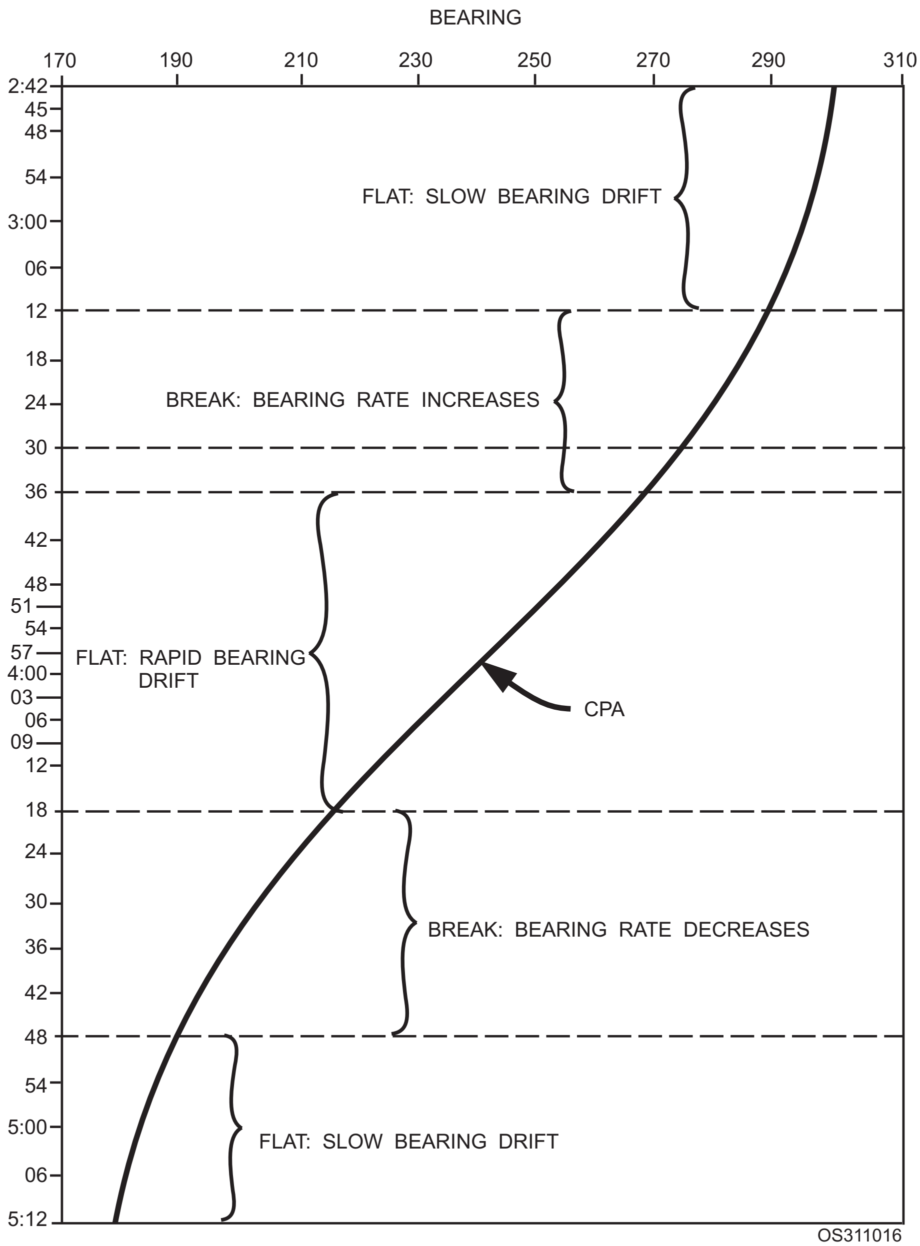


Figure 10-16.—Time/bearing curve (breakdown).

greater the probability that the target will be a short-range target. This relationship is frequently overlooked in determining the appropriateness of various passive TMA techniques versus an active sonar search. The plot supervisor must constantly examine the time/bearing plot as it develops, observing bearing rate and changes in bearing rate.

Time/Bearing Plot Equipment

Construction of the time/bearing plot requires the following equipment:

1. Plotting surface
2. Roll of 1-inch grid (graph) DRT paper
3. Bearing rate templates scaled 1" = 1 min/1" = 5°, and 1" = 1 min/1" = 1° (fig. 10-19)
4. Dividers
5. Parallel rulers
6. Number 2 lead pencils/colored pencils and gum erasers.
7. Ship's curve if available

Plotting Procedures

Initially construct a horizontal bearing scale of 1° per inch across the top of the grid, increasing to the

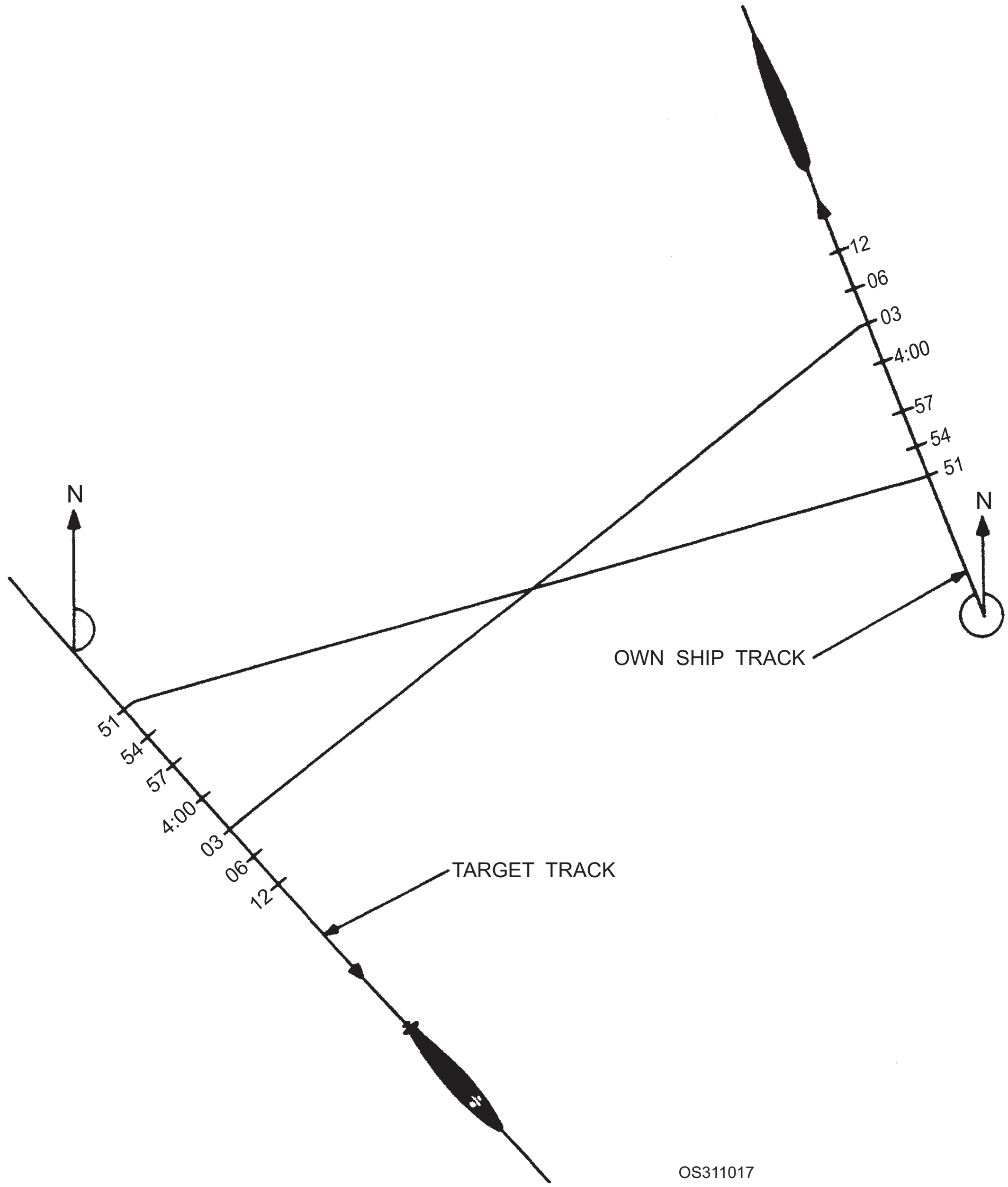


Figure 10-17.—Example of own ship and target actual tracks.

right. Mark off a vertical time scale of 1 minute per inch down the grid. If the bearing rate exceeds 3° per minute, change the horizontal scale to 5° per inch.

Plot each target bearing as it is reported. Plot the bearings as accurately as the grid will allow. The more accurate the initial bearing plots, the more accurate the solution. Figure 10-20 shows how the bearing scale and time scale are laid out on the grid for a contact with a 3º per minute or greater bearing rate.

After you observe a bearing drift of at least 5° or an interval of 10 to 20 minutes, draw a faired (average) line through the plotted points as in figure 10-18. This line helps average out the random error in raw sonar bearings. When you fair a line through bearing points, use a minimum of 10 minutes worth of data, and preferably 10 data points obtained during that time. Draw the faired line only through the first 8 minutes of points, however. Reserve the last two points as the first two points of the next set of data points through which you fair the next line. This provides continuity in target motion. If your plot includes vertically "stacked" bearings, use only the beginning data point of each stack. This may result in fairing less than the desired number of data points, but will provide a more accurate picture of target motion (fig. 10-20).

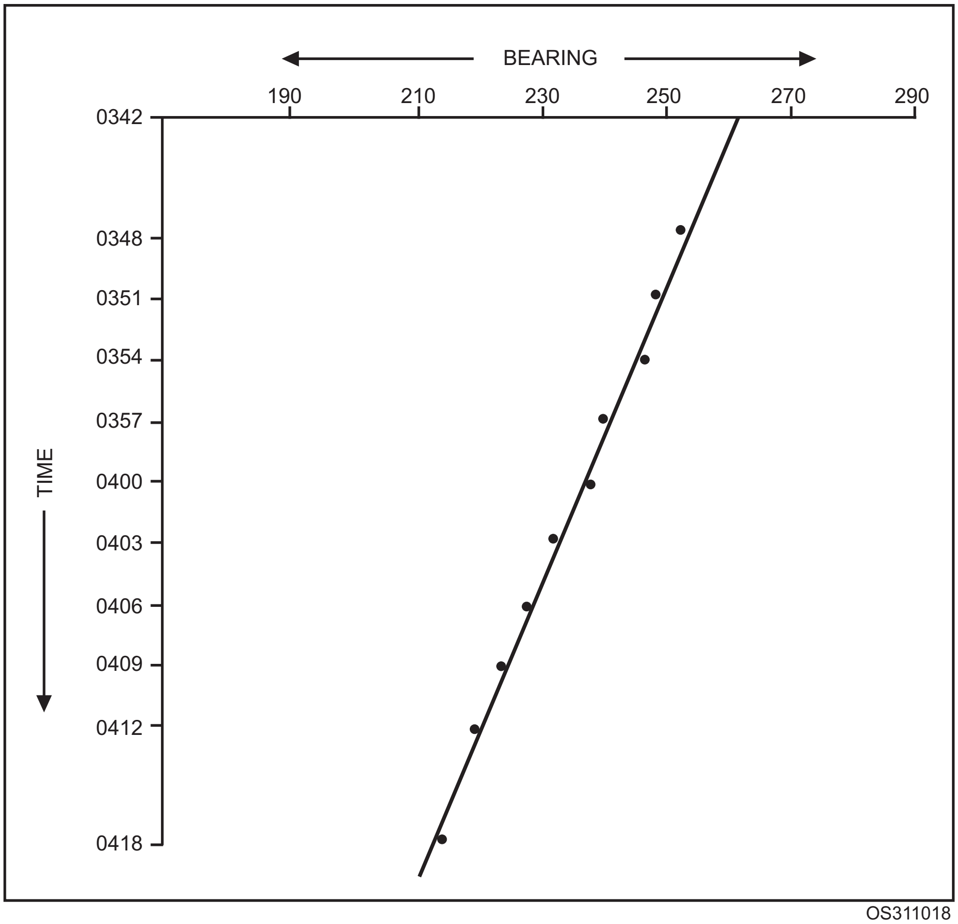


Figure 10-18.—Time/bearing plot segment.

If own ship changes course or speed, draw a horizontal line through the plot to indicate the time of the change. Resume plotting when own ship has steadied on its new course and speed. Draw another horizontal line through the plot at this time, and label this line with the new course and speed. If you are using bearings from a towed array, allow at least a time interval equal to that required to tow the array through two times its length after own ship is steady on the new course. Cross-hatch the plot during the time of the maneuver.

For each leg or segment of faired data, compute the bearing rate (slope of the faired bearing line), using a bearing rate template (fig. 10-21) as follows:

1. Select a template with a scale corresponding to the plot scale.
2. Place the zero line (center line, fig. 10-19) of the template along the faired bearing line.
3. Read the bearing rate from the line closest to parallel to the vertical line.

Another method is to set the zero scale vertically through a selected time mark and read the bearing rate ($\dot{B}$) where the faired bearing crosses the template scale.

Draw a box near the bearing midpoint of the data points that you measured. Record the midpoint bearing (B) and bearing rate ($\dot{B}$) in the box, and indicate the midpoint of the leg with an arrow. Label the bearing rate as measured either right or left.

Figures 10-22 and 10-23 show how a complete time/bearing plot will appear when plotted and labeled correctly.

NOTE

Accurate clock-time synchronization between CIC and sonar is extremely important and should be checked to the nearest second several times while passive ASW operations are being conducted.

For very-long-range contacts, bearing rates will be small (1°/min or less) and will be difficult to measure using the 1" = 1 minute time scale. In such instances, you may use a reduced time scale (for example, 5 or 10

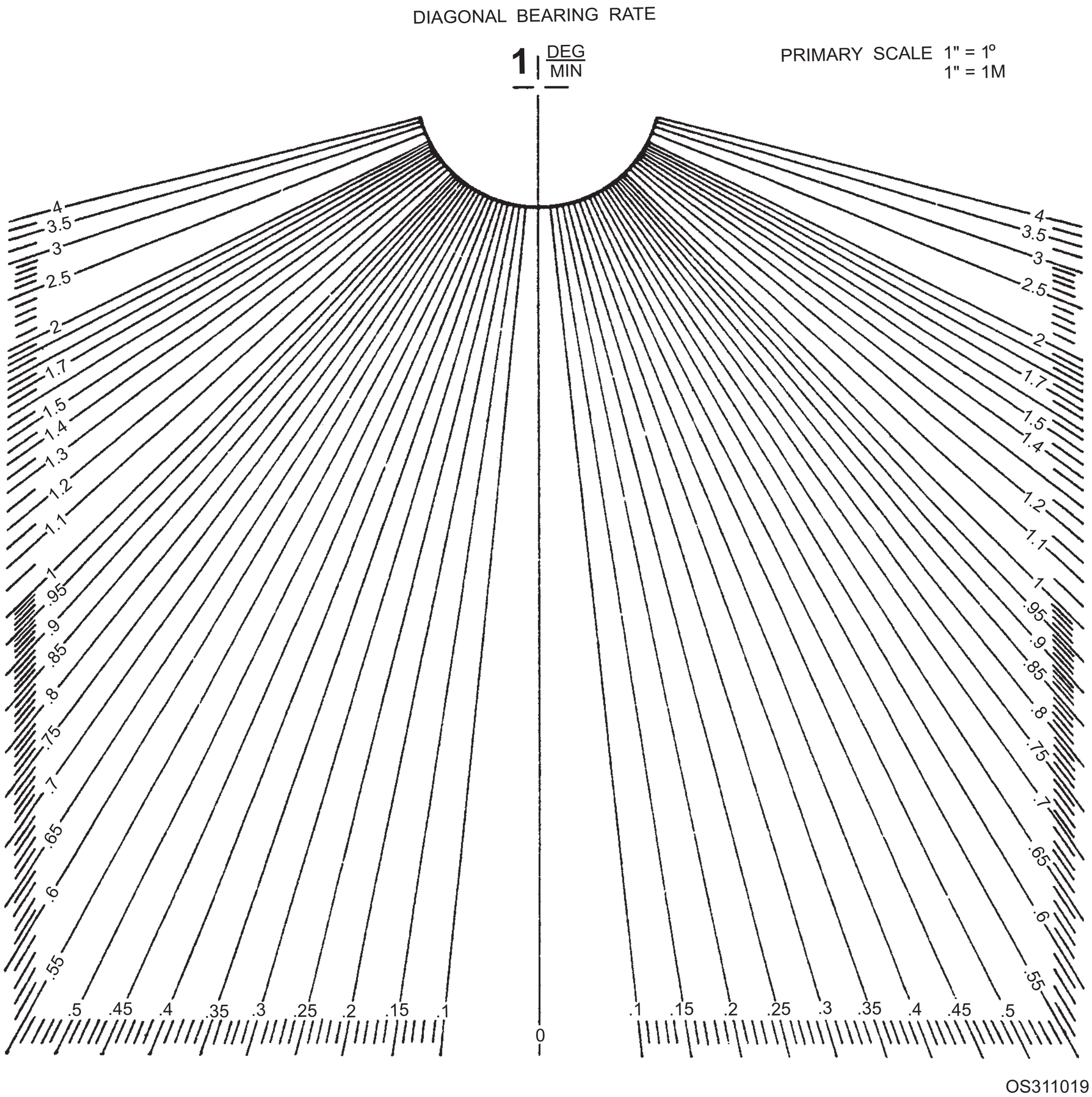


Figure 10-19.—Bearing rate template (one degree per minute).

minutes per inch) to display a greater amount of information. For extremely low bearing rates (0.5°/min or less), you may need to use up to 30 minutes or more of data to discern any evidence of bearing rate ($\dot{B}$). If you also reduce the horizontal bearing scale to an equivalent scale, you may still use the 1" = 1 min/1" = 1° bearing rate template. If the contact maneuvers during the extended plotting time, recompute the bearing rates from the point of the maneuver.

Q9. What is the primary purpose of establishing a bearing rate?

Q10. What plot is the keystone to almost all TMA techniques?

GEOGRAPHIC PLOTTING TECHNIQUES

Geographic plotting techniques attempt to estimate target course, speed, and range by fitting trial target tracks (speed strips) to a set of bearing lines drawn from own ship's position at designated times. Useful TMA information can be obtained on a single leg if the target's speed is known or can be estimated. Own ship can maneuver and extend the plot over two or more legs to obtain a complete TMA solution without an assumed target speed. As with any proven passive TMA technique, the target must maintain steady course and speed. Geographic plotting requires the following equipment.

1. DRT
2. PMP

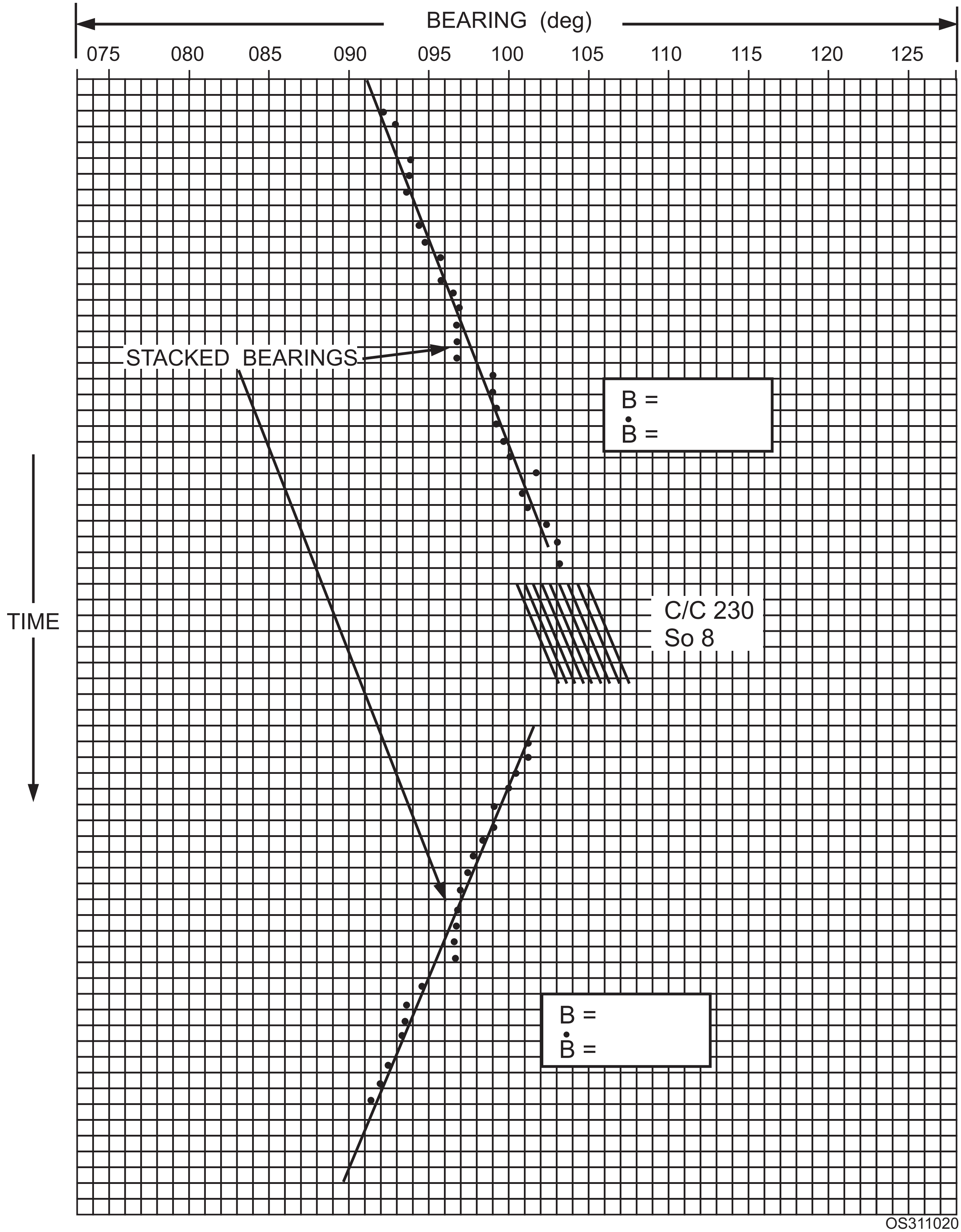


Figure 10-20.—Time/bearing plot (stacked bearings).

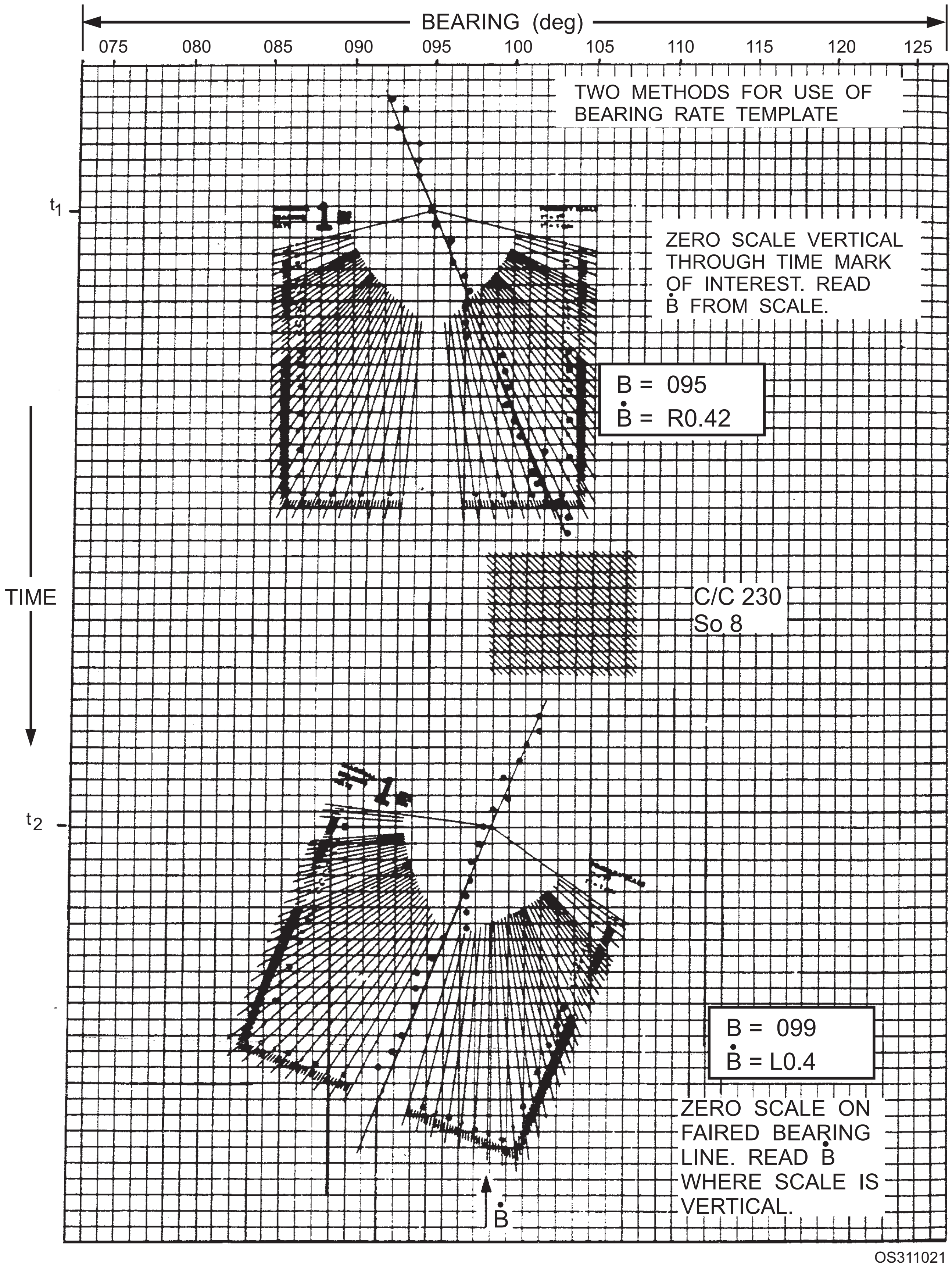


Figure 10-21.—Example of the use of bearing rate template.

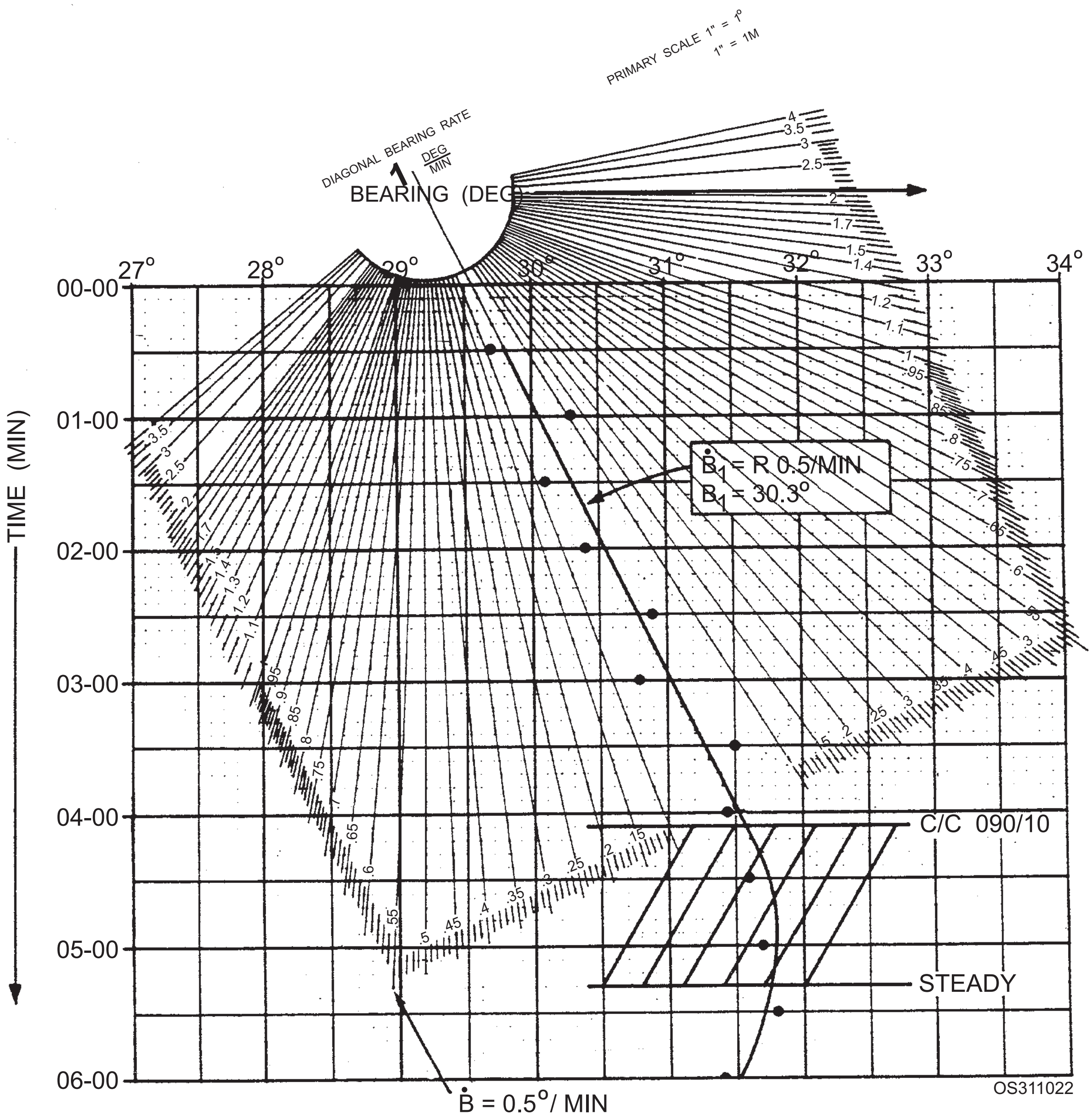


Figure 10-22.—Time/bearing plot (leg 1) measurement.

3. Tracing paper (DRT)
4. Hard lead and colored pencils
5. Gum erasers
6. Dividers
7. Speed strips from 4 to 20 knots (See figure 10-24). Speed strips should be made of transparent plastic, cut into individual strips, and placed on a ring clip.

Strip Plotting

The strip plot is a method of solving for target course and range by using an assumed target speed. In this method, target bearings are plotted out from own ship's track on a true geographic plot. Transparent plastic strips calibrated in distance per unit of time (speed strips) are fitted at various angles to the target bearing lines until the tick marks on the speed strips fit the bearing lines (fig. 10-25) and target course and range are derived.

Position the bug on the plotting table to allow maximum plotting room; that is, if the target is to the north, set the bug near the southern boundary and in the middle of the east-west direction.

Select a scale that will allow plotting the maximum target range, normally 2,000 or 5,000 yards to the inch. The sonar and TMA supervisors determine the maximum expected target range.

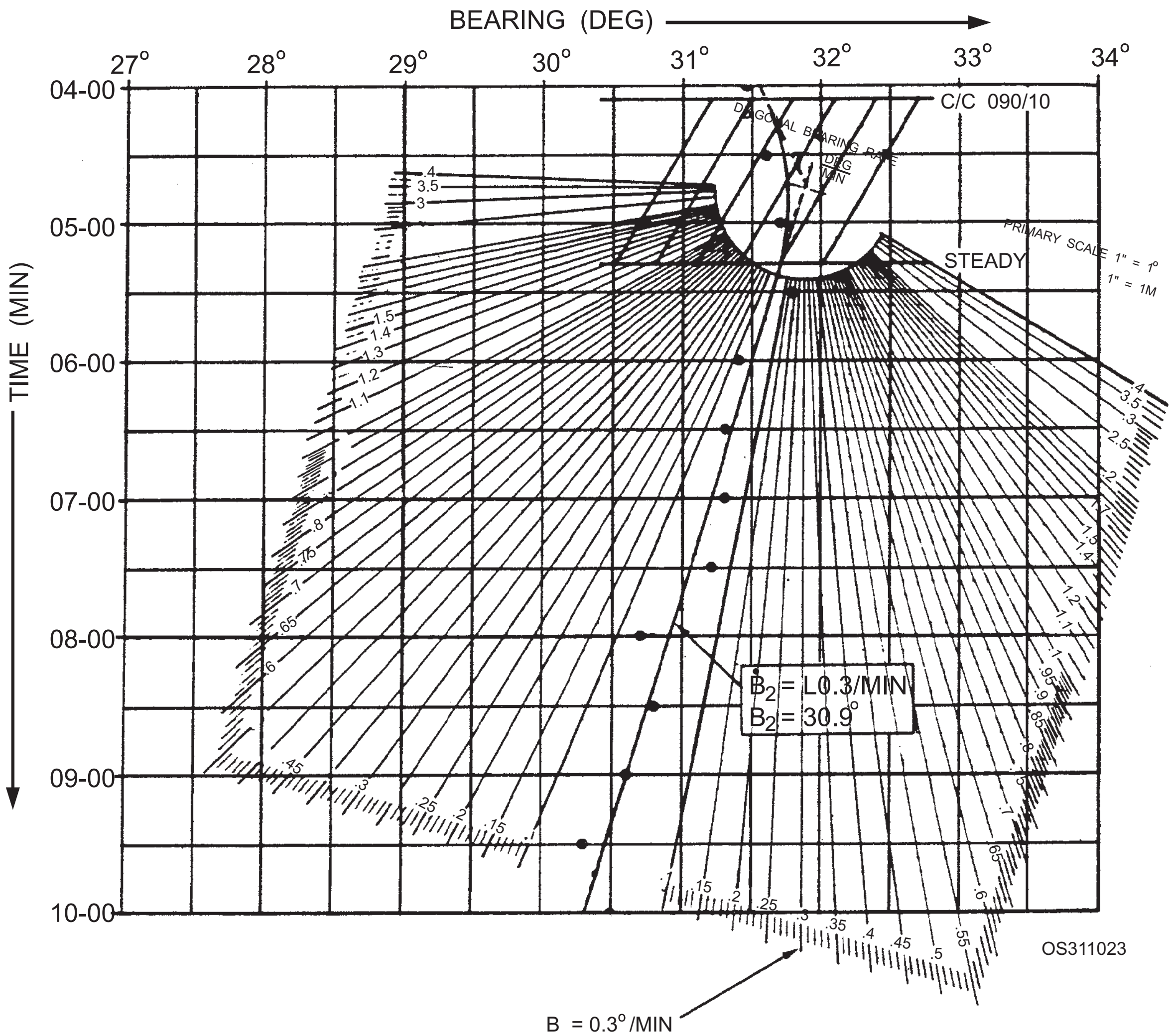


Figure 10-23.—Time/bearing plot after (leg 2) measurement.

Obtain a good time reference consistent with sonar and the time/bearing plot. If you use problem time instead of local time, make a note on the plot, correlating problem time to local time.

After beginning the plot, mark the bug precisely on the plotting interval. Usually this is every minute, but it could be as long as every 2 or 3 minutes, depending on the bearing rate ($\dot{B}$). Note the time beside own ship's position marks on the DRT, using two-digit numbers for minutes.

Use faired bearings ($\bar{B}$) from the time/bearing plot if at all possible. Faired bearings tend to be more accurate than raw sonar bearings. Keep in mind, though, that using faired bearings causes the plot to lag the problem.

With the parallel motion protractor (PMP), plot the faired bearings to the nearest 0.1°. Draw the bearing line well past the maximum expected target range, starting about 1 inch from own ship's position. Mark the time beside the end of the bearing line.

Begin your strip analysis after you plot three or four bearing lines. The ASW evaluator normally establishes a range of assumed target speeds based on a turn count or other estimate. Plan on using a maximum of three speed strips during your analysis. For example, if the estimated speed range is 6 to 11 knots, use the 6-, 8-, and 10-knot strips. Fit each strip across at least three bearings. The line along the edge of the fitted strip represents the target track (course). If, as is usually the case, you cannot make a good fit over the first three lines, try to fit a strip to three of the first four lines.

After you obtain a fit, predict the mark at least two points ahead, as in figure 10-26. The next bearing line may not fall through the predicted point, because of either a bad bearing or a target maneuver. If so, redo the problem using at least one more bearing. Trace a line along the edge of the fitted strip representing the

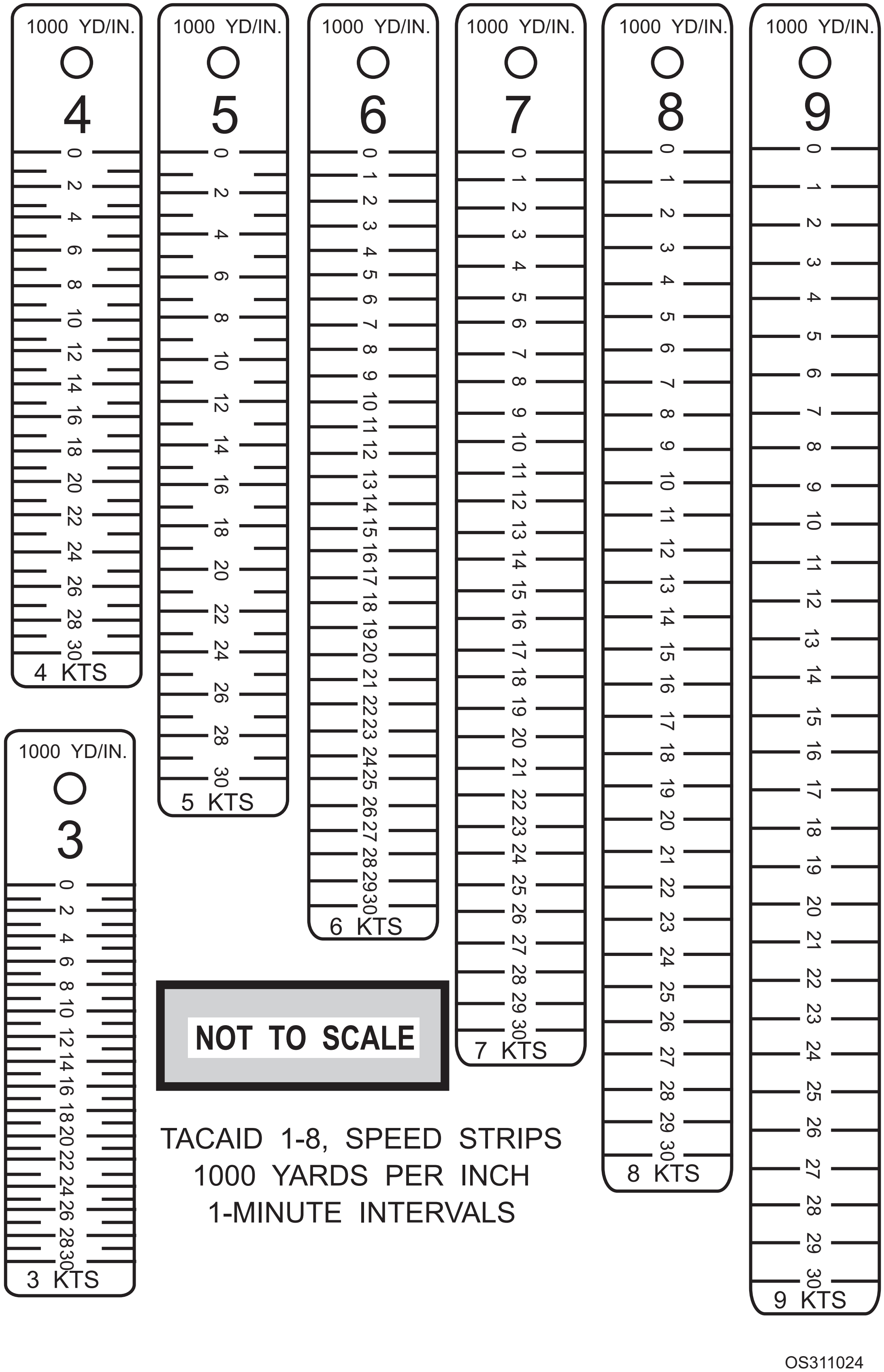


Figure 10-24.—Example of speed strips.

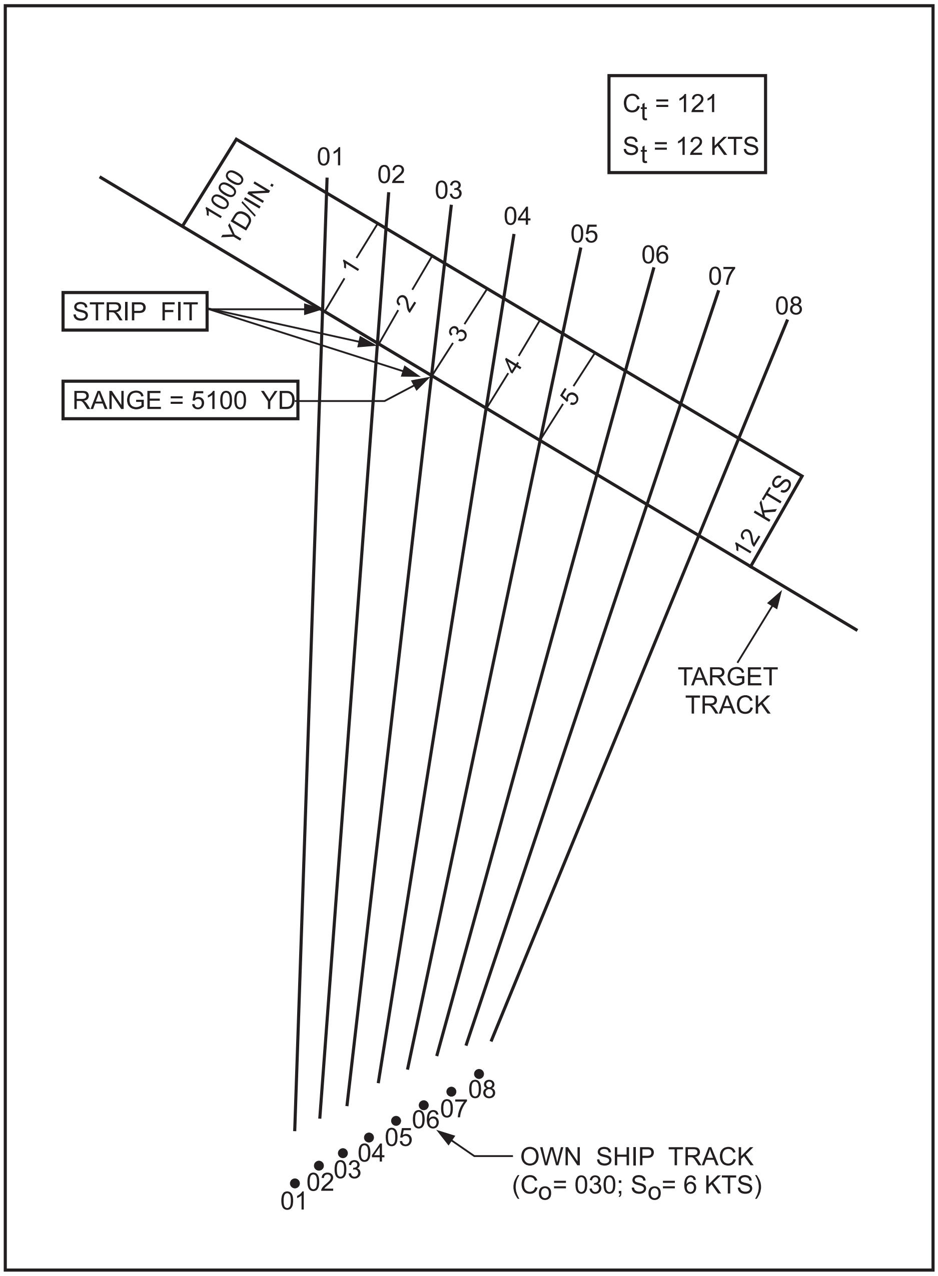


Figure 10-25.—Fitting speed strips.

target's track. Record the target's course and assumed speed in a box near the line.

After an own-ship maneuver, use a different color to plot the bearing lines. If plot information is coming from a towed array, do not collect bearings during a turn, but wait until the array has stabilized after the turn to start again. (For hull mounted arrays, wait until the ship steadies to obtained faired bearings.) Figure 10-27 shows three speed strips fitted prior to an own-ship maneuver. Note that only one strip fits following the maneuver.

The strip plot is most valuable when used in conjunction with other techniques such as DEKE and Ekelund ranging. When more mental analysis weight is given to one technique over another, the quality of information/data and equipment limitations must be kept in mind constantly. The more techniques you can apply, the greater confidence in the range estimate.

Maximum Range for Assumed or Estimated Target Speed

Sonar operators can frequently estimate a target's speed by counting screw beats and using

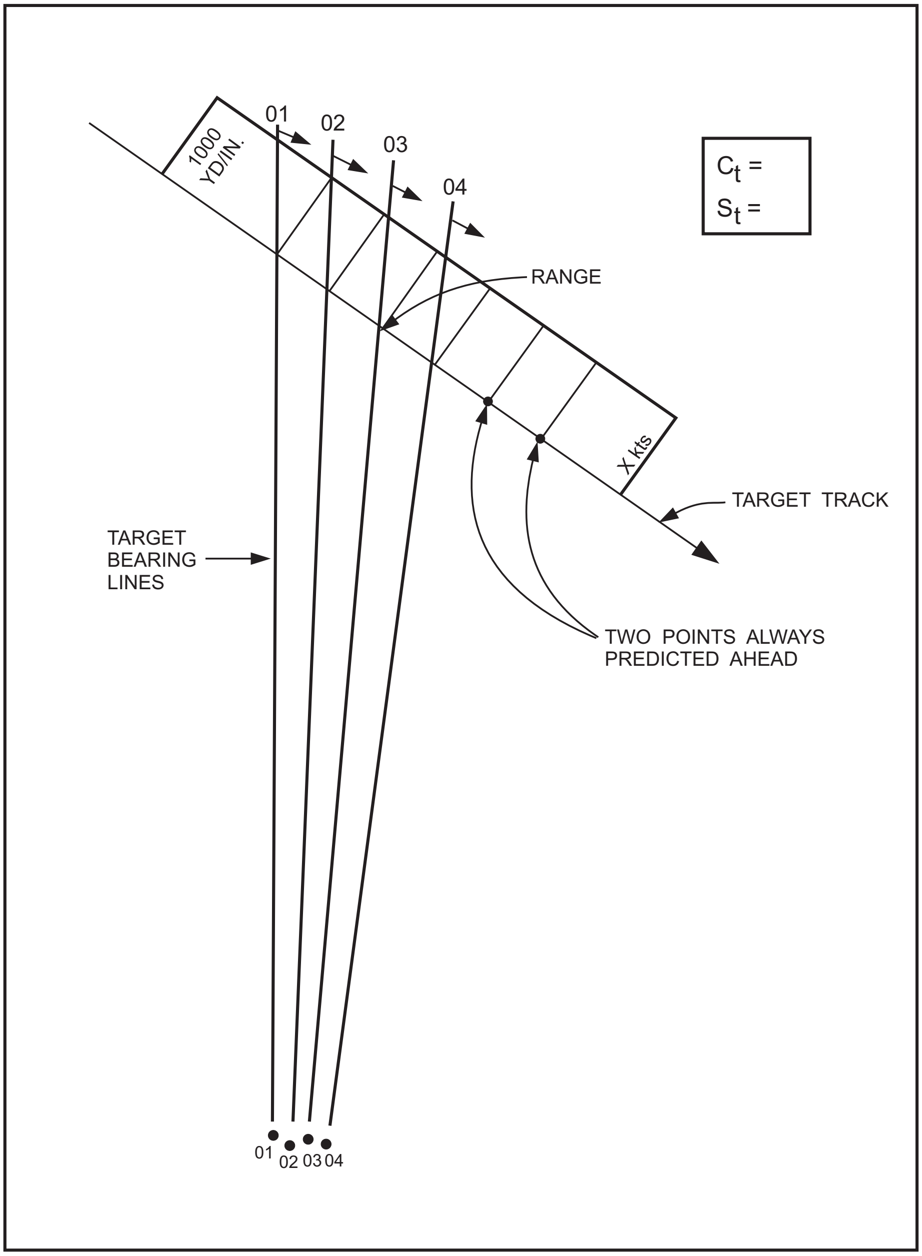


Figure 10-26.—Fitting speed strips with predicted points.

turns-per-knot ratios. You can determine the maximum range for an assumed or estimated speed at any instant by placing the chosen speed strip interval perpendicular to two consecutive bearing lines representing a corresponding interval of target travel. This assumes a 90° target angle; that is, all of the target speed is across the LOS. See figure 10-28.

Minimum Target Speed for a Given Range

You can determine a minimum speed for any given range by finding the speed strip that fits perpendicularly between two bearing lines at the given range. See figure 10-29.

Minimum Range

You can read an absolute minimum range from the strip plot if own ship and the target are moving in opposite directions relative to the line of sound (fig. 10-30). All bearing lines must cross between the target and own ship.

Absolute Maximum Range

You can determine an absolute maximum range when the motion of own ship and the target ship are in the same direction relative to the LOS, and own ship's speed across the LOS is greater than the target ship's

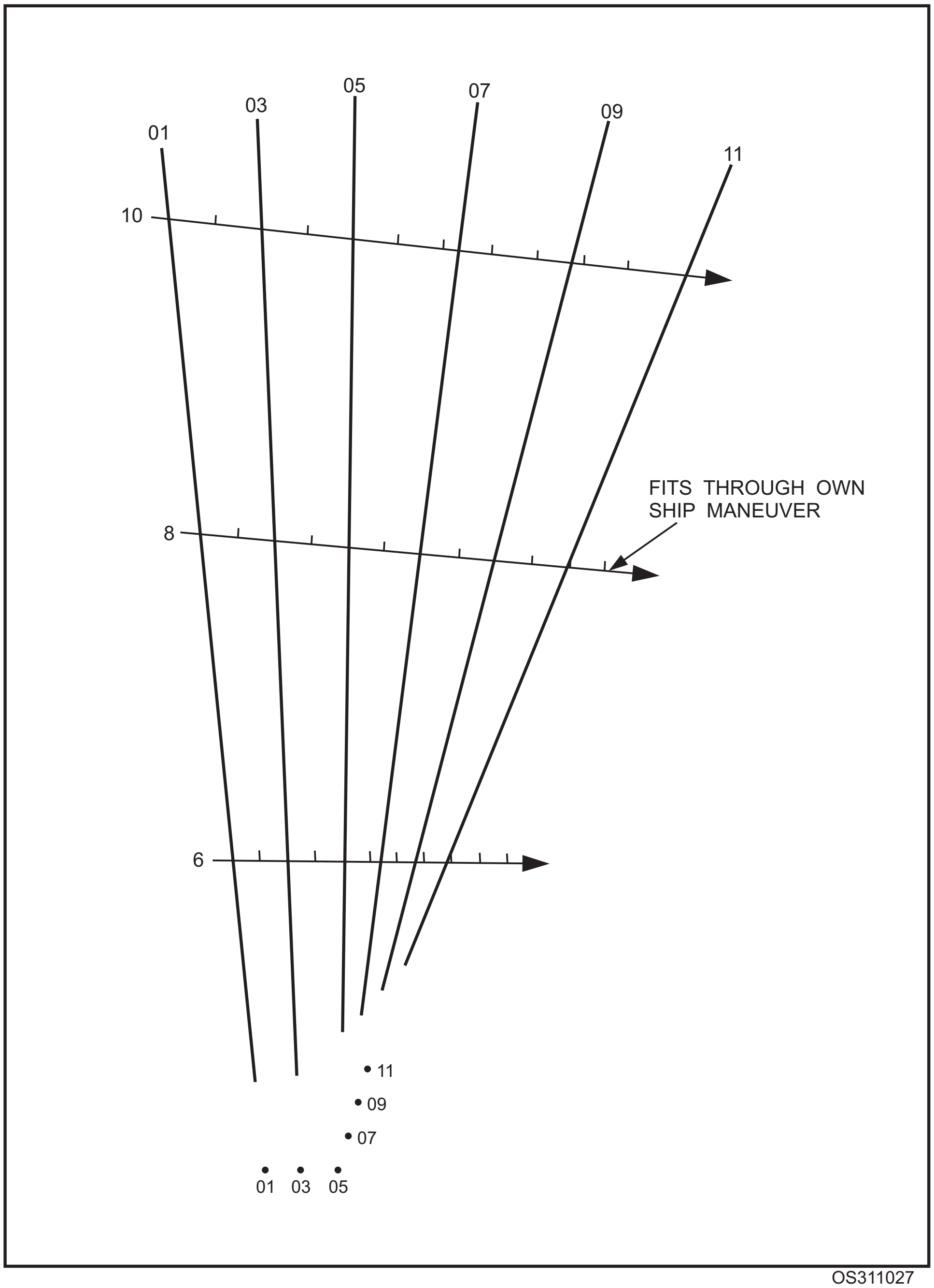


Figure 10-27.—Speed strips fitting through a maneuver.

(fig. 10-31). In this case, all bearing lines must cross at a range greater than that of the target.

General Direction of Target Motion

You can determine the direction of the target's motion if:

1. own ship points at the target (not applicable to towed arrays);
2. own ship's speed is zero or near zero (not applicable to towed arrays); and
3. own ship performs a maneuver when crossed bearings are present.

Situations 1 and 2 are self-explanatory. You can determine situation 3 from an analysis of the strip plot. On a single leg, you cannot determine if the target is beyond or closer than the cross bearings unless you have already determined the target's direction.

Note in figure 10-32 that the cross bearings determine minimum range, because the chronological sequence of bearings continues in the same direction at a greater range. At less than the minimum range, the

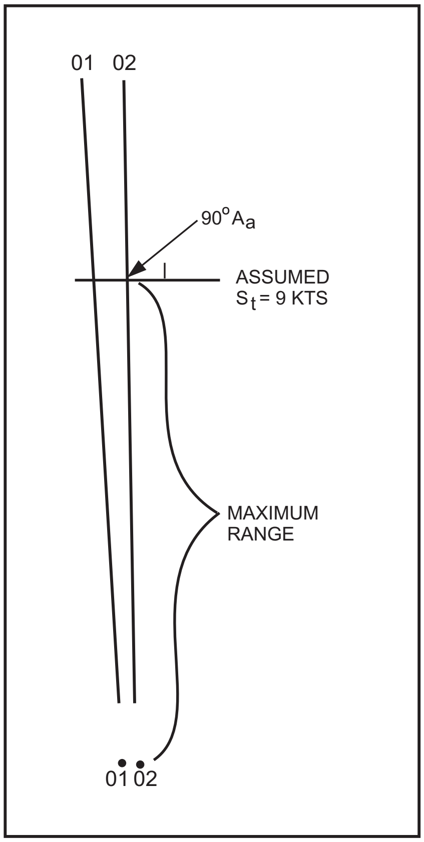


Figure 10-28.—Determining maximum range.

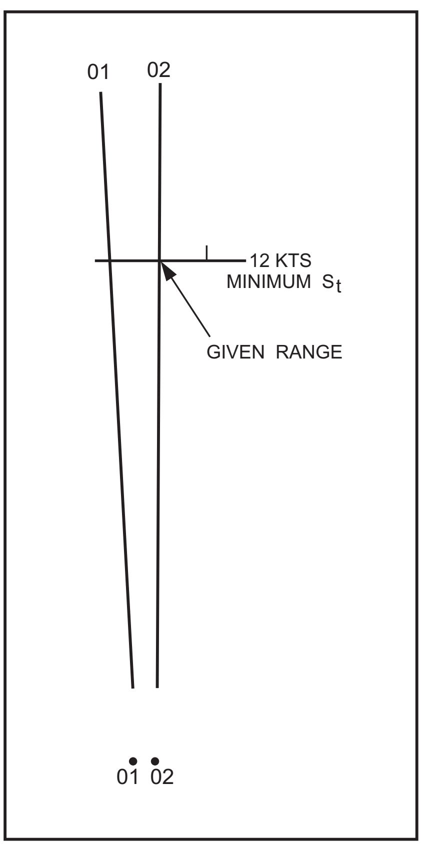


Figure 10-29.—Determining minimum speed.

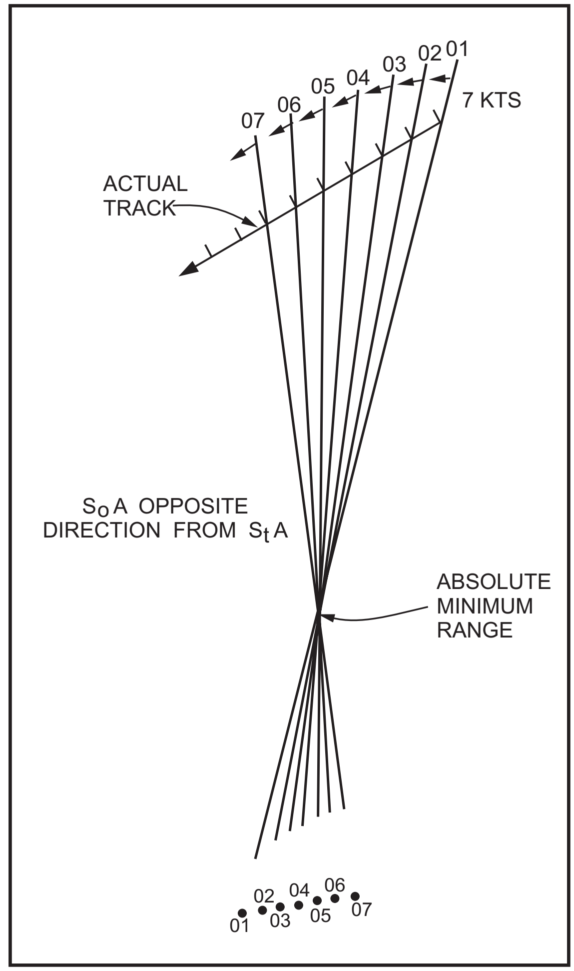


Figure 10-30.—Determining minimum range from cross bearings.

chronological sequence of bearings reverses directions. Unless a target maneuver has occurred, that is impossible. Therefore, the cross bearings indicate minimum range.

Small Target Angle

Figure 10-33 illustrates an example of a situation in which own ship reverses the direction of target motion across the LOS by crossing the target's track. In this circumstance, because the target angle is small, maximum and minimum ranges develop. The chronological sequence of bearings is continuous, not only beyond the first maximum range and inside the last minimum range, but also in between the maximum and minimum ranges. What has occurred in this instance is that target's position has been bracketed. This type of display on the strip plot is characteristic of small target angles.

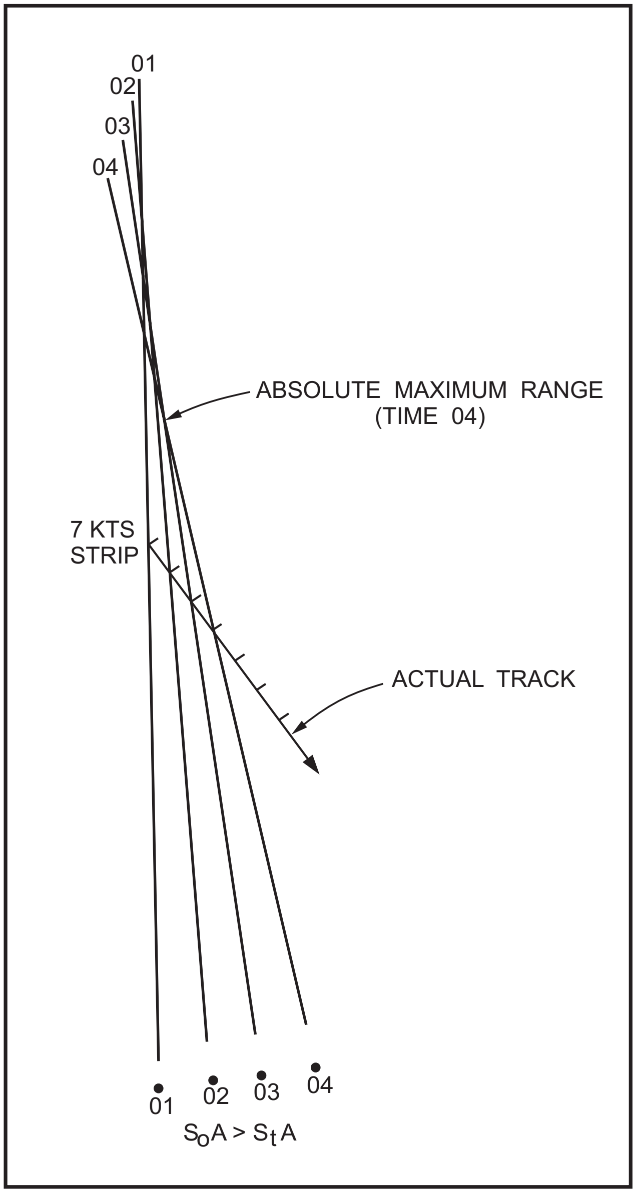


Figure 10-31.—Determining maximum range from cross bearings.

Detecting an Incorrect Target Speed Estimate

An incorrect target speed estimate can be easily detected on the strip plot after an own-ship maneuver. See figure 10-34. In this hypothetical case, 12 knots is the only speed that fits before and after own-ship's maneuver. For the other speeds used, a range jump occurred at the time of the maneuver. After determining an incorrect speed estimate in this manner, use figure 10-35 to determine whether the actual target speed is above or below the estimated speed according to the direction of the range jump and change in relative speed across the LOS (SA). Repeat this procedure as needed to obtain a best estimate of target speed.

Geographic Plot

The geographic plot is an all-purpose diagram that combines methods suitable for TMA, tracking, and attack. The plot can accommodate raw sporadic sonar bearings from very distant targets as well as continuous information at short range. Active sonar and radar bearing and range data can also be readily plotted and evaluated. The geographic plot is, in short, a device that can integrate and unify all sensor inputs to the combat information center.

The geographic plot can provide useful TMA information throughout an entire operation, from initial detection at long range, through intermediate tracking of both broad and narrow aspect targets, and finally as a post-torpedo launch device. Plot geometries are shown in figure 10-36.

The geographic plot provides a high degree of flexibility when bearing information is shifted from active to silent search or vice versa. The plot will also accommodate the special requirements of towed-array bearing data and provide continuity in tracking as the target is acquired by different ship sensors.

Finally, the geographic plot provides a real-time history of the encounter.

The geographic plot is used in the following situations:

1. Tracking non-maneuvering and maneuvering targets
2. Tracking broad aspect and narrow aspect targets

BROAD ASPECT TARGET—VERIFICATION

When target tracking has proceeded to a stage where the CIC evaluator has developed a reasonable solution from all TMA sources, the evaluator passes this solution to the geographic plot. (Because of manning levels and space limitations, the geographic plot and the strip plot are combined in one plot.) This solution will become a new anchor point.

The Coffey Assumption

The Coffey assumption process for target course solution may also prove valuable during this initial tracking period. The process has two limiting factors

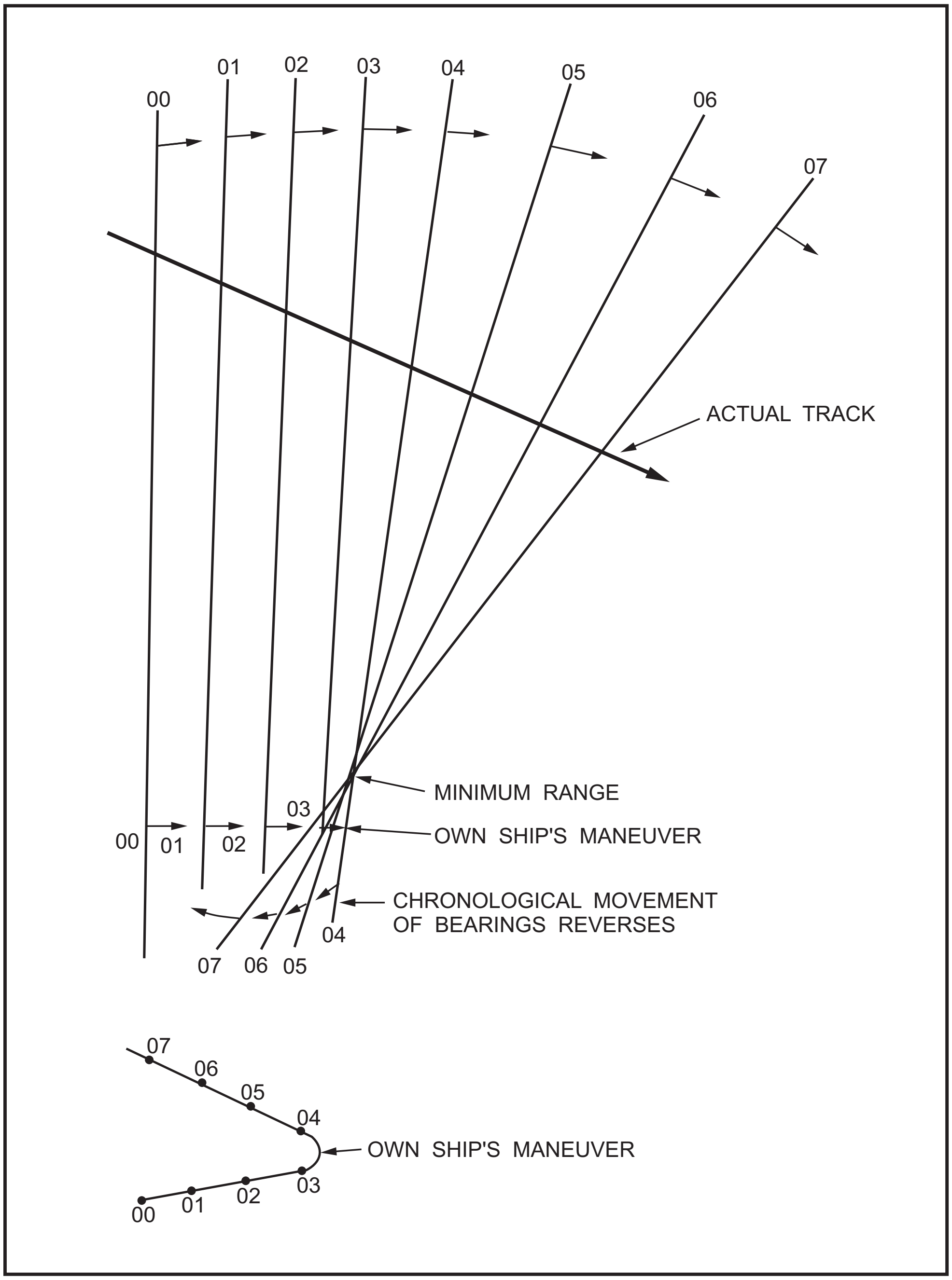


Figure 10-32.—Determining general direction of target motion.

that make it useful in the low-bearing rate, high-range-rate initial contact situations under discussion. First, $\dot{B}$ must be less than 1.5° a minute, and second, S_oA must be less than S_t.

The Coffey assumption is that the bearing rate is zero. Courses for zero-bearing-rate targets (opening and closing) are determined, then course corrections to the zero-bearing-rate courses are determined for the measured bearing rate. The following example refers to figure 10-37. To solve for zero-bearing-rate courses, place own ship's vector at the center of the maneuvering board. In this example, C_o = 060°, S_o = 5 knots, and the target bearing is 010°. If the target had a zero bearing rate, the bearing would remain at 010°. If own ship's course were 010°, the target's opening course would be 010°, and its closing course would be the reciprocal of 010°, or 190°. The target's DRM is drawn from the head of own ship's vector parallel to the 010° bearing line and to the edges of the maneuvering board. To determine target course, a target speed must be assumed. The Coffey assumption zero-bearing-rate courses are at the intersection of the DRM and the target's speed circle. In the example, a

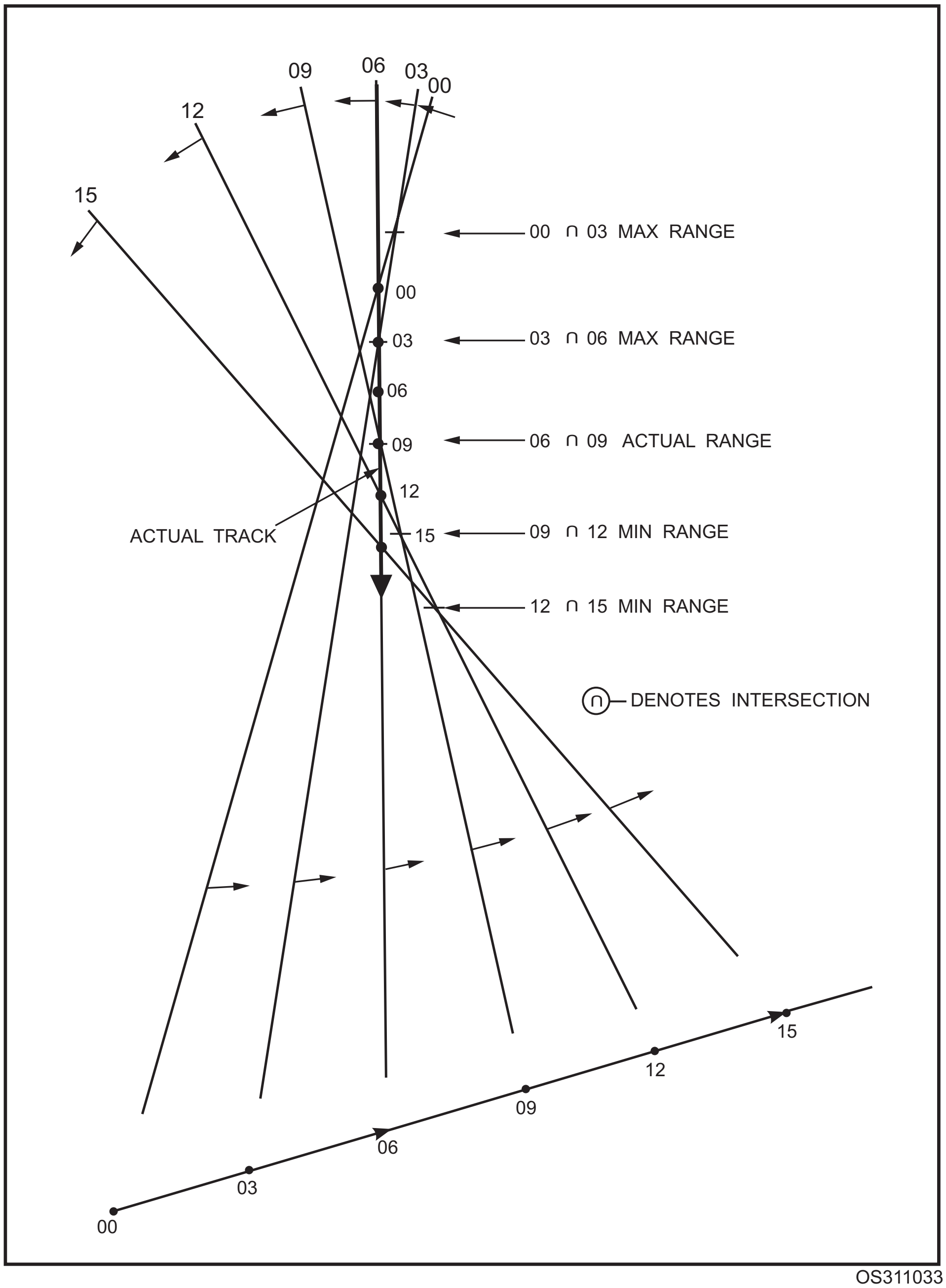


Figure 10-33.—Strip plot for small target aspect.

speed of 10 knots is assumed; therefore, the courses are 032° opening and 167° closing.

You continue the technique by using the measured bearing rate. In this example, assume the bearing rate is left 0.5°/min. Now compute a correction factor. Here, it is 50 x bearing rate. For the problem being computed, the correction is 50 x 0.5 = 25°. Use this factor correcting the zero-bearing-rate courses for measured bearing rate.

To apply the correction factor, divide the maneuvering board into two areas, left and right, with respect to the target's bearing. Then apply the correction to the zero-bearing-rate courses in the direction of the bearing rate. In the example, make the correction of 25° to the left area of the maneuvering board. The resulting target courses are 009° opening and 191° closing. This completes the Coffey assumption technique.

$$\frac{C_t}{\dot{B}} = \frac{X_1}{\dot{B}_1} - \frac{X_2}{\dot{B}_2}$$

Refer to figure 10-38 for construction of the plot for the following problem. Use the course, speed, and target bearing values given under "The Coffey Assumption" heading above as the first leg of the

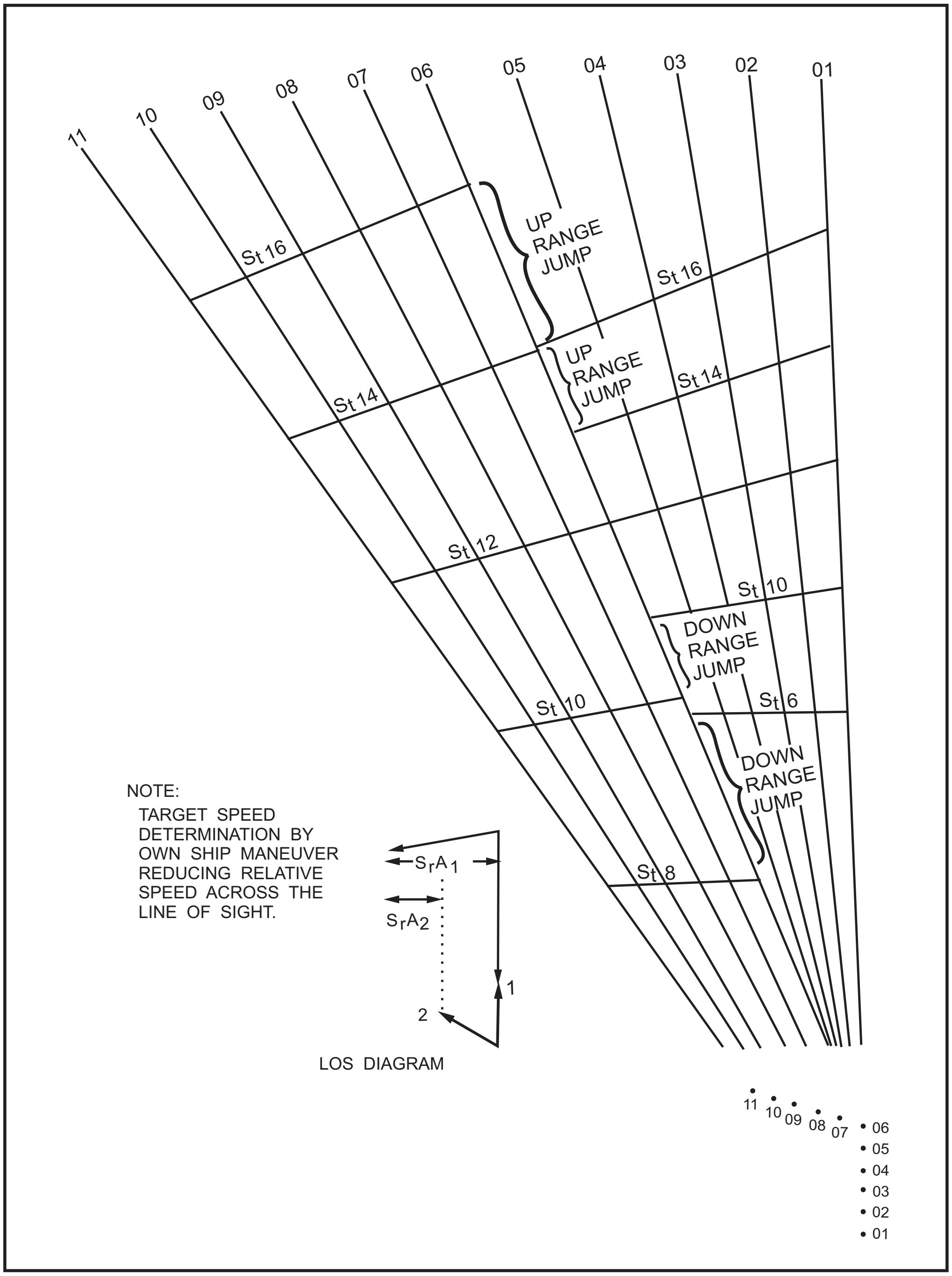


Figure 10-34.—Determining target speed using range jump.

$S_r A$	UP	DOWN
Decrease	Smaller S_t	Larger S_t
Increase	Larger S_t	Smaller S_t

OS311035

Figure 10-35.—Range jump significance.

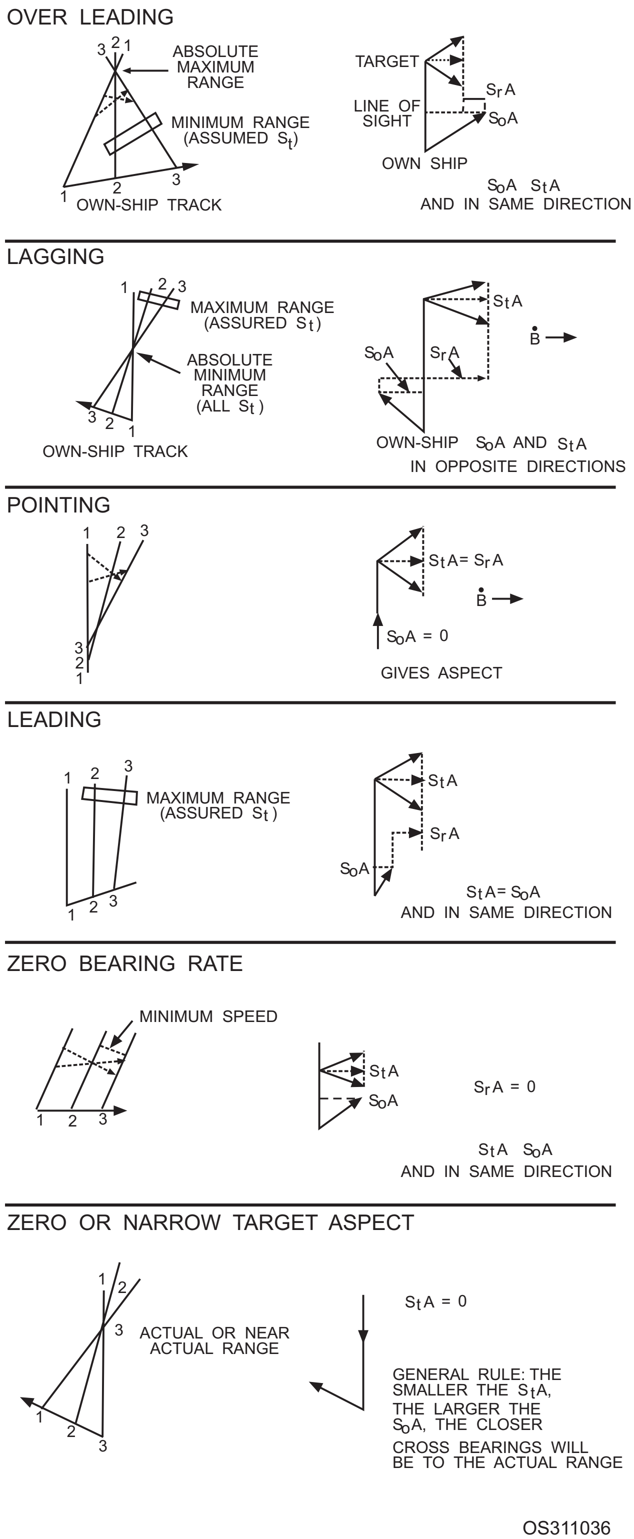


Figure 10-36.—Geograph/LOS plot geometries.

maneuver. Assume that own ship changes course to 300° for the second leg of the maneuver and increases speed to 7 knots. The figure shows the DRM and the zero-bearing-rate course (closing) for the second leg.

The values of interest can be summarized as follows:

VALUE	1st Leg	2nd Leg
C_o	060	300
S_o	5	7
$\dot{B}$	L 0.3	R0.9
B	010	008

Considering only the closing case:

$\dot{B}$ = L 0.3 + R 0.9 = 1.2 (add opposite, subtract same direction)

C_t = 229 - l66 = 63 degrees

Applying these numbers to the equation above, we find

$$\frac{63}{1.2} = \frac{X_1}{0.3} - \frac{X_2}{0.9}$$

Solving the equation produces the following corrections:

$$X_1 = 16$$

$$X_2 = 47$$

By looking at the plot, we can see that the application of the correction is obvious. For example, the resulting Coffey solution course (closing) is 182°. This completes the technique for closing course. The same technique is used for opening courses. The Coffey assumed courses and speeds should be updated as the tactical situation progresses and newer information becomes available.

Calculator-assisted Procedure

HP-67/97 programs for computing a relative motion TMA solution are available from the Fleet Mission Program Library (FMPL), Naval Tactical Support Activity (NTSA). The calculator program solves for the relative course and the relative speed numerically, using raw bearing data. It can use data from a single leg along with an estimate of target range, course, or speed to compute a TMA solution, or it can use data from two legs to compute a TMA solution without any additional estimates of TMA parameters.

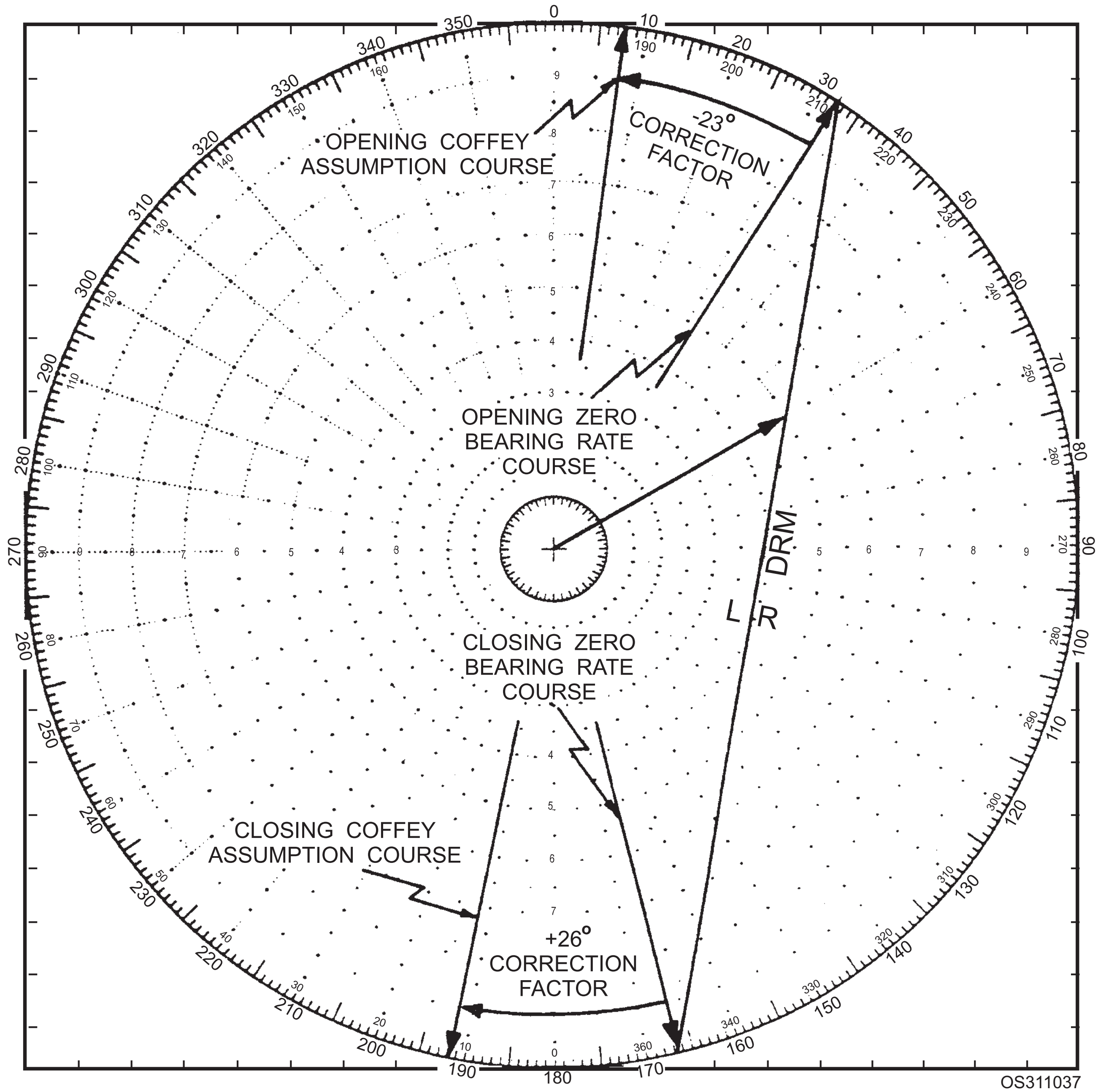


Figure 10-37.—Example of construction of the Coffey assumption.

NOTE

When you use raw data (bearing or frequency) in a calculator to solve for rates, use caution to prevent erroneously biasing the calculated rate by entering a large group of stacked data (bearing or frequency) or an obviously wrong piece of data. You can make this mistake easily when you are concentrating on keying the calculator and not on the quality of data you are entering.

Accuracy

The accuracy of the TMA solution derived from the relative motion plot depends on several factors. Predominant is the accuracy of the bearing information and the assumed target course and speed. The most

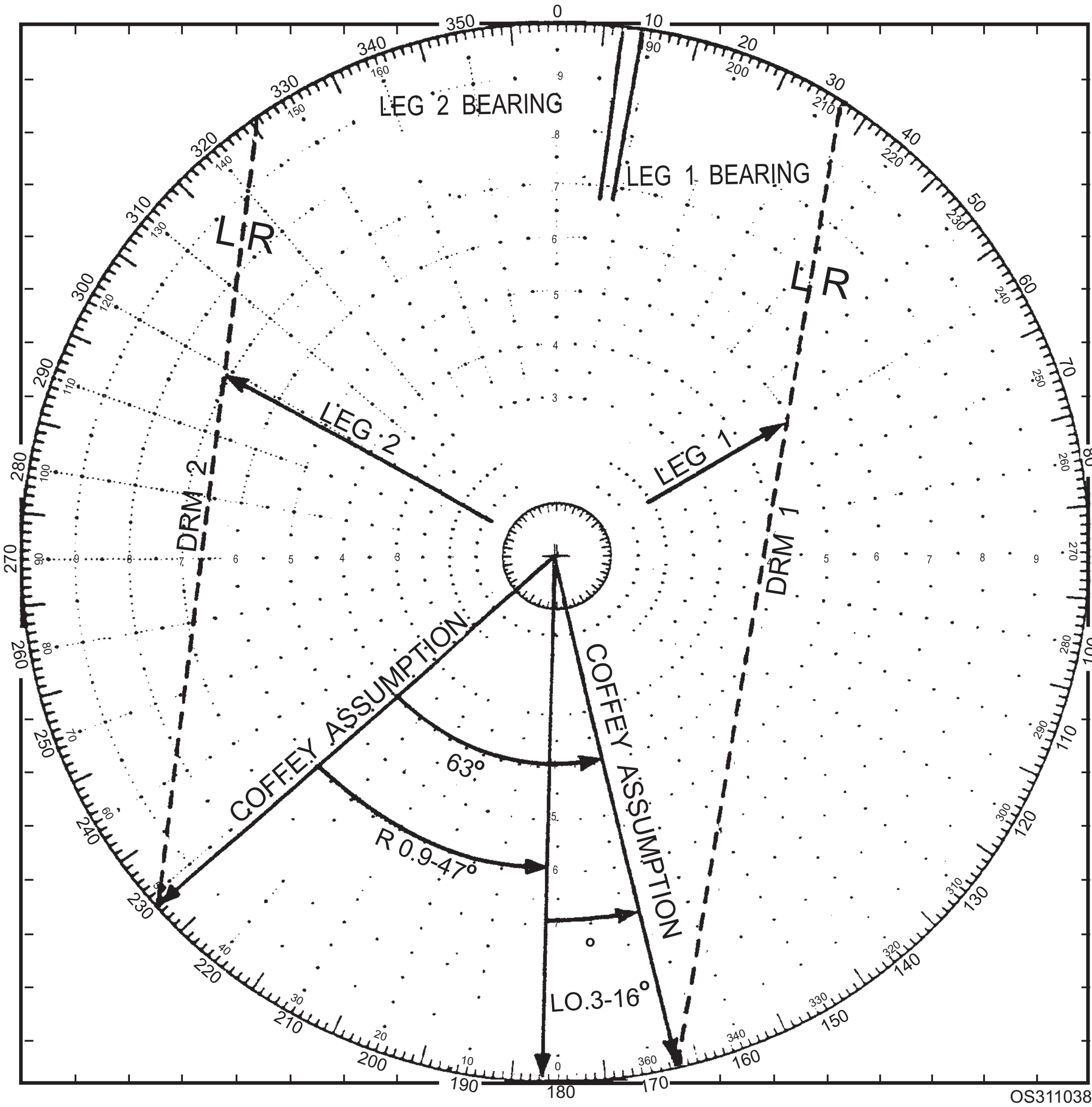


Figure 10-38.—Example of construction of Coffey solution.

accurate solution occurs when the target's speed is greater than own ship's speed.

You can design a smaller bearing-rate scale to increase plotting accuracy at low bearing rates by dividing the existing scale by 10 or by 100. If you do this, the outer scale should read 0.3°/min or 0.03°/min, respectively. Be sure to divide all bearing rates by the same scale factor.

INFORMATION TO THE BRIDGE

Information on new contacts should be passed to the CICWO, who will evaluate it and make recommendations to the OOD on the bridge as a matter of routine. By observing the following suggestions, you will help eliminate the "wait" you might otherwise have to give in response to queries from the OOD.

1. Immediately on detection, pass the range and bearing of all new contacts to the bridge.
2. Give the internal designation or track number.
3. Ascertain the contact's identification, either by a proper IFF/SIF mode response or on the basis of an evaluation of other available information.
4. Give the composition of the contact; for example, single large ship, formation of small ships, or many bogeys.
5. Give an estimate of the contact's true course and speed.

6. Announce a preliminary estimate after three of four plots concerning the point and time of closest approach, followed by more accurate information; also announce whether own ship is on or near a collision course.
7. Furnish an evaluation of the contact by weighing all available information and past movements, determining the contact's future movements and intentions, and recommending an appropriate course of action.

ANSWER TO CHAPTER QUESTIONS

A1. *A bearing that is 180°, plus or minus, from any given bearing.*

A2. *The relative bearing of own ship from a target ship.*

A3. *The geographic plot (also called the navigation plot) shows the true movement of surface, subsurface, and certain air contacts.*

A4. *A formation diagram shows the station of every ship in the formation. It is kept in polar coordinates relative to the formation's axis and center, with formation's center located at the center of the plot. The main body is shown, with each station number and the call sign of the ship occupying that station. Screen sectors are also shown with the call signs of assigned screen units. Sector boundaries are drawn from two groups of four numerals each, specified in a tactical message.*

A5. *Normally, the 20-miles-per-circle scale is used on the air summary plot so that coverage is out to 200 miles.*

A6 . *The tote board contains three sections—bogey, CAP, and other friendlies. It contains all of the amplifying information on every air contact plotted on the air summary plot.*

A7. *The No. 1 (or south) plotter records own ship's contact and, hence, must wear the 61JS phones. The No. 2 (or north) plotter plots the assisting ship and the assisting ship's contact. He or she, therefore, must wear the 21JS phones over one ear and, at the same time, listen to the TG REPT net speaker for the assisting ship's contact reports.*

A8. *Blue; surface friendly symbol.*

A9. *The primary objective of establishing bearing rate is to calculate target course and speed.*

A10. *The time/bearing curve or plot is the keystone to almost all TMA techniques.*