U.S. Department of
Homeland Security

United States
Coast Guard

BOAT CREW SEAMANSHIP MANUAL

"Train, Maintain, Operate"

COMDTINST M16114.5C
September 2003 **Chapter 14 Only**

Chapter 14
Navigation

Introduction

The art and science of navigation is an ancient skill. For thousands of years sailors navigated by using the stars as their guide. In the distant past only a select few were allowed access to the mysteries of navigation for possession of them gave one considerable power. A person who could safely follow the stars and navigate a ship - from one point to another - exercised significant influence over crewmembers who could not.

The art of navigation has expanded from using the stars and planets (celestial navigation) to sophisticated electronic systems (electronic navigation). The safe and confident navigation of the boat - is an absolute necessity, not only for the welfare of fellow crewmembers - but also for the welfare of those the crew is sent to assist. Boat navigation falls into three major categories:

- Piloting: use of visible landmarks and AtoN as well as by soundings.
- Dead Reckoning: by true or magnetic course steering and using speed to determine distance traveled from a known point in a known period.
- Electronic Navigation: by radio bearings, LORAN-C, GPS, and other electronic systems.

The coxswain is responsible for knowing the position of the boat at all times. Additionally, he/she has been entrusted with the safety of the boat, all crewmembers, and people from distressed vessels.

Each crewmember on a Coast Guard boat is a coxswain-in-training. A crewmember must learn all landmarks, charts and navigation aids used for the waters while operating. Through experience a crewmember will become proficient in the various skills necessary to perform any essential task in an emergency.

NOTE Additional information may also be found in the appropriate sections of the *Coast Guard Navigation Standards Manual*, COMDTINST M3530.2 (series).

In this chapter

This chapter contains the following sections:

Section A. The Earth and Its Coordinates

Introduction

Navigation is concerned with finding a position and calculating distances measured on the surface of the earth, which is a sphere. However, the earth is not a perfect sphere - the diameter through the equator is about 23 nautical miles longer than is the diameter through the North and South Poles. This difference is so small that most navigational problems are based on the earth being a perfect sphere. Charts are drawn to include this slight difference. Distance is figured from certain reference lines. Position at any given time, while underway, may be determined by location relative to these lines as well as visible landmarks in the local area. Knowing what these lines are and how to use them is essential.

A.1. Reference Lines of the Earth

The earth rotates around an axis; this axis may be defined as a straight line drawn through the center of the earth. The axis line meets the surface of the earth at the North Pole and at the South Pole. To determine location, a system of reference lines is placed on the surface of the earth as shown in **Figure 14-1**. This figure reveals the difficulty a boat navigator faces - the earth is curved as a sphere but navigation is typically done on a flat chart with straight reference lines running top to bottom and left to right.

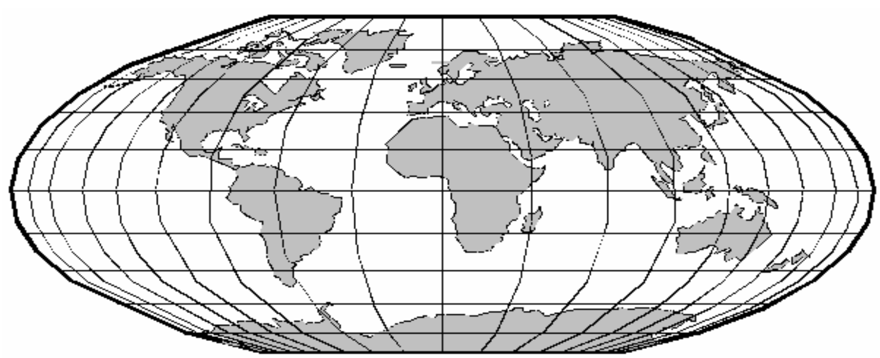

Figure 14-1
Earth with Reference Lines

A.2. Great Circles

A great circle is a geometric plane passing through the center of the earth, which divides the earth into two equal parts. A great circle always passes through the widest part of the earth. The equator is a great circle. All circles that pass through both the North and South Poles are great circles. The edge of a great circle conforms to the curvature of the earth, similar to seeing a circle when looking at a full moon.

NOTE The earth's circumference is 21,600 nautical miles. Determine a degree of arc on the earth's surface by dividing the earth's circumference (in miles) by 360 degrees.

A.2.a. Circle Properties

The outline of the moon also reveals another fact about great circles which is a property of all circles: each circle possesses 360° around its edge, which passes through a sphere, as to divide the sphere into two equal half-spheres. There are an infinite number of great circles on a sphere.

A.2.b. Degrees

Great circles have 360° of arc. In every degree of arc in a circle, there are 60 minutes. Sixty (60) minutes is equal to 1° of arc, and 360° are equal to a complete circle. When degrees are written, the symbol (°) is used.

A.2.c. Minutes

For every degree of arc, there are 60 minutes. When minutes of degrees are written, the symbol (') is used; 14 degrees and 15 minutes is written: 14°15'.

When written, minutes of degrees are always expressed as two digits. Zero through nine minutes are always preceded with a zero. Three minutes and zero minutes are written as 03' and 00' respectively.

A.2.d. Seconds

For every minute of arc in a circle, there are 60 seconds of arc. Sixty (60) seconds is equal to one minute of arc, and 60 minutes is equal to 1° of arc.

For every minute of arc, there are 60 seconds. When seconds are written, the symbol (") is used; 24 degrees, 45 minutes, and 15 seconds is written: 24°45'15".

When seconds are written, they are always expressed as two digits. Zero through nine seconds are always preceded with a zero. Six seconds and zero seconds are written as 06" and 00" respectively.

Seconds may also be expressed in tenths of minutes; 10 minutes, 6 seconds (10'06") can be written as 10.1'.

The relationship of units of "arc" can be summarized as follows:

Circle =	360 degrees (°)
1 degree (°) =	60 minutes (')
1 minute (') =	60 seconds (")

Parallels

A.3. Parallels

Parallels are circles on the surface of the earth moving from the equator to the North or South Pole. They are parallel to the equator and known as parallels of latitude, or just latitude.

Parallels of equal latitude run in a west and east direction (left and right on a chart). They are measured in degrees, minutes, and seconds, in a north and south direction, from the equator. (0° at the equator to 90° at each pole).

The North Pole is 90° north latitude, and the South Pole is 90° south latitude. The equator itself is a special parallel because it is also a great circle. One degree of latitude (arc) is equal to 60 nautical miles (NM) on the surface of the earth; one minute (') of latitude is equal to 1 NM. The circumference of the parallels decreases as they approach the poles. (see **Figure 14-2**)

On charts of the northern hemisphere, true north is usually located at the top. Parallels are normally indicated by lines running from side to side. Latitude scales, however, are normally indicated along the side margins by divisions along the black-and-white border as shown in the upper left and the lower right margins of **Figure 14-2**.

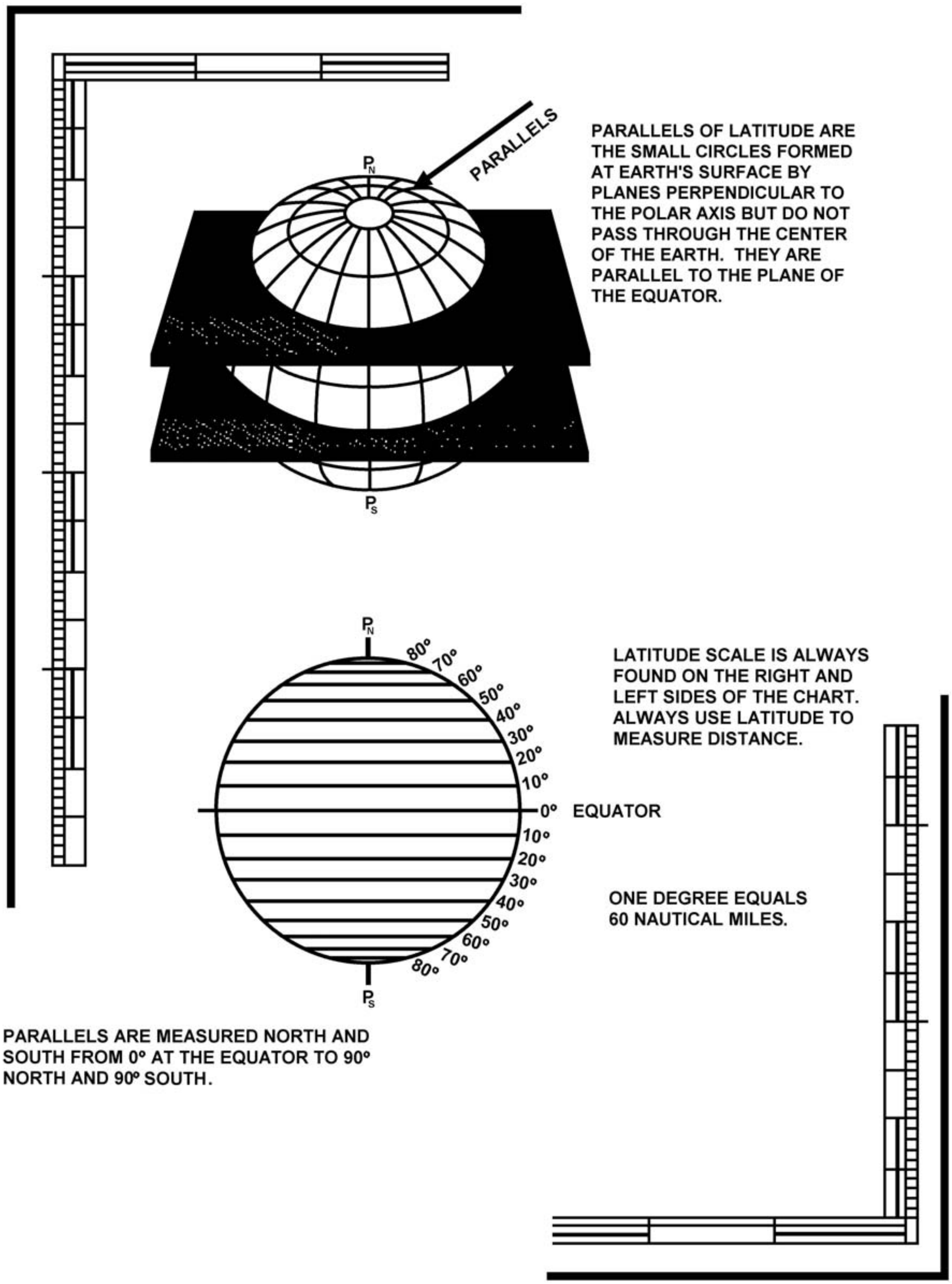

Figure 14-2
Parallels of Latitude

A.3.a. Measuring Latitude

To measure the latitudinal position of an object on a nautical chart, perform the procedures as follows:

Step	Procedure
1	Put one point of a pair of dividers on the parallel of latitude nearest to the object.
2	Place the other point of the dividers on the object.
3	Move the dividers to the nearest latitude scale, keeping the same spread on the dividers.
4	Place one point on the same parallel of latitude as used in step 1. The second point of the dividers will fall on the correct latitude of the object.
5	Read the latitude scale.

NOTE

- Always use the latitude scale to measure distance in navigation.
- A degree of latitude is measured up or down.

NOTE

On a Mercator projection chart (normally used for boat navigation), the scale varies along the latitude scale, but will always remain accurate in relation to actual distance within the latitude bounded by that scale.

CAUTION !

A degree of longitude is equal to 60 miles only at the equator. This is why parallels of latitude are used to measure distance in navigational problems.

A.4. Meridians

A meridian is a great circle formed by a plane, which cuts through the earth's axis and its poles. Such circles are termed meridians of longitude.

The meridian which passes through Greenwich, England, by international convention, has been selected as 000° and is called the Prime Meridian. From this point, longitude is measured both east and west for 180°.

The 180° meridian is on the exact opposite side of the earth from the 000° meridian. The International Date Line generally conforms to the 180th meridian. The great circle of the Prime Meridian and the International Date Line divide the earth into eastern and western hemispheres.

A degree of longitude equals 60 miles only at the equator and is undefined at the poles since all meridians meet there at one point. Meridians of Longitude run in a north and south direction (top to bottom on a chart) and are measured in degrees, minutes, and seconds, in an east or west direction. (see **Figure 14-3**)

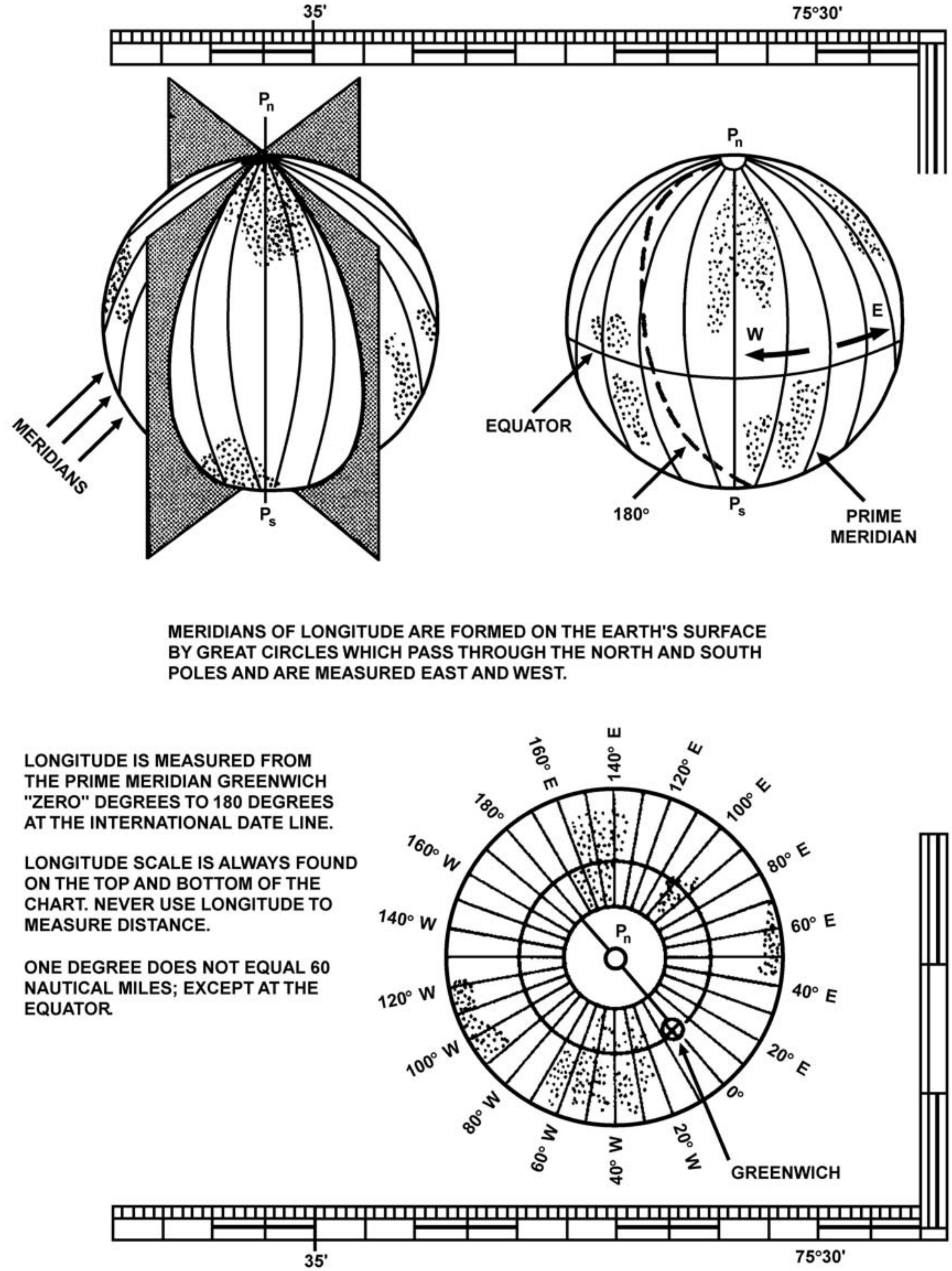

Figure 14-3
Meridians of Longitude

A.4.a. To Measure Longitude

To measure the longitude of an object on a nautical chart, the same procedures as in measuring a latitude position using the longitude scale shall be followed.

A.4.b. Rhumb Line

Typical boat navigation is done by plotting rhumb lines on a Mercator chart. A rhumb line is an imaginary line that intersects all meridians at the same angle. The rhumb line on the surface of a sphere is a curved line. On most nautical charts, this curved line (rhumb) is represented as a straight line.

A course line, such as a compass course, is a rhumb line that appears as a straight line on a Mercator chart. Navigating with a rhumb line course allows the helmsman to steer a single compass course.

A.5. Chart Projections

For the purpose of coastal navigation, the earth is considered to be a perfect sphere. To represent the features of the earth's spherical surface on the flat surface of a chart, a process termed "projection" is used. Two basic types of projection used in making piloting charts are:

- Mercator.
- Gnomonic.

A.5.a. Mercator Projection

Mercator charts are the primary charts used aboard boats. A Mercator projection is made by transferring the surface of the globe (representing the earth) onto a cylinder.

The equator is the reference point for accomplishing the projection from one geometric shape to another. The distinguishing feature of the Mercator projection is that the meridians are projected so they appear to be equal distance from each other and parallel. (see Error! Reference source not found.)

NOTE

> Only the latitude scale is used for measuring distance.

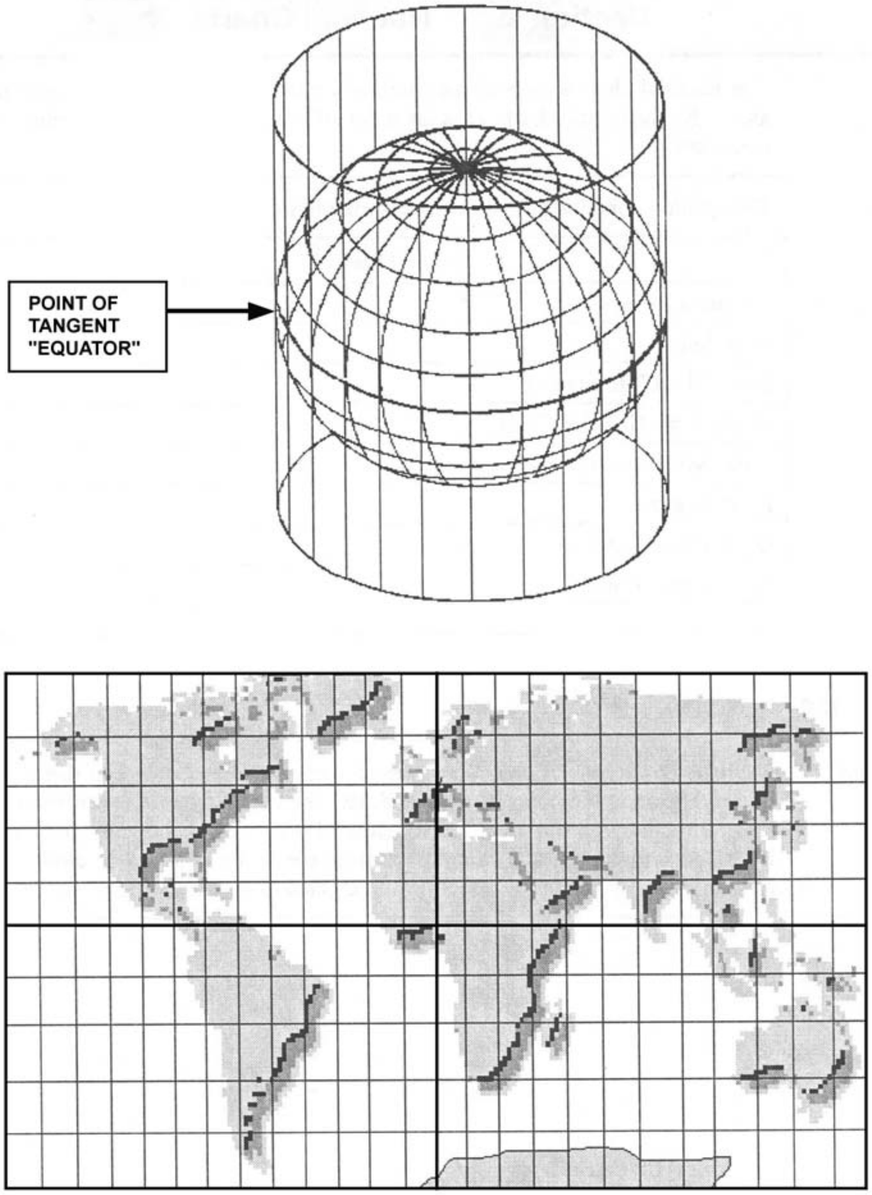

Figure 14-4
Mercator Projection

A.5.b. Gnomonic Projection

Gnomonic projections aid in long distance navigation by allowing navigators to use great circle courses. Meridians appear as straight lines that converge as they near the closest pole. The equator is represented by a straight line; all other parallels appear as curved lines.

NOTE

> Gnomonic charts are not normally used for boat navigation.

Section B. Nautical Charts

Introduction

The nautical chart is one of the mariner's most useful and most widely used navigational aids. Navigational charts contain a lot of information of great value to you as a boat coxswain.

In this section

This section contains the following information:

Compass Rose

B.1. Description

Nautical charts usually have one or more compass roses printed on them. These are similar in appearance to the compass card and, like the compass card, are oriented with north at the top. Directions on the chart are measured by using the compass rose. (see **Figure 14-5**) Direction is measured as a straight line from the center point of the circle to a number on the compass rose. Plotting the direction and explanation of the terms is discussed later.

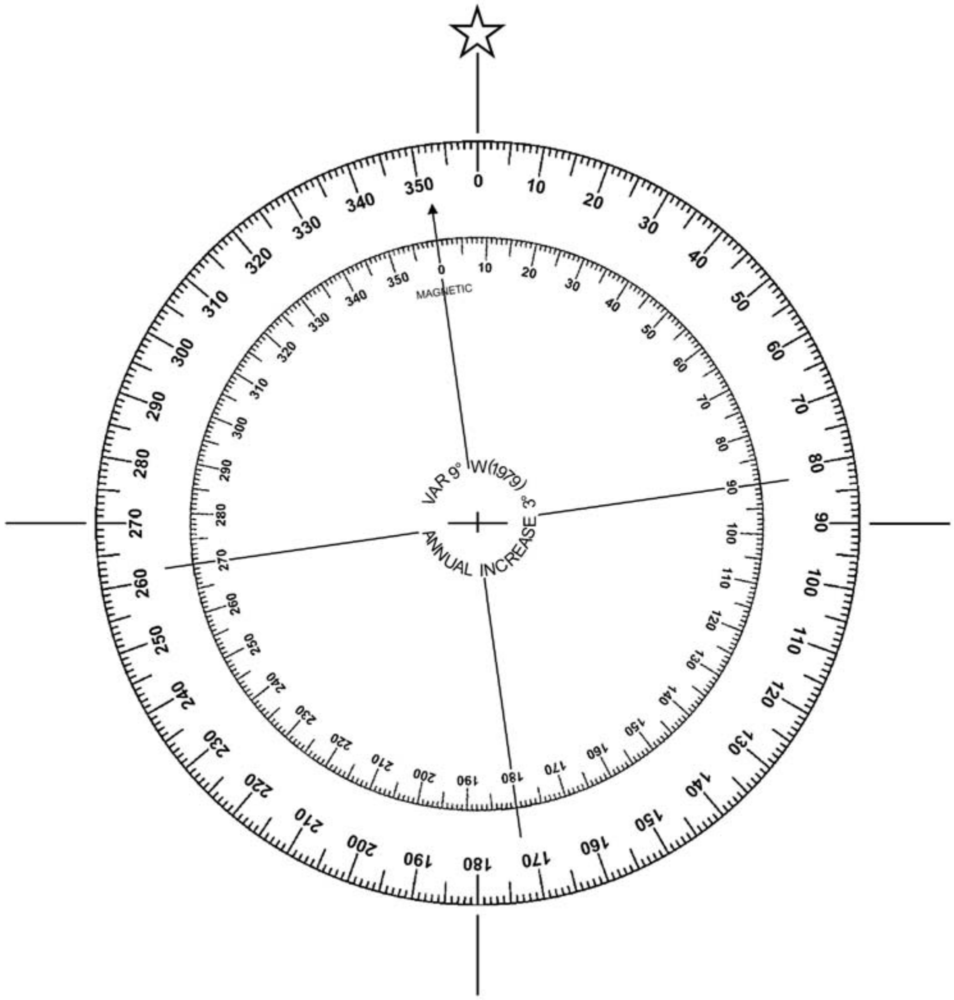

Figure 14-5
Compass Rose

B.2. True Direction

True direction is printed around the outside of the compass rose.

B.3. Magnetic Direction

Magnetic direction is printed around the inside of the compass rose. An arrow points to magnetic north.

B.4. Variation

Variation, the difference between true and magnetic north for the particular area covered by the chart, is printed in the middle of the compass rose (as well as any annual change).

Soundings

B.5. Description

One of the more vital services a chart performs is to describe the bottom characteristics to a boat operator. This is accomplished through the use of combinations of numbers, color codes, underwater contour lines, and a system of symbols and abbreviations.

B.6. Datum

The nautical chart water depth is measured downward from sea level at low water (soundings). Heights or landmarks are given in feet above sea level. In the interest of navigation safety, the mean, or average, of the lower of the two tides in the tidal cycle is used for soundings.

B.6.a. Mean Low Tide

Most of the numbers on the chart represent soundings of the water depth at mean low tide. Datum refers to a base line from which a chart's vertical measurements are made.

B.6.b. Mean Low Water

"Mean low water" is a tidal datum that is the average of all the low water heights observed over the National Tidal Datum Epoch (19 year average).

B.6.c. Average Low Tide

Since the greatest danger to navigation is during low tide, a number of the depths of low tide are averaged to produce the average low tide.

B.6.d. Mean Lower Low Water

"Mean lower low water" is a tidal datum that is the average of the lowest low water height of each tidal day observed over the National Tidal Datum Epoch (19 year average).

B.7. Color Code

Generally, shallow water is tinted darker blue on a chart, while deeper water is tinted light blue or white.

B.8. Contour Lines

Contour lines, also called fathom curves, connect points of roughly equal depth and provide a profile of the bottom. These lines are either numbered or coded, according to depth, using particular combinations of dots and dashes. Depth of water may be charted in feet, meters or fathoms (a fathom equals six feet). The chart legend will indicate which unit (feet, meters or fathoms) is used.

Basic Chart Information

B.9. Description

The nautical chart shows channels, depth of water buoys, lights, lighthouses, prominent landmarks, rocks, reefs, sandbars, and much more useful information for the safe piloting of the boat. The chart is the most essential part of all piloting equipment. Below are some basic facts to know about charts:

- Charts are oriented with north at the top.
- The frame of reference for all chart construction is the system of latitude and longitude.
- Any location on a chart can be expressed in terms of latitude or longitude. (see **Figure 14-6**)
  - The latitude scale runs along both sides of the chart.
  - The longitude scale runs across the top and bottom of the chart.
  - Latitude lines are reference points in a north and south direction with the equator as their zero reference point.
  - Longitude lines are the east and west reference points with the prime meridian as their zero reference point.

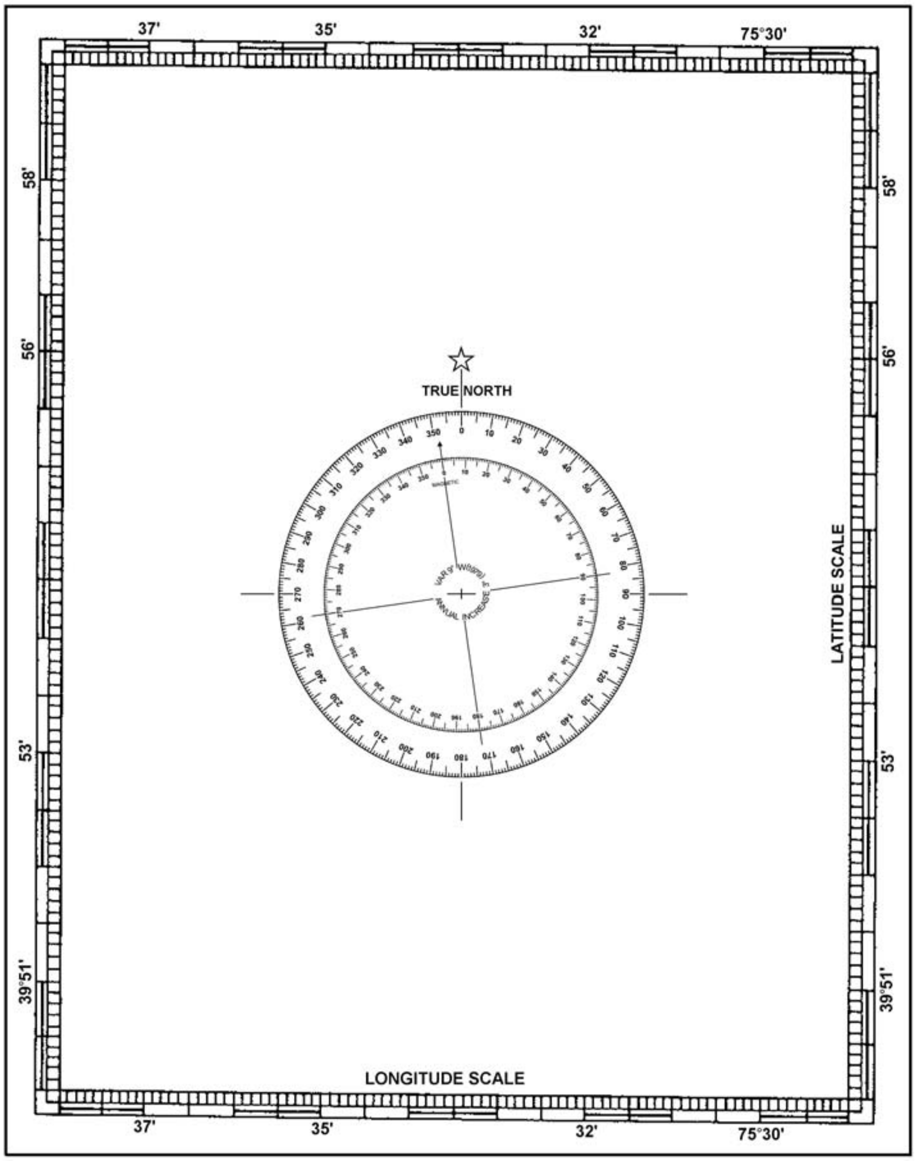

Figure 14-6
Chart Orientation

B.10. Title Block

The general information block (see **Figure 14-7**) contains the following items:

- The chart title which is usually the name of the prominent navigable body of water within the area covered in the chart.
- A statement of the type of projection and the scale.
- The unit of depth measurement, listed as soundings (feet, meters or fathoms).

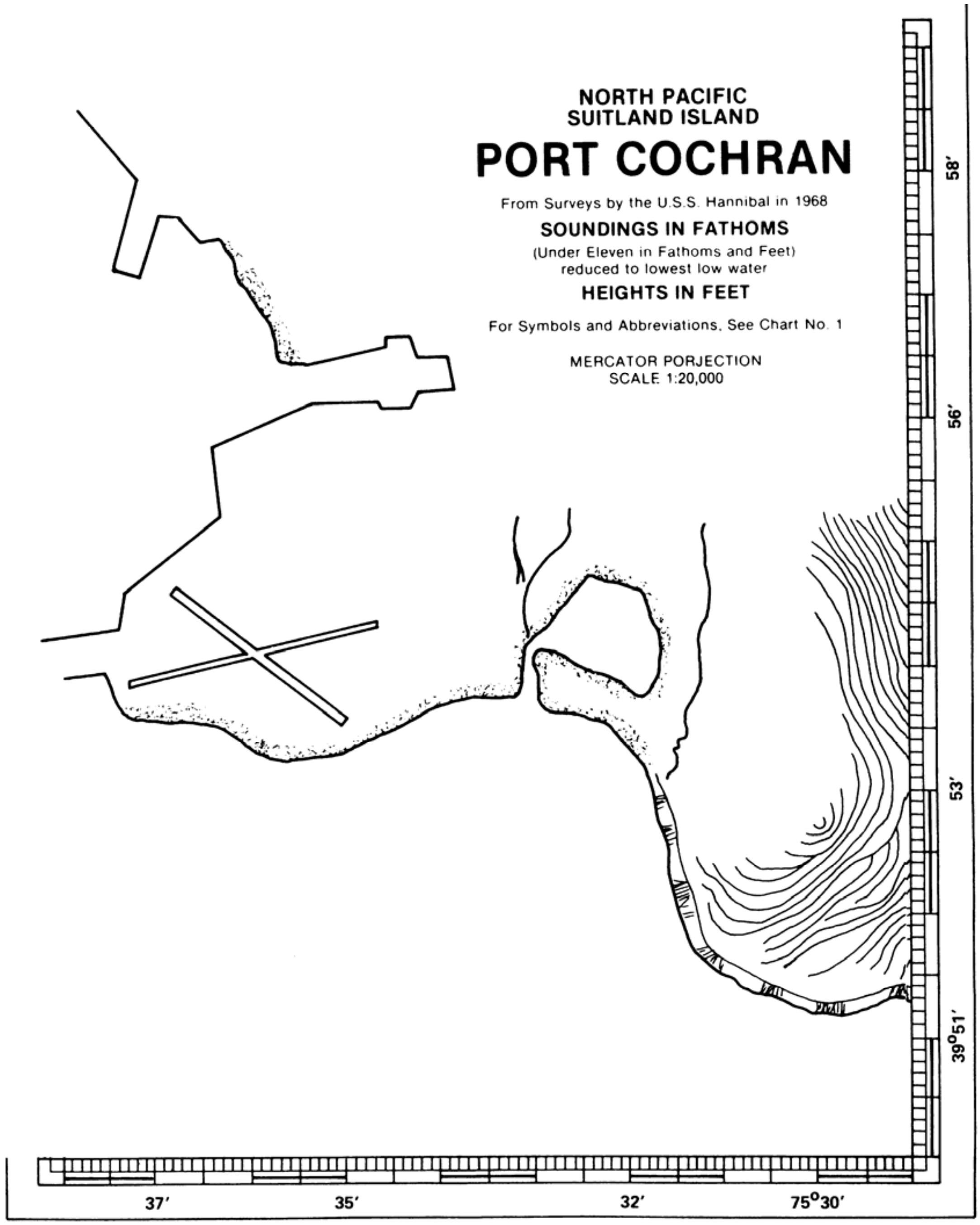

Figure 14-7
Title Block of a Chart

B.11. Notes

Notes are found in various places on the chart, such as along the margins or on the face of the chart. They may contain information that cannot be presented graphically, such as:

- The meaning of abbreviations used on the chart.
- Special notes of caution regarding danger.
- Tidal information.
- Reference to anchorage areas.

B.12. Edition Number

The edition number of a chart and latest revisions indicate when information on the chart was updated.

- The edition number and date of the chart is located in the margin of the lower left hand corner.
- The latest revision date immediately follows in the lower left hand corner below the border of the chart. Charts show all essential corrections concerning lights, beacons, buoys and dangers that have been received to the date of issue.

Corrections occurring after the date of issue are published in the Notice to Mariners and must be entered by hand on the chart of your local area upon receipt of the notice.

Scale of the Nautical Chart

B.13. Description

The scale of a nautical chart is the ratio comparing a unit of distance on the chart to the actual distance on the surface of the earth.

For example: The scale of 1:5,000,000 means that one of some kind of measurement of the chart is equal to 5,000,000 of the same kind of measurement on the earth's surface. One inch on the chart would equal 5,000,000 inches on the earth’s surface. This would be a small scale, chart, since the ratio 1/5,000,000 is a very small number.

A large scale chart represents a smaller area than that of a small scale chart. There is no firm separation between large scale and small scale.

NOTE Remember large scale - small area, and small scale - large area.

For example: The scale of 1:2,500 (one inch on chart equals 2,500 inches on the earth’s surface) is a much larger number and is referred to as a large scale chart.

NOTE Navigate with the largest scale chart available.

B.14. Sailing Charts

Sailing charts are produced at scales of 1:600,000 and smaller. They are used in fixing the mariners position for approach to the coast, from the open ocean, or for sailing between distant coastal ports.

On such charts, the shoreline and topography are generalized. Only offshore soundings, such as the principal lights, outer buoys and landmarks visible at considerable distances are shown.

B.15. General Charts

General charts are produced at scales between 1:150,000 and 1:600,000. They are used for coastwise navigation outside of outlying reefs and shoals when the ship or boat is generally within sight of land or AtoN and its course can be directed by piloting techniques.

B.16. Coastal Charts

Coastal charts are produced at scales between 1:50,000 and 1:150,000. They are used for inshore navigation, for entering bays and harbors of considerable width, and for navigating large inland waterways.

B.17. Harbor Charts

Harbor charts are produced at scales larger than 1:50,000. They are used in harbors, anchorage areas, and the smaller waterways.

B.18. Small Craft Charts

Small craft charts are produced at scales of 1:40,000 and larger. There are special charts of inland waters, including the intracoastal waterways. Special editions of conventional charts, called small craft charts, are printed on lighter weight paper than a normal chart and folded.

These "SC" charts contain additional information of interest to small craft operators, such as data on facilities, tide predictions, and weather broadcast information.

Chart Symbols and Abbreviations

B.19. Description

Many symbols and abbreviations are used on charts. It is a quick way to determine the physical characteristics of the charted area and information on AtoN.

These symbols are uniform and standardized, but may vary depending on the scale of the chart or chart series. These standardized chart symbols and abbreviations are shown in the Pamphlet 'CHART No. 1'; published jointly by the Defense Mapping Agency Hydrographic Center and the National Ocean Service.

B.20. Color

Nearly all charts employ color to distinguish various categories of information such as shoal water, deepwater, and land areas. Color is also used with AtoN to make them easier to locate and interpret.

Nautical purple ink (magenta) is used for most information since it is easier to read under red light normally used for navigating at night.

B.21. Lettering

Lettering on a chart provides valuable information. Slanted Roman lettering on the chart is used to label all information that is affected by tidal change or current (with the exception of bottom soundings). All descriptive lettering for floating AtoN is found in slanted lettering.

Vertical Roman lettering on the chart is used to label all information that is not affected by the tidal changes or current. Fixed aids such as lighthouses and ranges are found in vertical lettering. (see **Figure 14-8**)

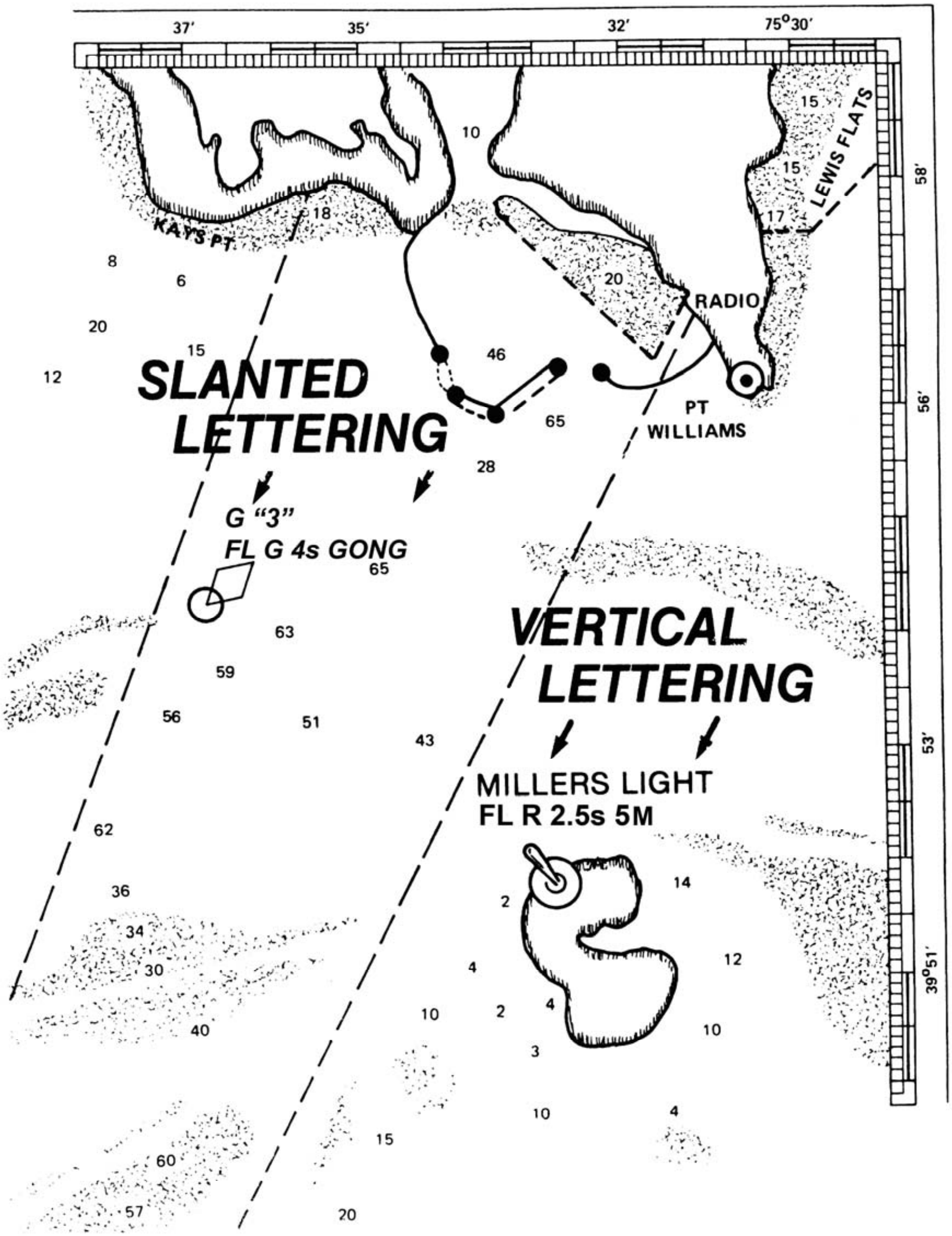

Figure 14-8
Chart Lettering

Buoy Symbols

B.22. Description

Buoys are shown with the following symbols:

- The basic symbol for a buoy is a diamond and small circle.
- A dot will be shown instead of the circle on older charts.
- The diamond may be above, below or alongside the circle or dot.
- The small circle or dot denotes the approximate position of the buoy mooring.
- The diamond is used to draw attention to the position of the circle or dot and to describe the aid.

See *Chapter 13, Aids To Navigation* for AtoN chart symbols, additional information and color pictures of AtoN.

Other Chart Symbols

B.23. Lighthouses and Other Fixed Lights

The basic symbol is a black dot with a magenta "flare" giving much the appearance of a large exclamation mark (!). Major lights are named and described; minor lights are described only.

B.24. Ranges and Beacons

Chapter 13, Aids To Navigation, has chart symbols and color pictures of these AtoN.

B.24.a. Ranges

Ranges are indicated on charts by symbols for the lights (if lighted) and dashed line indicating the direction of the range.

B.24.b. Daybeacons

Daybeacons are indicated by small triangles or squares, which may be colored to match the aid. Daybeacons, also commonly called day marks, are always fixed aids. That is, they are on a structure secured to the bottom or on the shore. They are of many different shapes.

B.25. Prominent Landmarks

Prominent landmarks, such as water towers, smoke stacks, and flagpoles, are pinpointed by a standard symbol of a dot surrounded by a circle. A notation next to the symbol defines the landmark's nature. The omission of the dot indicates the location of the landmark is only an approximation. (see **Figure 14-9**)

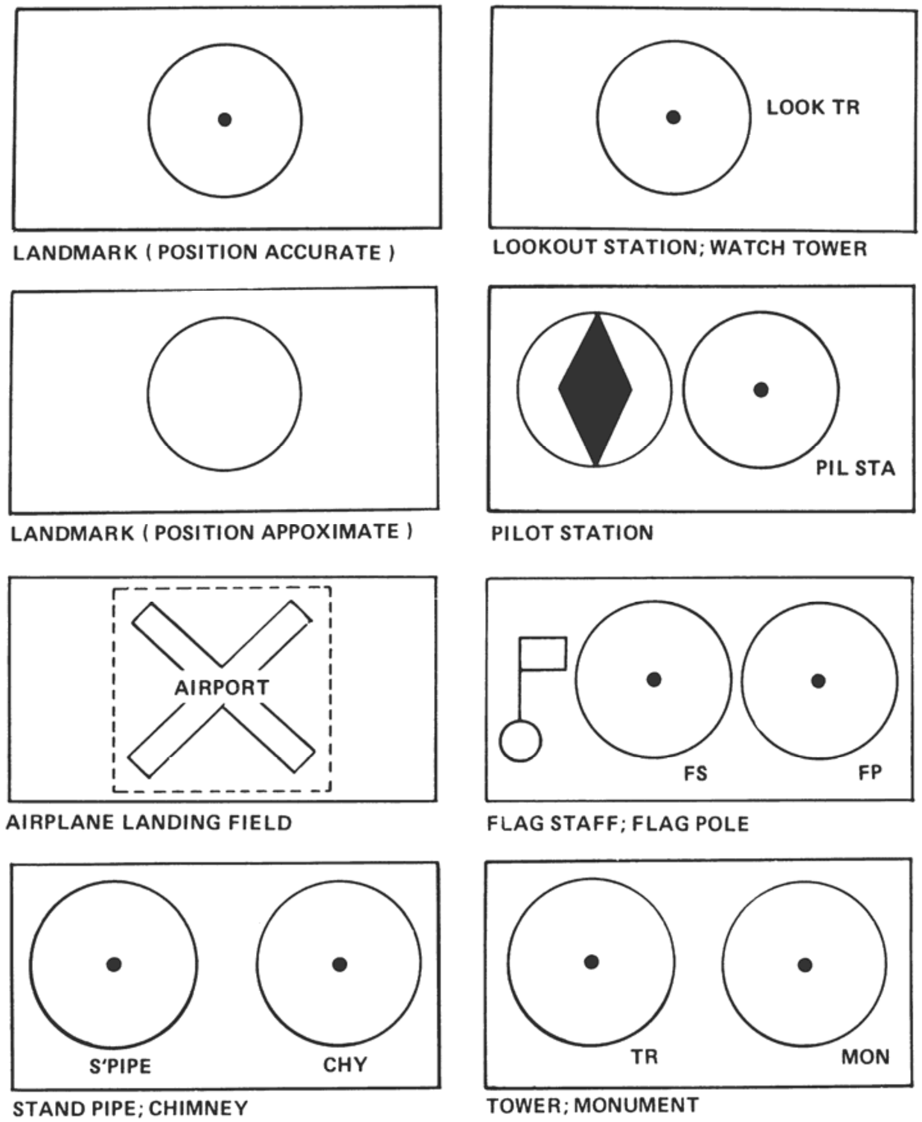

Figure 14-9
Symbols for Prominent Landmarks

B.26. Wrecks, Rocks, and Reefs

These are marked with standardized symbols, for example, a sunken wreck may be shown either by a symbol or by an abbreviation plus a number that gives the wreck's depth at mean low or lower low water. A dotted line around any symbol calls special attention to its hazardous nature. (see **Figure 14-10**)

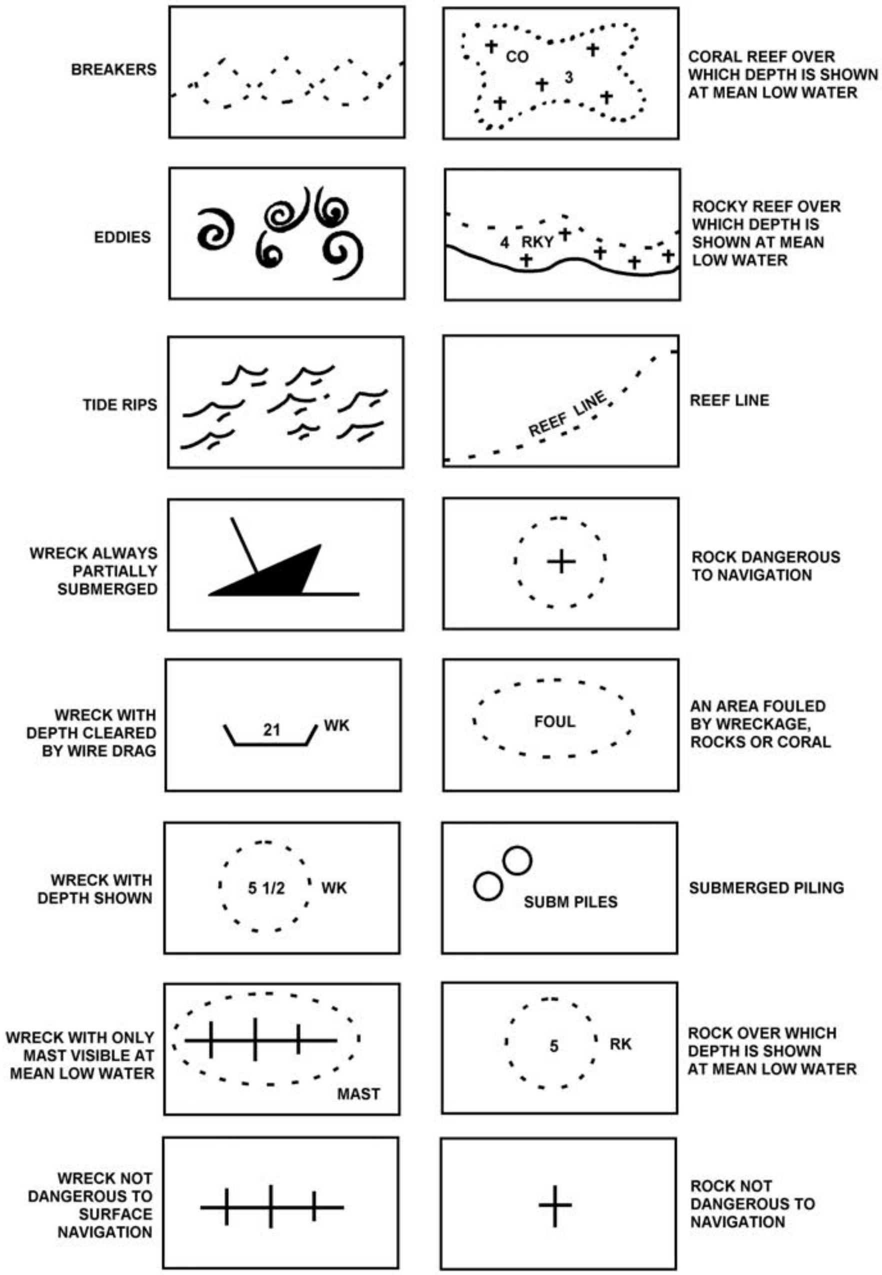

Figure 14-10
Breakers, Rocks, Reefs, Pilings

B.27. Bottom Characteristics

A system of abbreviations, used alone or in combination, describes the composition of the bottom allowing selection of the best holding ground for anchoring. (see **Table 14-1**)

NOTE ☞

> Knowledge of bottom quality is very important in determining an anchorage.

Table 14-1
Bottom Composition

Abbreviation	Composition	Abbreviation	Composition
hrd	Hard	M	Mud; Muddy
Sft	Soft	G	Gravel
S	Sand	Stk	Sticky
Cl	Clay	Br	Brown
St	Stone	Gy	Gray
Co	Coral	Wd	Seaweed
Co Hd	Coral Head	Grs	Grass
Sh	Shells	Oys	Oysters

B.28. Structures

Shorthand representations have been developed and standardized for low-lying structures such as jetties, docks, drawbridges, and waterfront ramps. Such symbols are drawn to scale and viewed from overhead. (see **Figure 14-11**)

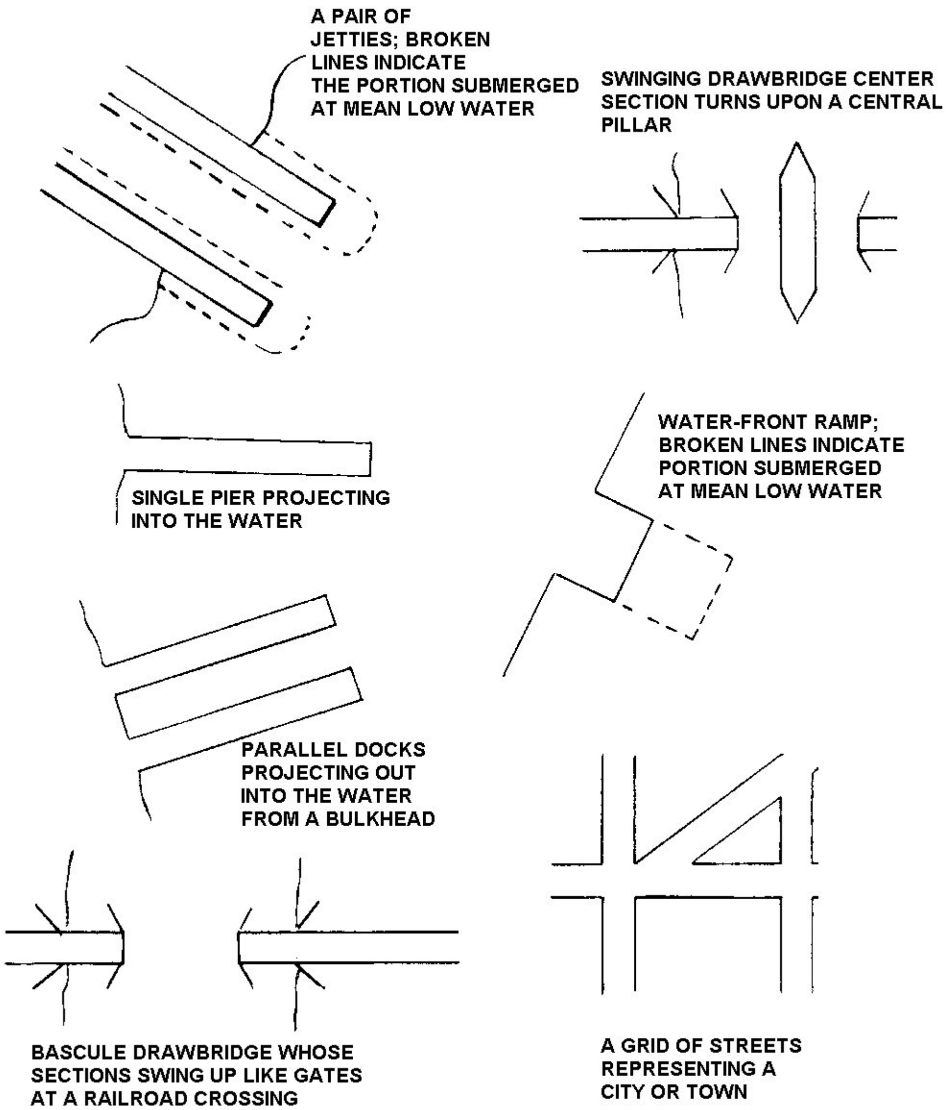

Figure 14-11
Structures

B.29. Coastlines

Coastlines are viewed at both low and high water. Landmarks that may help in fixing position are noted and labeled. (see **Figure 14-12**)

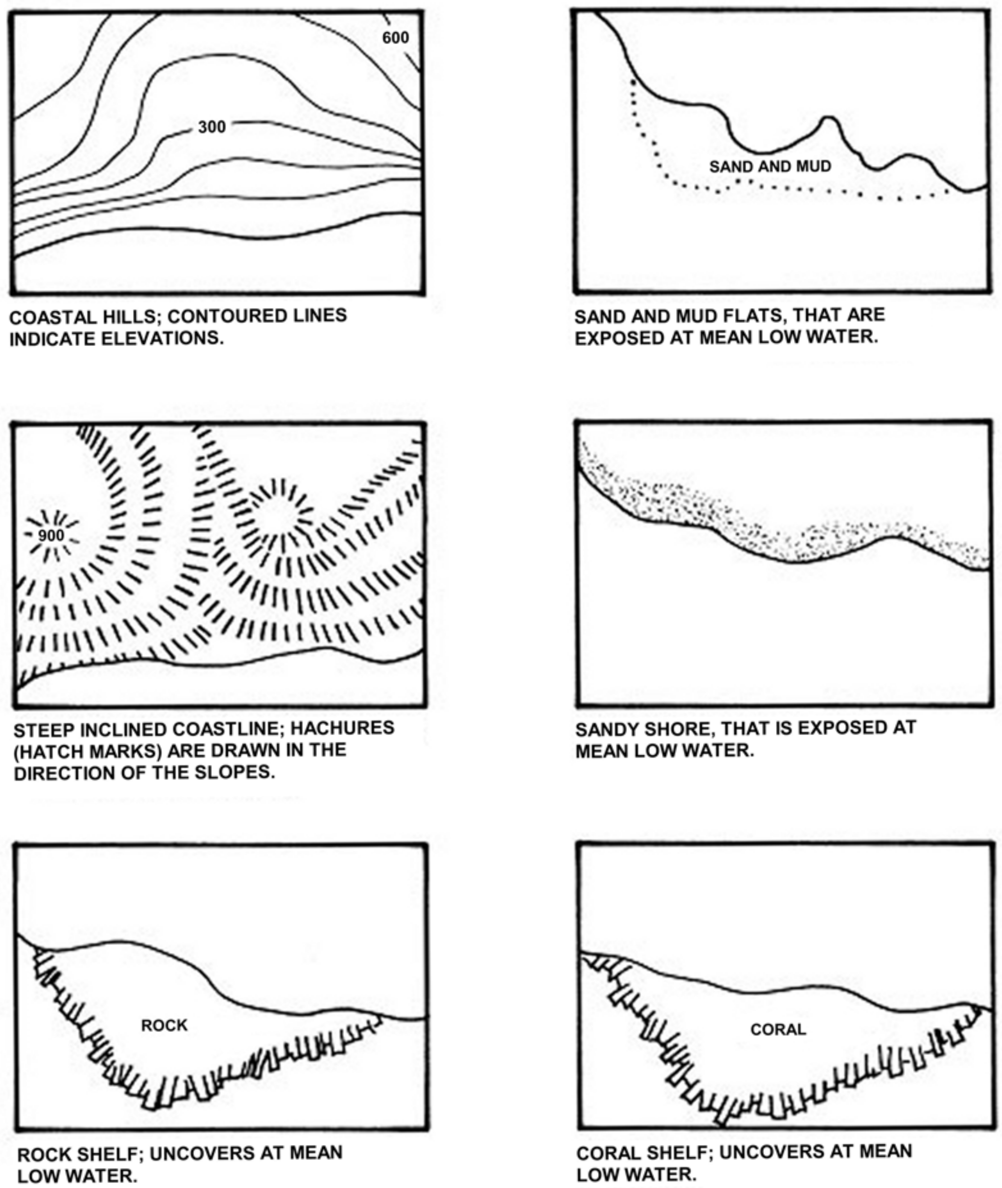

Figure 14-12
Coastlines

Accuracy of Charts

B.30. Description

A chart is only as accurate as the survey on which it is based. Major disturbances, such as hurricanes and earthquakes, cause sudden and extensive changes in the bottom contour. Even everyday forces of wind and waves cause changes in channels and shoals. The prudent sailor must be alert to the possibilities of changes in conditions and inaccuracies of charted information.

B.31. Determining Accuracy

Compromise is sometimes necessary in chart production as various factors may prevent the presentation of all data that has been collected for a given area. The information shown must be presented so that it can be understood with ease and certainty.

In order to judge the accuracy and completeness of a survey, the following should be noted:

- Source and date.
- Testing.
- Full or sparse soundings.
- Blank spaces among sounding.

B.31.a. Source and Date

The source and date of the chart are generally given in the title along with the changes that have taken place since the date of the survey. The earlier surveys often were made under circumstances that precluded great accuracy of detail.

B.31.b. Testing

Until a chart based on such a survey is tested, it should be regarded with caution. Except in well-frequented waters, few surveys have been so thorough as to make certain that all dangers have been found.

B.31.c. Full or Sparse Soundings

Noting the fullness or scantiness of the soundings is another method of estimating the completeness of the survey, but it must be remembered that the chart seldom shows all soundings that were obtained. If the soundings are sparse or unevenly distributed, it should be taken for granted, as a precautionary measure, that the survey was not in great detail.

B.31.d. Blank Spaces Among Soundings

Large or irregular blank spaces among soundings mean that no soundings were obtained in those areas. Where the nearby soundings are deep, it may logically be assumed that in the blanks the water is also deep. When the surrounding water is shallow, or if the local charts show that reefs are present in the area, such blanks should be regarded with suspicion. This is especially true in coral areas and off rocky coasts. These areas should be given wide berth.

Electronic Charts

B.32. Electronic Charts

Raster Charts and Vector Charts are the two types of electronic charts. Raster Charts are basically electronic photographs of an official, paper chart. Vector Charts are distillations of paper charts, but their presentation is different. Vector displays allow you to select "layers" of information to reduce clutter or add detail. Audible alarms can often be set to signal warnings based on the information in these layers such as depth sounding or distances off land.

Section C. Magnetic Compass

Introduction

The magnetic compass, even though it has been around for a long time, is still very important for safely navigating a boat. Whether steering a course out of sight of landmarks or in poor visibility, the magnetic compass is the primary tool for guiding the boat to its destination. Though used by larger vessels, the gyrocompass will not be discussed since it is not commonly used by boats.

In this section

This section contains the following information:

Components of the Magnetic Compass

C.1. Description

The magnetic compass is standard equipment on all boats. Mechanically, it is a simple piece of equipment. The magnetic compass is used to determine the boat's heading. A prudent seaman will check its accuracy frequently realizing that the magnetic compass is influenced, not only by the earth's magnetic field, but also by fields radiating from magnetic materials aboard the boat. It is also subject to error caused by violent movement as might be encountered in heavy weather.

C.2. Compass Card

The arc of the compass card is divided into 360 degrees (°) and is numbered all the way around the card from 000° through 359° in a clockwise direction. Attached to the compass card is a magnet that aligns itself with the magnetic field around it. The zero (north) on the compass card is in line with the magnet or needle attached to the card. When the boat turns, the needle continues to align itself with the magnetic field. This means the compass card stays stationary and the boat turns around it. (see **Figure 14-13**)

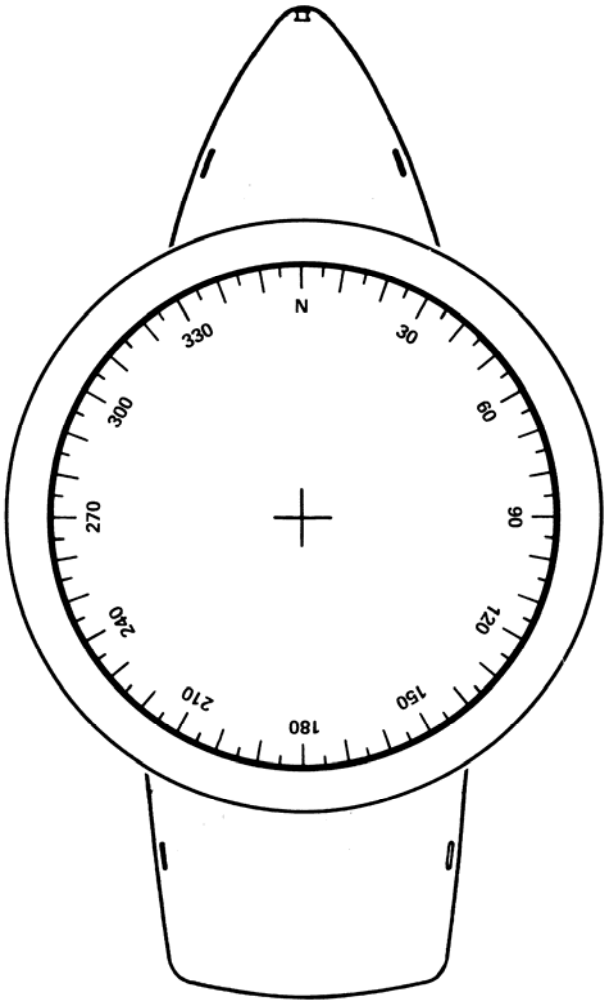

Figure 14-13
Compass Card

C.3. Lubber's Line

The lubber's line is a line or mark scribed on the compass housing to indicate the direction in which the boat is heading. The compass is mounted in the boat with the lubber's line on the boat's centerline and parallel to its keel. (see **Figure 14-14**)

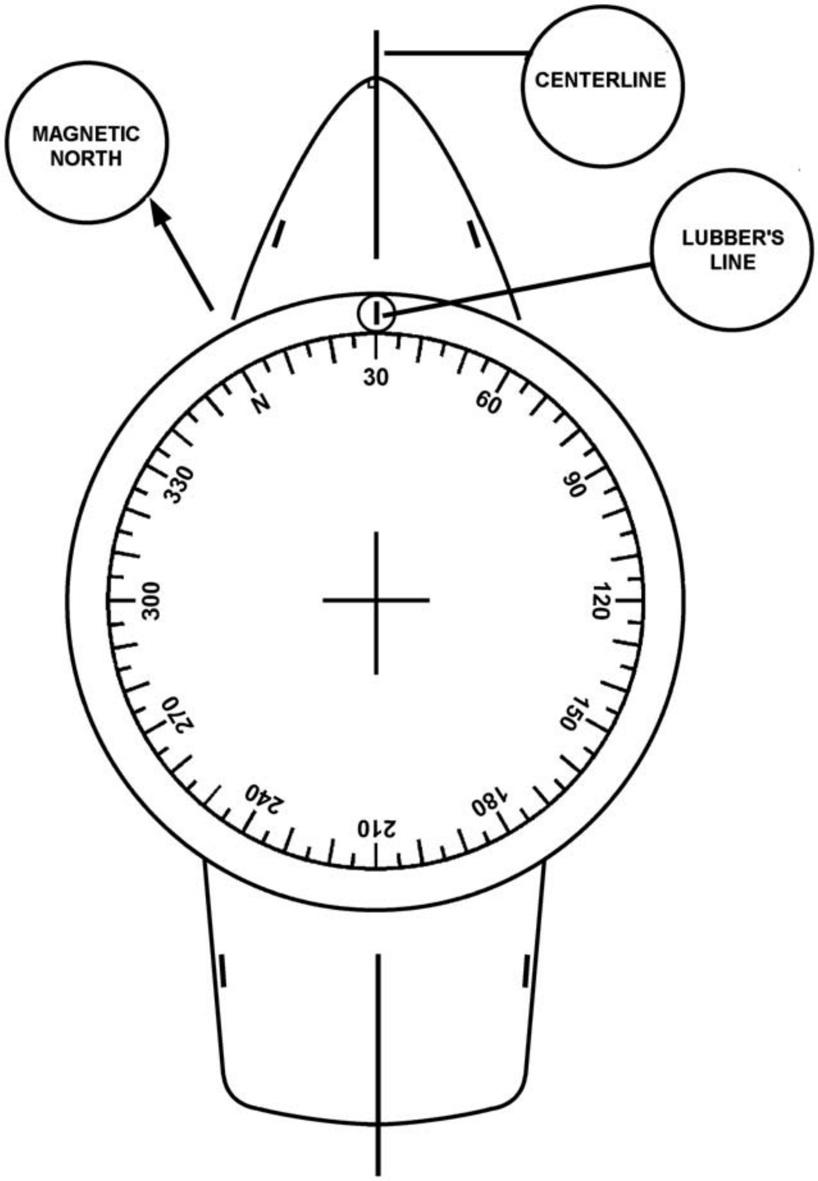

Figure 14-14
Lubber's Line and Magnetic North

Direction

C.4. Description

Direction is measured clockwise from 000° to 359°. When speaking of degrees in giving course or heading, three digits should always be used, such as 270° or 057°. The heading of 360° is always referred to or spoken as 000°.

C.5. True and Magnetic

Directions measured on a chart are in true degrees or magnetic degrees as follows:

- True direction uses the North Pole as a reference point.
- Magnetic direction uses the magnetic North Pole as a reference point.
- True direction differs from magnetic direction by variation.

Directions steered on the compass by the boat are magnetic degrees. (see **Figure 14-15**)

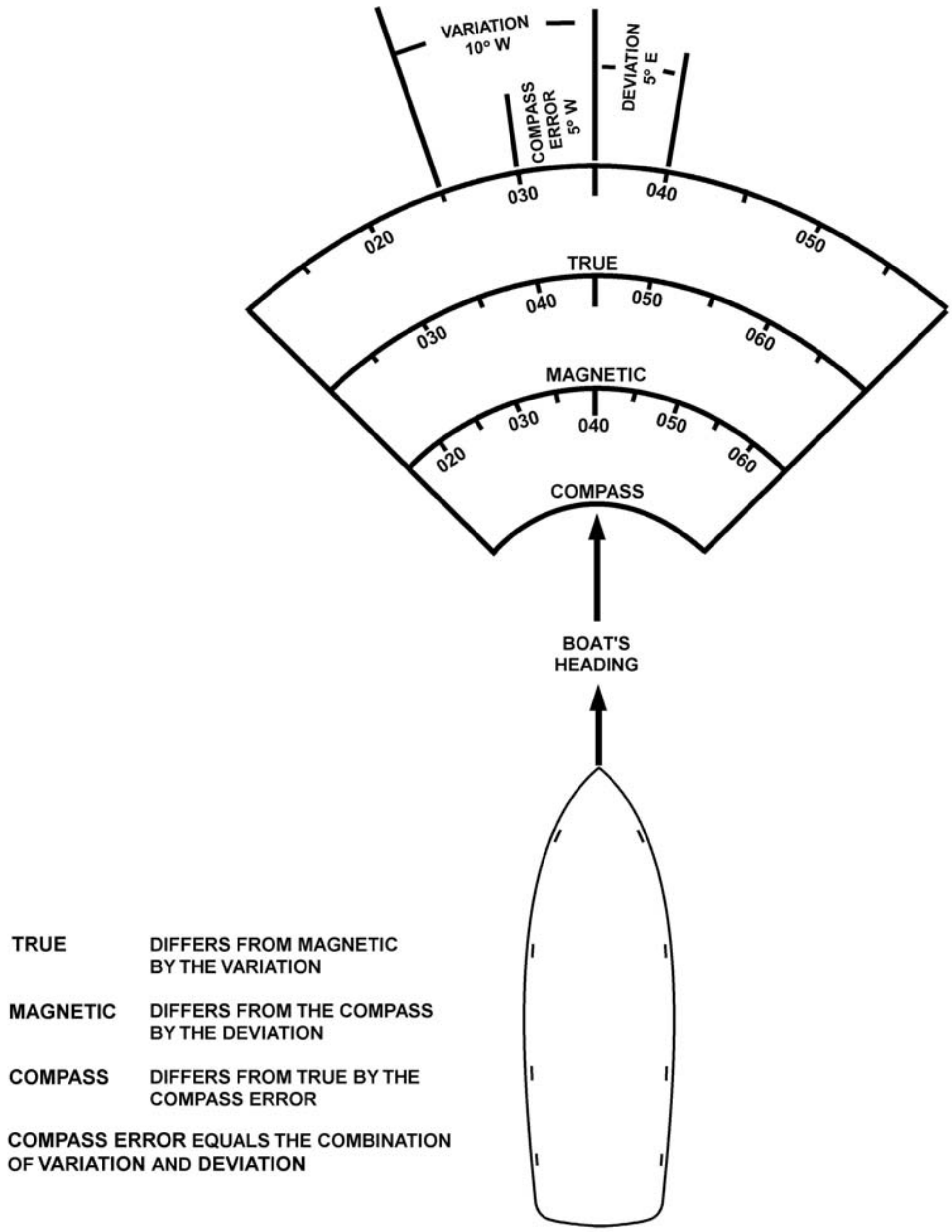

Figure 14-15
True, Magnetic, and Compass Courses

Compass Error

C.6. Description

Compass error is the angular difference between a compass direction and its corresponding true direction. The magnetic compass reading must be corrected for variation and deviation.

Variation

C.7. Description

Variation is the angular difference, measured in degrees, between true and magnetic north. It varies according to geographic location.

C.8. Amount of Variation

The amount of variation changes from one point to the next on the earth's surface. It is written in degrees in either an easterly or a westerly direction. The variation is on the inside of the compass rose of the chart.

C.9. Variation Increases/ Decreases

Increases in variation may continue for many years, sometimes reaching large values, remaining nearly the same for a few years and then reverse its trends (decrease). Predictions of the change of variation are intended for short-term use, that is a period of only a few years. The latest charts available should always be used. The compass rose will show the amount of predicted change.

C.10. Calculating the Variation

Perform the following the procedures for determining the amount of annual increase or decrease of variation:

Step	Procedure
1	Locate the compass rose nearest to area of operation on the chart.
2	Locate the variation and annual increase/decrease from the center of the compass rose.
3	Locate the year from the center of the compass rose where variation and the year are indicated.
4	Subtract year indicated in the compass rose from the present year.
5	Multiply the number of years difference by the annual increase or decrease.
6	Add or subtract the amount from step 5 to the variation within the compass rose.

NOTE

Since variation is caused by the earth's magnetic field, its value changes with the geographic location of the boat. Variation remains the same for all headings of the boat.

Deviation

C.11. Description

Deviation is the amount of deflection influenced by a vessel and its electronics on the compass. It varies according to the heading of the vessel and can be caused by:

- Metal objects around the compass.
- Electrical motors.
- The boat itself.

Deviation creates an error in the compass course that a boat attempts to steer. For navigational accuracy and the safety of the boat and crew, the boat's compass heading must be corrected for deviation so that the actual magnetic course can be accurately steered.

NOTE Deviation changes with the boat's heading; it is not affected by the geographic location of the boat.

C.12. Deviation Table

Coast Guard regulations require Unit Commanders to ensure compass errors are accurately known and properly recorded and posted. This is accomplished for a magnetic compass by "swinging ship" to determine deviation. A deviation table may be created or the Coast Guard deviation table used by ships may be altered for use by boats. (Boats do not fill in the "Degaussing On" column since they do not carry this equipment.) Unit Commanders are also required to develop procedures to compensate or calibrate compasses as necessary.

A new deviation table must be completed and approved by the Unit Commander annually, after yard availabilities, and after addition or deletion of equipment or structural alterations that would affect the magnetic characteristics of the boat. The original deviation table shall be placed in the permanent boat record and a copy posted on the boat near the compass.

C.13. Preparing a Deviation Table

Since deviation varies from boat to boat, crewmembers should know the effect of deviation on the compass. The amount of deviation is normally determined by "swinging ship" (procedures are discussed later) and recording them on a deviation table. The table is tabulated for every 15° of the compass. Deviation varies for different courses steered and can be easterly (E), westerly (W), or no error. Deviation would then be applied to the boat's compass heading to determine the correct magnetic course.

C.14. Deviation By Running a Range

A commonly used practice to determine deviation is running a range. A range is a line of bearing made by two fixed objects. Sometimes, specific range marks are installed so that when they are lined up, the vessel is on the center of a channel (and a true or magnetic direction that can be read on the compass rose). Or, the chart may be checked for prominent landmarks that may line up as a natural range.

C.14.a. Finding Bearing of a Range

When obtaining the deviation, a position that will not interfere with normal shipping traffic should be selected. To find the magnetic bearing of the range:

- Align the edge of the parallel rulers (or course plotter) so that it passes through the charted positions of the two objects.
- Line up the edge of the parallel rulers with the center of the nearest compass rose.
- Read the magnetic bearing off of the inner ring of the compass rose.`

The correct side of the compass rose must be read. Going in the wrong direction will give the reciprocal bearing which is 180° in the wrong direction. To go in the correct direction, crewmembers should try to imagine the boat positioned in the center of the compass rose and looking out towards the range.

NOTE ☞ Man-made ranges may have their direction marked on the chart. If marked, the direction will be in degrees true, not magnetic.

C.14.b. Example

Example: The magnetic bearing (M) of the range measured on the chart is 272°. The bearing of the range read off of the magnetic compass (C) is 274°. (see **Figure 14-16**)

Answer: 2°W is the deviation.

The amount of deviation is the difference between C and M; this is 2°. The direction of deviation is based upon "compass best, error west". Since C is greater than M, the error is west. (This will be discussed in more detail later.)

NOTE ☞ To correct the compass - subtract easterly errors; add westerly errors.

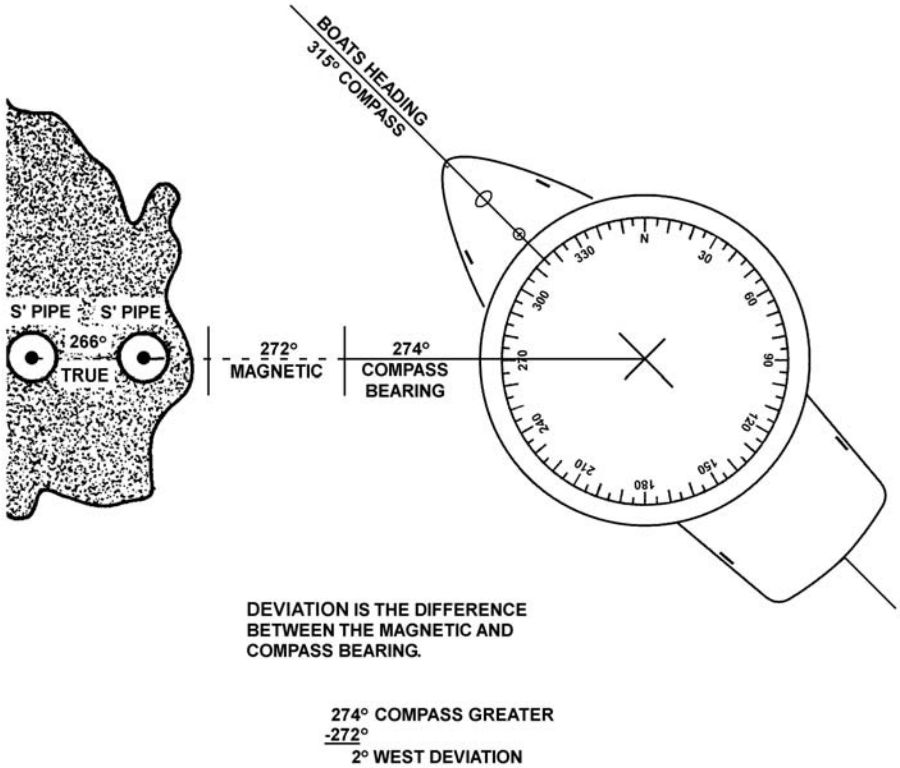

Figure 14-16
Obtaining Deviation Using Ranges

C.14.c. Exercise

The example above and **Figure 14-16** should be used for guidance in developing a deviation table. Prepare a work table using the procedures as follows:

NOTE Enter all compass bearings to the nearest whole degree.

Step	Procedure
1	Enter the boat's compass headings for every 15° in the first column.
2	Enter the range's magnetic bearing as measured on the chart (272°) in the third column. It is the same value for all entries.
3	Get the boat underway at slow speed and in calm water. Steer the boat's compass heading listed in the first column, normally starting with a compass heading of 000°. Steer a steady heading and cross the range.
4	Observe the compass bearing of the range at the instant the range is crossed. Use 266° for this exercise. Enter the range's bearing by compass in the second column on the same line as the boat's compass heading of 000°.
5	Come around to the boat's compass heading of 015°. Steer a steady heading and cross the range.
6	Observe the compass bearing of the range at the instant the range is crossed. Use 265° for this exercise. Enter the range's bearing by compass in the second column on the same line as the boat's compass heading of 015°.
7	Come around to the boat's compass heading of 030°. Steer a steady heading and cross the range.
8	Observe the compass bearing of the range at the instant the range is crossed. Use 265° for this exercise. Enter the range's bearing by compass in the second column on the same line as the boat's compass heading of 030°.
9	Continue changing course by 15° increments until the range is crossed and the compass bearing of the range for each for each boat's compass heading is noted. The table is already filled in for this exercise.
10	Having completed "swinging ship", determine deviation for each heading by taking the difference between the magnetic bearing and the compass bearing. (see **Table 14-2**)

Table 14-2
Completed Work Table, Deviation

Boat's Compass Heading	Compass Bearing of Range	Magnetic Bearing of Range	Deviation	Magnetic Course
000°	266°	272°	6° E	006°
015°	265°	272°	7° E	022°
030°	265°	272°	7° E	037°
045°	267°	272°	5° E	050°
060°	270°	272°	2° E	062°
075°	269°	272°	3° E	078°
090°	271°	272°	1° E	091°
105°	272°	272°	0°	105°
120°	267°	272°	5° E	125°
135°	273°	272°	1° W	134°
150°	268°	272°	4° E	154°
165°	275°	272°	3° W	162°
180°	274°	272°	2° W	178°
195°	277°	272°	5° W	190°
210°	278°	272°	6° W	204°
225°	279°	272°	7° W	218°
240°	275°	272°	3° W	237°
255°	279°	272°	7° W	248°
270°	279°	272°	7° W	263°
285°	277°	272°	5° W	280°
300°	270°	272°	2° E	302°
315°	274°	272°	2° W	313°
330°	269°	272°	3° E	333°
345°	266°	272°	6° E	351°

Step	Procedure
11	Prepare a smooth deviation table to be placed next to the boat's compass. The table must give the deviation for a magnetic course so the table may be used to correct courses. (see **Table 14-3**) As noted before, the deviation table used by ships can be altered for use by boats.

NOTE

When the compass bearing is less than the magnetic bearing - deviation (error) is east. When the compass bearing is greater than the magnetic bearing - deviation (error) is west.

MEMORY AID

Determining the direction of deviation compass least, error east; compass best, error west.

Table 14-3
Deviation Table (Mounted Close to Compass)

Compass Course	Deviation	Magnetic Course
000°	6° E	006°
015°	7° E	022°
030°	7° E	037°
045°	5° E	050°
060°	2° E	062°
075°	3° E	078°
090°	1° E	091°
105°	0°	105°
120°	5° E	125°
135°	1° W	134°
150°	4° E	154°
165°	3° W	162°
180°	2° W	178°
195°	5° W	190°
210°	6° W	204°
225°	7° W	218°
240°	3° W	237°
255°	7° W	248°
270°	7° W	263°
285°	5° W	280°
300°	2° E	302°
315°	2° W	313°
330°	3° E	333°
345°	6° E	351°

C.15. Deviation By Multiple Observations From One Position

To conduct a deviation by multiple observation from one position, an accurately charted object such as a solitary piling, with maneuvering room and depth around it, must be available. In addition, there must be charted and visible objects, suitable for steering on with accuracy, at a distance of greater than ½ mile. The largest scale chart possible should be used.

C.15.a. Preparation

To prepare for this task, perform the following procedures:

Step	Procedure
1	Determine and record the magnetic bearing from the chart (from piling to object) of various selected objects.
2	Ideally, the objects should be 15 ° apart. However, this is not necessary as long as a minimum of ten objects/bearings, evenly separated through the entire 360°, are available.
3	For ready reference, record this information as shown in columns (1) and (2) in the table below.

(1) Object (on chart)	(2) Magnetic Heading (plotted)	(3) Compass Heading (measured)	(4) Deviation (calculated)
Steeple	013°	014.0°	1.0° W
Stack	040°	041.5°	1.5° W
R. Tower	060°	062.0°	2.0° W
Lt. #5	112°	115.0°	3.0° W
Left Tangent Pier	160°	163.0°	3.0° W
Water Tower	200°	201.0°	1.0° W
Right Tangent Jetty	235°	235.0°	0.0° W
Light House	272°	271.0°	1.0° E
Flag Pole	310°	309.0°	1.0° E
Lookout Tower	345°	344.5°	0.5° E

C.15.b. Observation

To carry out this task, perform the following procedures:

Step	Procedure
1	With the above information (column (1) and (2)), proceed to and tie off to the piling.
2	With the piling amidships, pivot around it and steer on the objects that were identified, then record the compass heading in column (3). Comparing column (2) and (3) will yield the deviation for that heading (4).
3	Use the observed deviation (4) for the indicated magnetic heading (2) as reference points, then draw a deviation curve on the graph as is shown in **Figure 14-17**.

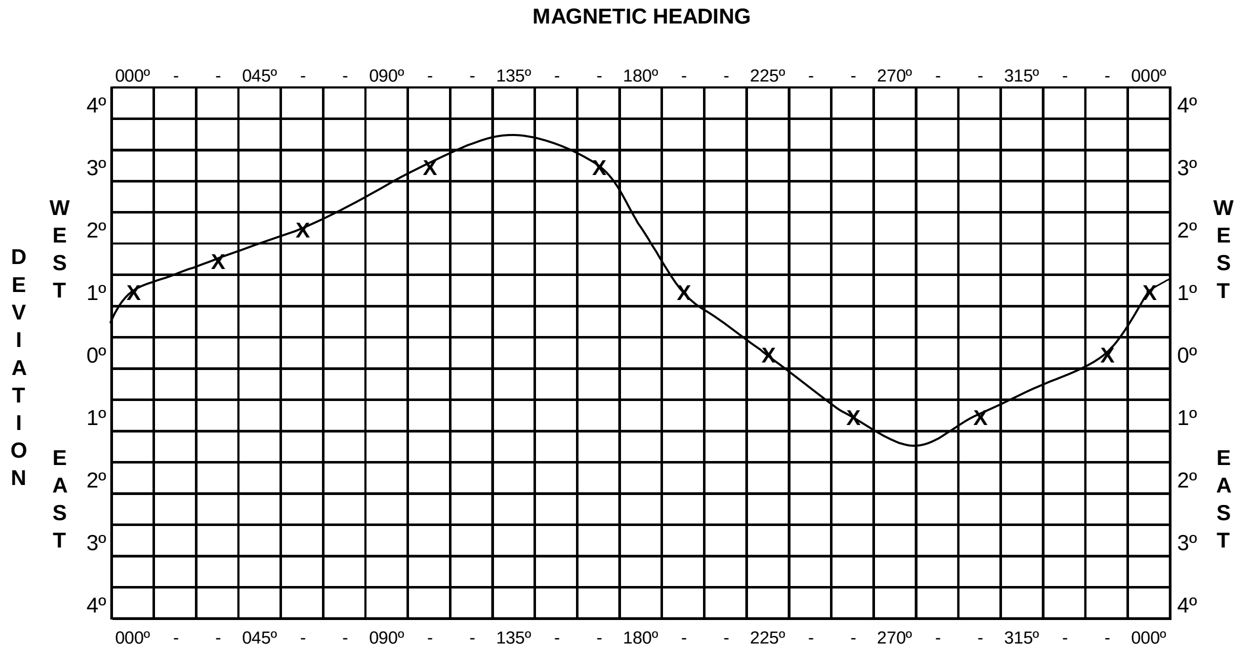

Figure 14-17
Example Deviation Curve

C.15.c. Determination

Deviations should be extracted from the deviation curve for any heading.

NOTE

> The graph is divided vertically in 15° increments and horizontally in half (for east and west deviation) and then further divided according to amount of deviation. This later subdivision may be greater than the 4° depicted. However, do not tolerate deviations of more than 3°. If excessive deviations are noted, the compass should be adjusted by the technique discussed later or by a professional compass adjuster.

C.16. Deviation by Multiple Ranges

The largest scale chart available covering the local area should be used. With parallel rulers, triangles, etc., crewmembers should identify as many terrestrial ranges as possible that will be visible when underway, and also provide lines of position (LOPs) across expanses of water with adequate maneuvering room and depth. As far as possible, the ranges should be in the same area, so that variation remains constant.

CAUTION ! Ensure that there are no local magnetic anomalies (such as wrecks, pipe lines, bridges or steel piers) near the boat that could affect the local variation indicated on the chart. Check the chart for any indication of local disturbances.

C.16.a. Preparation

The number of terrestrial ranges available may be limited. However, for each range, deviation will be for both the "steering toward" and the "steering away" (reciprocal) heading. To prepare for this task, perform the following procedures:

Step	Procedure
1	Be careful when "running" the reciprocal heading that the lubber's line of the compass aligns with the axis of the range.
2	Make every effort to identify no less than four ranges to yield deviation values for the cardinal points (N, S, E, W) and intercardinal points (NE, SE, SW, NW).
3	Determine the magnetic bearing from the chart. Record this information in the format shown below.

(1) Range (on chart)	(2) Magnetic Heading (plotted)	(3) Compass Heading (measured)	(4) Deviation (calculated)
Steeple -Jetty Lt. #4	015°/195°	014°/195°	1° E/0°
R. Tower - Tank	103°/283°	104°/282°	1° W/1° E
Flag Pole – Lt. #5	176°/356°	177°/355.5°	1° W/.5° E
Stack - Left Tangent Pier	273°/093°	272°/094°	1° E/1° W
Ent Channel Range	333°/153°	332°/154.5°	1° E/1.5° W

C.16.b. Observation

To carry out this task, perform the following procedures:

Step	Procedure
1	With the information from columns (1) and (2) get underway and "run" the various ranges.
2	Record the compass heading in column (3), as appropriate.
3	Take care not to become so preoccupied with running the range that the boat is in jeopardy of collision, grounding, etc.
4	Compare column (2) and (3) to yield the deviation from that heading (4).

C.16.c. Determination

The deviation for the indicated headings may be plotted on the deviation graph resulting in a deviation curve. With the resulting deviation curve, deviation for any heading is possible. (see **Figure 14-18**)

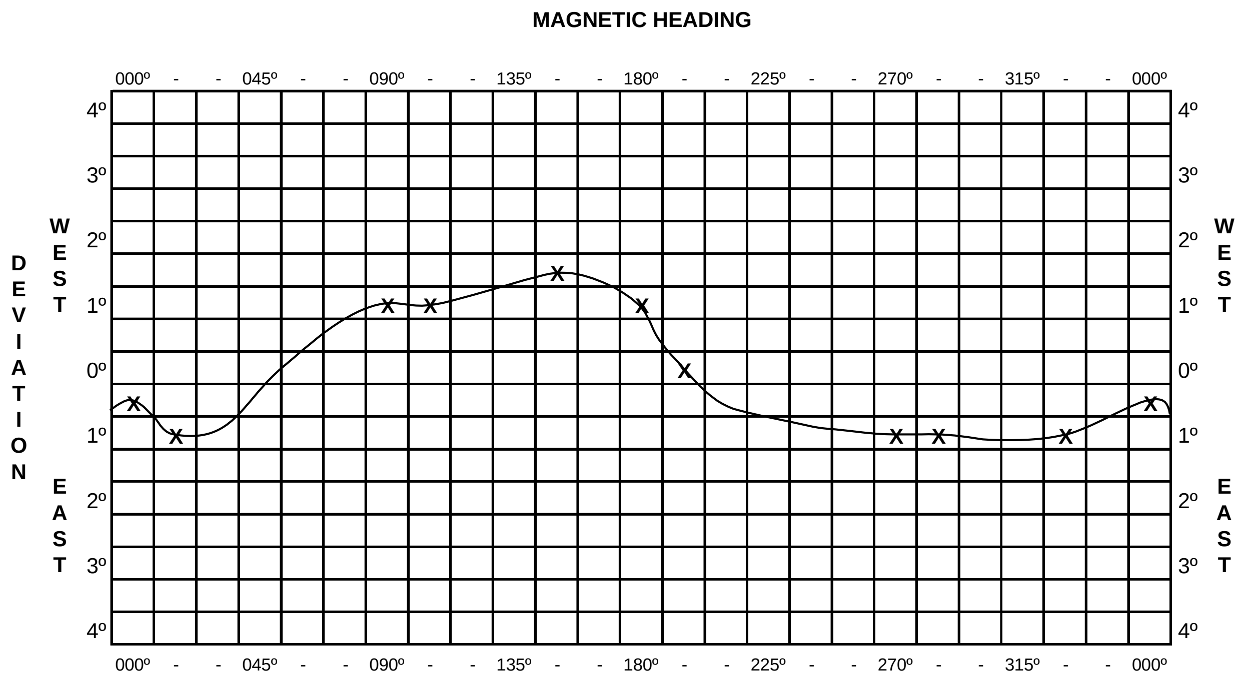

Figure 14-18
Example Deviation Curve

Compass Adjustment

C.17. Description

The following are the procedures for adjusting a small boat compass:

Step	Procedure
1	Steer a course in a northerly direction as close to magnetic north as possible as defined by the known objects on the chart. With a nonmagnetic tool, adjust the N/S compensating magnet to remove half the observed error. (Do not try to shortcut. Removing all the error in the first step will just overcompensate the error.)
2	Steer a course in a southerly direction. Again remove half the observed error.
3	Steer a course in an easterly direction. Adjust the E/W compensating magnet to remove half the observed error.
4	Steer a course in a westerly direction. Again remove half the observed error.
5	Repeat the above procedures, as often as needed, to reduce observed error to the minimum achievable.
6	Record the final observed instrument error for N, S, E, and W.
7	Determine the observed error for NE, SE, SW, and NW. Record these but do not try to adjust these errors manually.
8	Use the recorded values for compass corrections.

These simple procedures are sufficiently precise for most boats. To gain greater precision, a qualified compass adjuster should be used or a book on the subject should be consulted.

Applying Compass Error

C.18. Description

"Correcting" is going from magnetic direction (M) to true (T), or going from the compass direction (C) to magnetic (M). To apply compass error to correct course or direction:

- Take the compass course.
- Apply deviation to obtain the magnetic course.
- Apply variation to obtain true course.

The sequence of the procedure is outlined below: (see **Figure 14-19**)

- Compass (C).
- Deviation (D).
- Magnetic (M).
- Variation (V).
- True (T).

MEMORY AID

Applying compass error:
Can **D**ead **M**en **V**ote **T**wice **A**t **E**lection
(**C**ompass) (**D**eviation) (**M**agnetic) (**V**ariation) (**T**rue) (**A**dd) (**E**asterly error)
Add easterly errors - subtract westerly errors

C.19. Obtaining True Course

For **Figure 14-19**, the compass course is 127°, variation from the compass rose is 4° W, and the deviation from the boat's deviation table is 5° E. Then, the true course (T) is obtained as follows:

Step	Procedure
1	Write down the correction formula:
	• C = 127°
	• D = 5° E
	• M = 132°
	• V = 4° W
	• T = 128°
2	Compute the information opposite the appropriate letter in the previous step.
3	Add the easterly error of 5° E deviation to the compass course (127°) and obtain the magnetic course of 132°.
4	Subtract the westerly error of 4° W variation from the magnetic course (132°).
5	The true course is 128°.

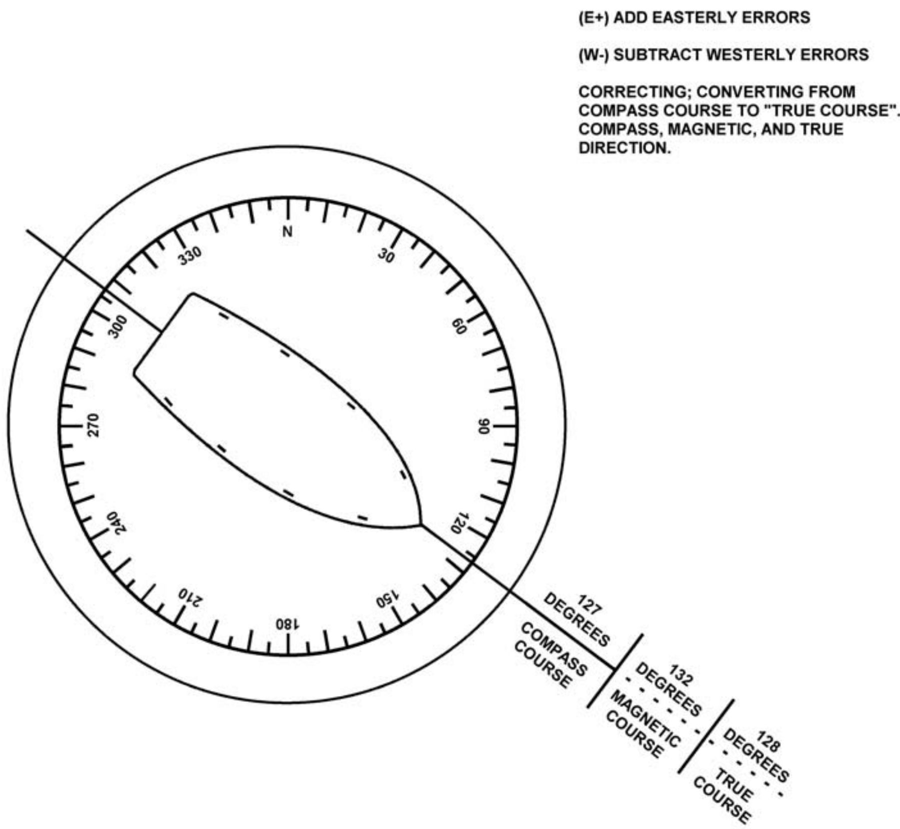

Figure 14-19
Applying Compass Error, Correcting

C.20. Converting True Course to Compass Course

Converting from true (T) direction to magnetic (M), or going from magnetic (M) to compass (C) is "uncorrecting". For converting from true course to compass course:

- Obtain the true course.
- Apply variation to obtain the magnetic course.
- Apply deviation to obtain the compass course.

The sequence of the procedure is outlined below:

- True (T).
- Variation (V).
- Magnetic (M).
- Deviation (D).
- Compass (C).

MEMORY AID

Converting true course to compass course:
True **V**irtue **M**akes **D**ull **C**ompany **A**fter **W**edding
(**T**rue) (**V**ariation) (**M**agnetic) (**D**eviation) (**C**ompass) (**A**dd) (**W**esterly error)
Subtract easterly errors - add westerly errors

C.21. Obtaining Compass Course

For **Figure 14-20**, by using parallel rulers, the true course between two points on a chart is measured as 221° T, variation is 9° E and deviation is 2° W. Then, obtain the compass course (C) is obtained as follows:

Step	Procedure
1	Write down the conversion formula: • T = 221° • V = 9° E • M = 212° • D = 2° W • C = 214°
2	Compute the information opposite the appropriate letter in the previous step.
3	Subtract the easterly error of 9° E variation from true course of 221° and obtain the magnetic course of 212°.
4	Add the westerly error of 2° W deviation to the magnetic course (212°).
5	The compass course (C) is 214°.

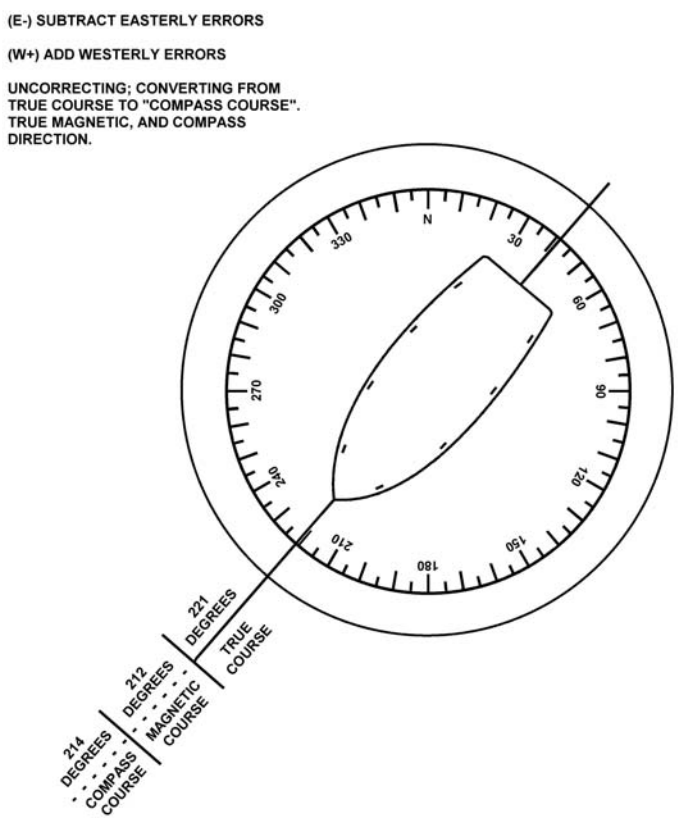

Figure 14-20
Applying Compass Error, Uncorrecting

Section D. Piloting

Introduction

Piloting is directing a vessel by using landmarks, other navigational aids, and soundings. Safe piloting requires the use of correct, up-to-date charts. Piloting deals with both present and future consequences. Therefore, it is important to be alert and attentive, and always be consciously aware of where the vessel is and where it soon will be.

In this section

This section contains the following information:

Basic Piloting Equipment

D.1. Description

Adequate preparation is very important in piloting a boat. Piloting is the primary method of determining a boat's position. In order for a boat coxswain to make good judgment on all decisions in navigation, tools such as compasses, dividers, stopwatches, parallel rulers, pencils, and publications must be available. (see **Figure 14-21**)

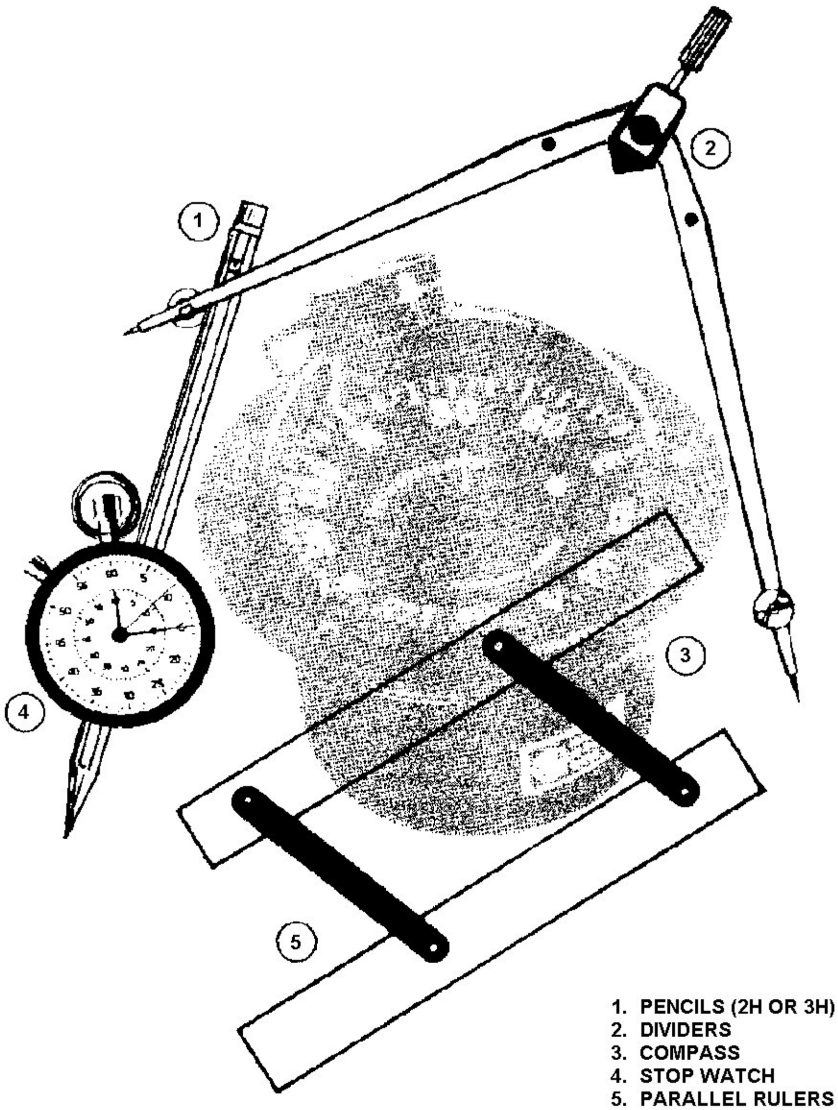

Figure 14-21
Basic Piloting Tools

D.2. Compass

For a boat, the magnetic compass is used:

- To steer the course.
- To give a constant report on the boat's heading.
- As a sighting instrument to determine bearings.

A mark called a "lubber's line" is fixed to the inner surface of the compass housing. Similar marks, called 90° lubber's lines, are usually mounted at 90° intervals around the compass card and are used in determining when an object is bearing directly abeam or astern. Centered on the compass card is a pin (longer than the lubber's line pins), which is used to determine a position by taking bearings on visible objects.

D.3. Parallel Rulers

Parallel rulers are two rulers connected by straps that allow the rulers to separate while remaining parallel. They are used in chart work to transfer directions from a compass rose to various plotted courses and bearing lines and vice versa. Parallel rulers are always walked so that the top or lower edge intersects the compass rose center to obtain accurate courses.

D.4. Course Plotter

A course plotter may be used for chart work in place of the parallel rulers discussed above. It is a rectangular piece of clear plastic with a set of lines parallel to the long edges and semi-circular scales. The center of the scales is at or near the center of one of the longer sides and has a small circle or bull's eye. The bull's eye is used to line up on a meridian so that the direction (course or bearing) can be plotted or read off of the scale. A popular model is the "Weems Plotter" that is mounted on a roller for ease of moving.

D.5. Pencils

It is important to use a correct type of pencil for plotting. A medium pencil (No. 2) is best. Pencils should be kept sharp; a dull pencil can cause considerable error in plotting a course due to the width of the lead.

D.6. Dividers

Dividers are instruments with two pointed legs, hinged where the upper ends join. Dividers are used to measure distance on a scale and transfer them to a chart.

D.7. Stopwatch

A stopwatch, or navigational timer, which can be started and stopped at will, is very useful to find the lighted period of a navigational aid. This is usually done for purposes of identification. Also, it is used to run a speed check.

D.8. Nautical Slide Rule

The nautical slide rule will be discussed in the Distance, Speed, and Time portion of this chapter.

D.9. Drafting Compass

The drafting compass is an instrument similar to the dividers. One leg has a pencil attached. This tool is used for swinging arcs and circles.

D.10. Speed Curve (Speed vs. RPMs)

A speed curve is used to translate tachometer readings of revolutions per minute (RPMs) into the boat's speed through the water. A speed curve is obtained by running a known distance at constant RPM in one direction and then in the opposite direction. The time for each run is recorded and averaged to take account for current and wind forces. Using distance and time, the speed is determined for the particular RPM. (see Error! Reference source not found.)

Table 14-4
Sample Speed vs. RPMs Conversion

Speed, Kts Calm Water	Approx. RPM	Fuel Gal/Hour	Consumption Gal/Mile	Cruise Radius/Miles
7.60	760	3.86	.51	882
7.89	1000	4.99	.63	712
9.17	1250	7.50	.82	550
9.48	1500	12.75	1.31	335
12.50	1750	16.80	1.35	333
15.53	2000	21.00	1.35	333
19.15	2250	33.00	1.72	261
21.34	2400	33.75	1.58	284

D.11. Charts

Charts are essential for plotting and determining your position, whether operating in familiar or unfamiliar waters. Boat crews should never get underway without the appropriate charts.

D.12. Depth Sounder

There are several types of depth sounders, but they operate on the same principle. The depth sounder transmits a high frequency sound wave that reflects off the bottom and returns to the receiver. The "echo" is converted to an electrical impulse and can be read from a visual scale on the depth sounder. It shows only the depth of water the vessel is in; it does not show the depth of water being headed for.

D.12.a. Transducer

The transducer is the part of the depth sounder that transmits the sound wave. The transducer is usually mounted through the hull and sticks out a very short distance. It is not mounted on the lowest part of the hull. The distance from the transducer to the lowest point of the hull must be known. This distance must be subtracted from the depth sounding reading to determine the actual depth of water available.

Example: Depth sounder reading is 6 feet. The transducer is 1 foot above the lowest point of the hull - the boat extends 1 foot below the transducer. This 1 foot is subtracted from the reading of 6 feet, which means the boat has 5 feet of water beneath it.

NOTE Always consider the location of the transducer; it is usually mounted above the lowest point of the hull.

D.12.b. Water Depth

Water depth is indicated by a variety of methods:

- Indicator: A digital display or a flashing light that rotates clockwise around a scale on a visual screen in the pilothouse. In the flashing light type, the first "flash" is when the pulse goes out and the second flash is the "echo" back that indicates the depth.
- Recorder: Depths are recorded on paper tape.
- Video display screen: The display is similar to a small television set with brightness on the bottom of the screen indicating the sea floor.

NOTE To determine the actual water depth below the boat's hull, subtract the distance between the transducer and the lowest point of the hull from all readings.

D.12.c. Bottom Conditions

With practice and experience, the bottom characteristics and conditions can be determined. Flashing light and video display sounders may be generally interpreted as:

- Sharp, clear flash - hard bottom.
- Broad, fuzzy flash - soft, muddy bottom.
- Multiple, fairly sharp flashes - rocky bottom.
- Additional flashes or displays at multiples of the least depth indicated may reveal the need to turn down the sensitivity control.

D.12.d. Adjustment Controls

Adjustment controls depend on the type of depth sounder. The equipment operator's manual should be reviewed for correct use. Typical adjustment controls include depth scales (which may include feet and fathoms) and a sensitivity control.

D.13. Lead Line

Depth of water is one of the most important dimensions of piloting. A hand-held lead line is used for ascertaining the depth of water when a depth sounder is not available, the depth sounder is not operational, or the crew is operating in known shallow water.

It consists of a line marked in fathoms and a lead weight of 7 to 14 pounds, hollowed at one end in which tallow is inserted to gather samples of the bottom. It is simple and not subject to breakdown. Lead line limitations include:

- Not useable in adverse sea conditions.
- Awkward to use.
- Usable only at slow speed.

NOTE Always keep a lead line neatly stowed and ready for use in the event the depth sounder becomes inoperative.

D.13.a. Lead Line Markings

Lead lines are marked as follows: (see **Figure 14-22**)

Depth	Lead Line Marking
2 Fathoms	Two (2) strips of leather
3 Fathoms	Three (3) strips of leather
5 Fathoms	One (1) white rag (usually cotton)
7 Fathoms	One (1) red rag (usually wool)
10 Fathoms	One (1) strip of leather with a hole
13 Fathoms	Three (3) strips of leather
15 Fathoms	One (1) white rag (usually cotton)
17 Fathoms	One (l) red rag (usually cotton)
20 Fathoms	Two (2) knots
25 Fathoms	One (1) knot

NOTE Lead lines should be wetted and stretched prior to marking. Lines should be checked periodically for accuracy of markings.

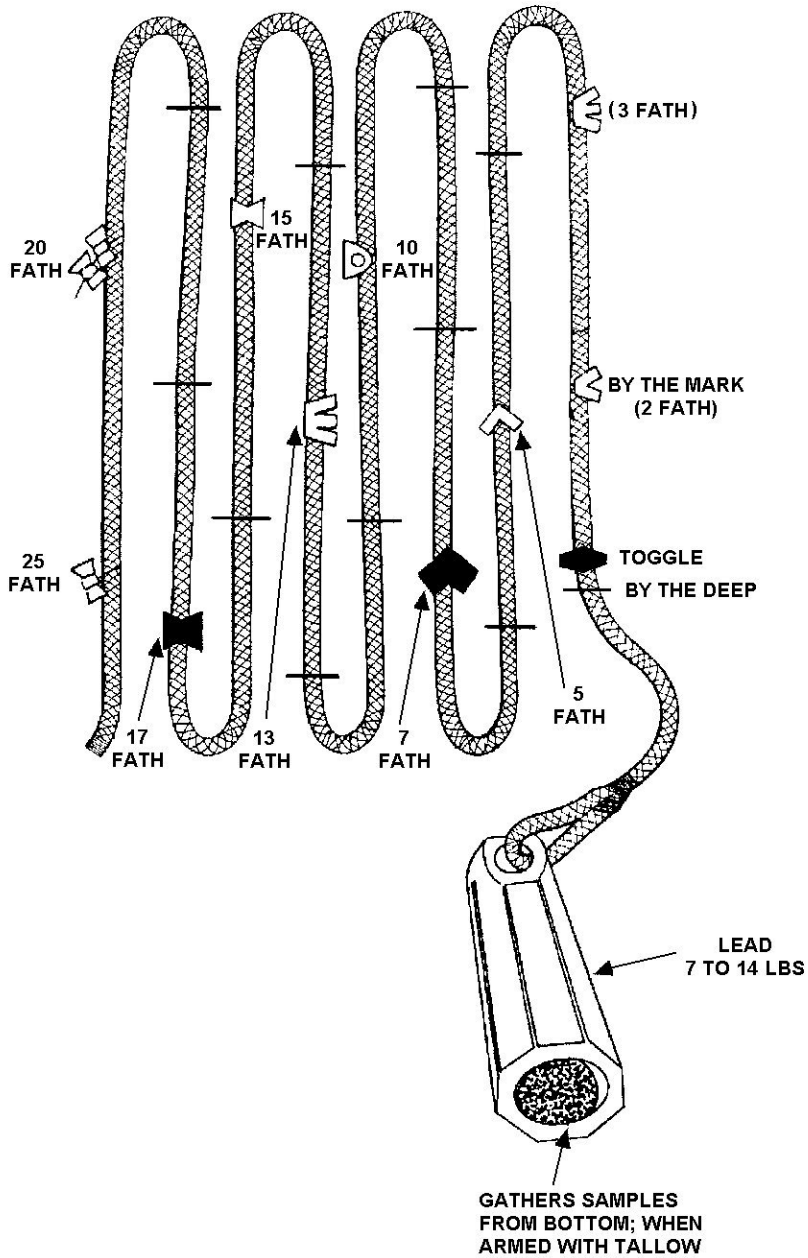

Figure 14-22
Handheld Lead Line

D.13.b. Casting the Hand-Held Lead Line

The following procedures should be used in casting a lead line:

Step	Procedure
1	Grasp the line by the toggle.
2	Swing the lead in a fore-and-aft arc.
3	When sufficient momentum is obtained and at shoulder level, throw the lead as far forward as possible. Keep hold of the bitter end of the line!
4	Pull the slack out of the line until the lead on the bottom is felt is felt.
5	When the line is straight up and down, read the sounding.

D.13.c. Reporting the Soundings

There are two ways to report soundings, depending upon where the watermark is located on the lead line.

- Depth that corresponds to any mark on the lead line is reported: “by the mark”, that is, should the depth align with the two strips of leather, it would be reported “by the mark 2”.
- All other unmarked whole fathoms are called deeps. This would be reported as “by the deep 6” for a depth of 6 fathoms.

Fractions of a fathom should be reported as halves and quarters, such as, “and a half seven” or “less a quarter ten”.

D.14. RDF and ADF

A radio direction finder (RDF) will allow the users to take bearings on radio transmitters which are well beyond their visual range. One type of RDF requires manual operation to obtain bearings. The automatic radio direction finder (ADF) automatically takes and displays the bearings.

Radio bearings are not as accurate as visual bearings. It takes a great deal of experience to be able to effectively use the equipment. Care should be taken when plotting radio bearings, especially in the correct direction.

D.15. VHF-FM Homer

The VHF-FM homer (direction finder homing device) allows the users to home in on the source of any FM radio signals being received. This unit will also function as a backup VHF-FM receiver.

The VHF-FM homer measures the small difference in angle of a signal, from a known source and received by each antenna, then converts this signal into the angle of direction from the boat. This direction is shown on a swinging needle display screen mounted in the pilothouse. The source must continue to transmit to be able to track it.

The following procedures should be used for operating the homer:

NOTE

A needle centered in the middle of the screen may indicate a source dead ahead, or dead astern. The homer cannot distinguish this since both signals would arrive at 90 degrees to each antenna. To determine which direction, turn off course 30 degrees and observe the needle. If it directs to return to the original heading, the source is ahead. If the needle points elsewhere, follow it. The indicator needle is affected by radio wave reflections and may bounce around when passing near large metal objects.

Step	Procedure
1	The homer has six channels (6, 12, 13, 14, 16, and 22) in addition to the weather channels. Set the channel switch to the channel receiving the signal.
2	Request a long count from the transmitting station.
3	Turn the squelch control fully counterclockwise.
4	Set volume to a comfortable level.
5	Rotate squelch control to remove speaker noise.
6	Push squelch control in for homing, out for monitoring.
7	Turn the boat in the direction of the pointer until it centers itself.
8	Turn 30° to be sure the source is ahead, not aft.
9	Change course as indicated by the needle and proceed to the source of the signals, giving due caution to navigation hazards that may be between the vessel and the destination.

D.16. Light List

Light Lists provide more complete information concerning aids to navigation than can be shown on charts. They are not intended to replace charts for navigation and are published in seven volumes, as follows:

Volume	Area of Coverage
I	Atlantic Coast, from St. Croix River, Maine to Toms River, New Jersey
II	Atlantic Coast, from Toms River, New Jersey to Little River Inlet, South Carolina
III	Atlantic Coast, from Little River Inlet, South Carolina, to Econfina River, Florida, and the Greater Antilles
IV	Gulf of Mexico, from Econfina River, Florida, to Rio Grande, Texas
V	Mississippi River System
VI	Pacific Coast and Pacific Islands
VII	Great Lakes

D.17. Tide Tables

Tide Tables give daily predictions of the height of water, at almost any place, at any given time, and are published annually in four volumes. Instructions for using the tables are provided within the publication. The four volumes are as follows:

Volume	Area of Coverage
I	Europe and West Coast of Africa (including the Mediterranean Sea)
II	East Coast of North and South America (including Greenland)
III	West Coast of North and South America (including the Hawaiian Islands)
IV	Central and Western Pacific Ocean and Indian Ocean.

D.18. Tidal Current Tables

Tidal current tables provide the times of maximum flood and ebb currents, and times of the two slack waters when current direction reverses. They also tell the predicted strength of the current in knots. The time of slack water does not correspond to times of high and low tide. The tide tables cannot be used for current predictions. The tables are published in two volumes. Instructions for using the tables are provided within the publication. The two volumes are as follows:

Volume	Area of Coverage
I	Atlantic Coast of North America
II	Pacific Coast of North America and Asia

D.19. Coast Pilots

The amount of information that can be printed on a nautical chart is limited by available space and the system of symbols that is used. Additional information is often needed for safe and convenient navigation. Such information is published in the *Coast Pilot*. These are printed in book form covering the coastline and the Great Lakes in nine separate volumes.

Each *Coast Pilot* contains sailing directions between points in its respective area, including recommended courses and distances. Channels with their controlling depths and all dangers and obstructions are fully described. Harbors and anchorages are listed with information on those points at which facilities are available for boat supplies and marine repairs. Information on canals, bridges, docks, and more, is included. The nine volumes are as follows:

Volume	Area of Coverage
	Atlantic Coast
No. 1	Eastport to Cape Cod
No. 2	Cape Cod to Sandy Hook
No. 3	Sandy Hook to Cape Henry
No. 4	Cape Henry to Key West
No. 5	Gulf of Mexico, Puerto Rico, and Virgin Islands
	Great Lakes
No. 6	Great Lakes and connecting waterways
	Pacific Coast
No. 7	California, Oregon, Washington, and Hawaii
	Alaska
No. 8	Dixon Strait to Cape Spencer
No. 9	Cape Spencer to Beaufort Sea

D.20. COLREGS

The Rules of the Road set forth regulations for navigable waters and are covered in *Navigation Rules, International – Inland*, COMDTINST M16672.2 (series).

Distance, Speed, and Time

D.21. Description

Distance, speed, and time are critical elements in navigational calculations. Each has its own importance and use in piloting. All three are closely associated in the way they are calculated. In planning the sortie or while underway, the typical navigation problem will involve calculating one of these elements based on the value of the other two elements.

D.22. Expressing Distance, Speed, and Time

Units of measurement are:

- Distance in nautical miles (NM) except statute miles on the western rivers.
- Speed in knots.
- Time in minutes.

In calculations and answers, express:

- Distance to the nearest tenth of a nautical mile.
- Speed to the nearest tenth of a knot.
- Time to the nearest minute.

D.23. Formulas

There are three basic equations for distance (D), speed (S), and time (T). Actually, they are the same equation rewritten to calculate each specific element. In each case, when two elements are known, they are used to find the third, which is unknown. The equations are:

- D = S x T/60
- S = 60D/T
- T = 60D/S

In the equation, 60 is for 60 minutes in an hour.

The following examples show how these equations work:

D.23.a. Example #1

If a boat is traveling at 10 knots, how far will you travel in 20 minutes? Solve for distance (D).

Step	Procedure
1	D = S x T/60
2	D = 10 x 20/60
3	D = 200/60 D = 3.3 NM

D.23.b. Example #2

At a speed of 10 knots, it took the boat 3 hours and 45 minutes to go from the Station to the shipping channel. What is the distance to the shipping channel?

Step	Procedure
1	Convert the hours to minutes for solving this equation. First, multiply the 3 hours by 60 (60 minutes in an hour), add the remaining 45 minutes, that is: 3 x 60 + 45 = 225 minutes
2	Write the equation. D = S x T/60
3	Substitute information for the appropriate letter and calculate the distance. D = 10 knots X 225 minutes/60
4	D = 2250/60 D = 37.5 NM (nearest tenth)

D.23.c. Example #3

A boat has traveled 12 NM in 40 minutes. What is its speed (S)?

Step	Procedure
1	S = 60D/T
2	S = 60 x12/40
3	S = 720/40 S = 18 knots

D.23.d. Example #4

Also, when distance and time are known, speed can be calculated. Departure time is 2030; the distance to the destination is 30 NM. Calculate the speed the boat must maintain to arrive at 2400.

Step	Procedure
1	Calculate the time interval between 2030 and 2400. To determine the time interval, convert time to hours and minutes and then subtract. 23 hours 60 minutes (2400) - 20 hours 30 minutes (2030) 3 hours 30 minutes
2	Distance - speed - time equations are computed in minutes. Convert the 3 hours to minutes, add the remaining 30 minutes. 3 x 60 = 180 minutes + 30 210
3	Write the equation. S = 60D/T
4	Substitute information for the appropriate letter and calculate the speed. S = 60D/T S = 60 x 30 NM/210 minutes
5	S = 1800/210 S = 8.6 knots

D.23.e. Example #5

The boat is cruising at 15 knots and has 12 NM more before reaching its destination. Determine how much longer before arriving at the destination.

Step	Procedure
1	T = 60D/S D= 12 NM S = 15 knots
2	T = 60 x 12/15
3	T = 720/15
4	T = 48 minutes

D.24. Nautical Slide Rule

The nautical slide rule was designed to solve speed, time and distance problems. Use of the slide rule provides greater speed and less chance of error than multiplication and division. There are several types of nautical slide rules but all work on the same basic principle.

The nautical slide rule has three scales that can rotate. The scales are clearly labeled for:

- Speed.
- Time.
- Distance.

By setting any two of the values on their opposite scales, the third is read from the appropriate index. See Error! Reference source not found. which is set for the approximate values of speed of 18.2 knots, time of 62 minutes and distance of 18.4 NM or 36,800 yards.

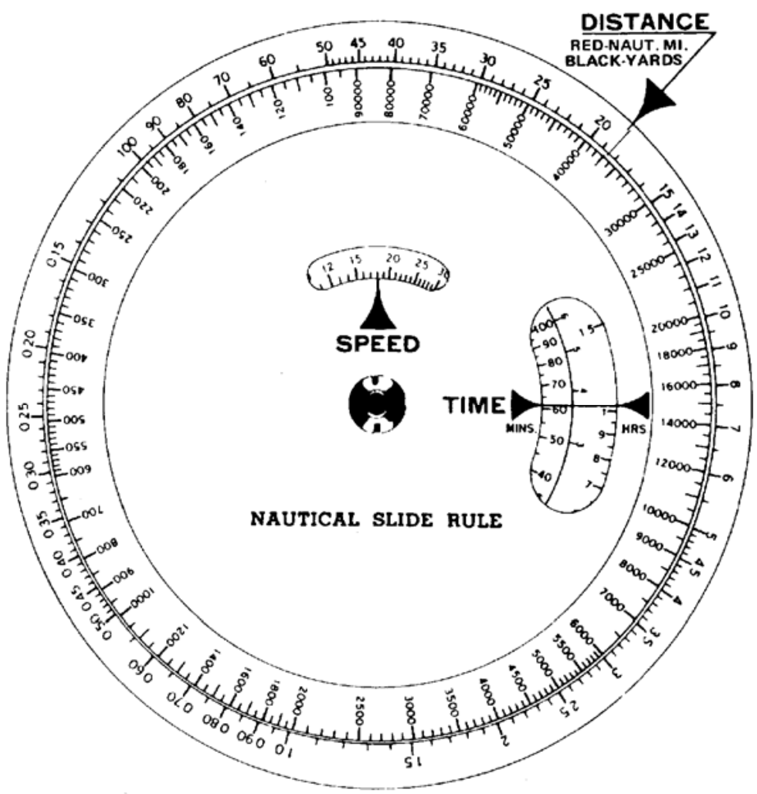

Figure 14-23
Nautical Slide Rule

Fuel Consumption

D.25. Description

In calculating solutions for navigation problems it is also important to know how much fuel the boat will consume. This is to ensure that there will be enough fuel onboard to complete the sortie. There must be enough fuel to arrive on scene, conduct operations, and return to base (or a refueling site).

D.26. Calculating Fuel Consumption

Calculating fuel consumption may be done by performing the following procedures:

Step	Procedure
1	Ensure fuel tank(s) are topped off.
2	Measure and record total gallons in fuel tank(s).
3	Start engine(s).
4	Record time engine(s) were started.
5	Set desired RPMs for engine(s).
6	Record set RPMs.
7	Maintain set RPMs.
8	Stop engine(s) at a specified time (usually one hour).
9	Record time.
10	Measure and record total gallons of fuel in tank(s).
11	Subtract total gallons in tank(s) after running one (1) hour from total gallons recorded on boat at beginning of underway period.
12	Record the difference.
13	Measure the distance traveled and record.
14	Compute boat speed and record.
15	Apply the equation: Time (T) multiplied by gallons per hour (GPH) equals total fuel consumption (TFC); or T x GPH = TFC.
16	Calculate TFC for other selected RPM settings. (Change RPM setting and repeat steps 6 through 15.)

Terms Used In Piloting

D.27. Description

The following terms and their definitions (**Table 14-5**) are the most commonly used in the practice of piloting.

Table 14-5
Piloting Terms

Term	Abbreviation	Description
Bearing	B, Brg.	The horizontal direction of one terrestrial (earth bound) point from another (the direction in which an object lies from the vessel) is its bearing, expressed as the angular distance (degrees) from a reference direction (a direction used as a basis for comparison of other direction). A bearing is usually measured clockwise from 000° through 359° at the reference direction - true north, magnetic north or compass north.
Course	C	The intended horizontal direction of travel (the direction intended to go), expressed as angular distance from a reference direction clockwise from 000° through 360°. For marine navigation, the term applies to the direction to be steered. The heading of 360° is always referred to or spoken as 000°.
Heading	Hdg.	The actual direction the boat's bow is pointing at any given time.
Course line		Line drawn on a chart going in the direction of a course.
Current sailing		Current sailing is a method of allowing for current in determining the course made good, or of determining the effect of a current on the direction or motion of a boat.
Dead reckoning	DR	Dead reckoning is the determination of approximate position by advancing a previous position for course and distance only, without regard to other factors, such as, wind, sea conditions and current.
Dead reckoning plot		A DR plot is the plot of the movements of a boat as determined by dead reckoning.
Position		Position refers to the actual geographic location of a boat. It may be expressed as coordinates of latitude and longitude or as the bearing and distance from an object whose position is known.
DR position		A DR position is a position determined by plotting a single or a series of consecutive course lines using only the direction (course) and distance from the last fix, without consideration of current, wind, or other external forces on a boat.
Estimated position	EP	A DR position modified by additional information, which in itself is insufficient to establish a fix.
Estimated time of arrival	ETA	The ETA is the best estimate of predicted arrival time at a known destination.
Fix		A fix is a position determined from terrestrial, electronic or celestial data at a given time with a high degree of accuracy.
Line of position	LOP	A line of bearing to a known object, which a vessel is presumed to be located on at some point.

Table 14-5 (continued)
Piloting Terms

Term	Abbreviation	Description
Coast piloting		Coast piloting refers to directing the movements of a boat near a coast.
Range		There are two types of ranges used in piloting: • Two or more fixed objects in line. Such objects are said to be in range. • Distance in a single direction or along a great circle. Distance ranges are measured by means of radar or visually with a sextant.
Running fix	R Fix	A running fix is a position determined by crossing LOPs obtained at different times.
Nautical mile	NM	A nautical mile is used for measurement on most navigable waters. It is 6076 feet or approximately 2000 yards and is equal to one minute of latitude.
Knots	Kn or kt	A knot is a unit of speed equal to one nautical mile per hour.
Speed	S	The rate of travel of a boat through the water measured in knots is the speed. Speed of Advance (SOA) is the average speed in knots that must be maintained to arrive at a destination at any appointed time. Speed made good: Speed over ground (SOG) is the speed of travel of a boat along the track, expressed in knots. The difference between the estimated average speed (SOA) and the actual average speed (SOG) is caused by external forces acting on the boat (such as wind, current, etc.).
Track	TR	A track is the course followed or intended to be followed by a boat. The direction may be designated in degrees true or magnetic.
Set		The direction toward which the current is flowing expressed in degrees true.
Drift		The speed of the current usually stated in knots.
Course over ground/course made good	COG/CMG	The resultant direction of movement from one point to another.

Laying the Course

D.28. Description

The navigation plot typically includes several course lines to steer from the beginning point to arrival at the destination. The technique for laying each course line is the same and is summarized as follows: (see **Figure 14-24**)

NOTE Ensure the rulers do not slip. If they do, the original line of direction will be lost.

Step	Procedure
1	Draw a straight line from the departure point to the intended destination. This is the course line.
2	Lay one edge of the parallel rulers along the course line.
3	Walk the rulers to the nearest compass rose on the chart, moving one ruler while holding the other in place.
4	Walk the rulers until one edge intersects the crossed lines at the center of the compass rose.
5	Going from the center of the circle in the direction of the course line, read the inside degree circle where the ruler's edge intersects. This is the magnetic course (M).
6	Write the course along the top of the penciled trackline as three digits followed by the letter (M) magnetic, for example, C 068° M. **Figure 14-24** shows a course of 068° M between two buoys as measured by parallel rulers on a chart's compass rose.

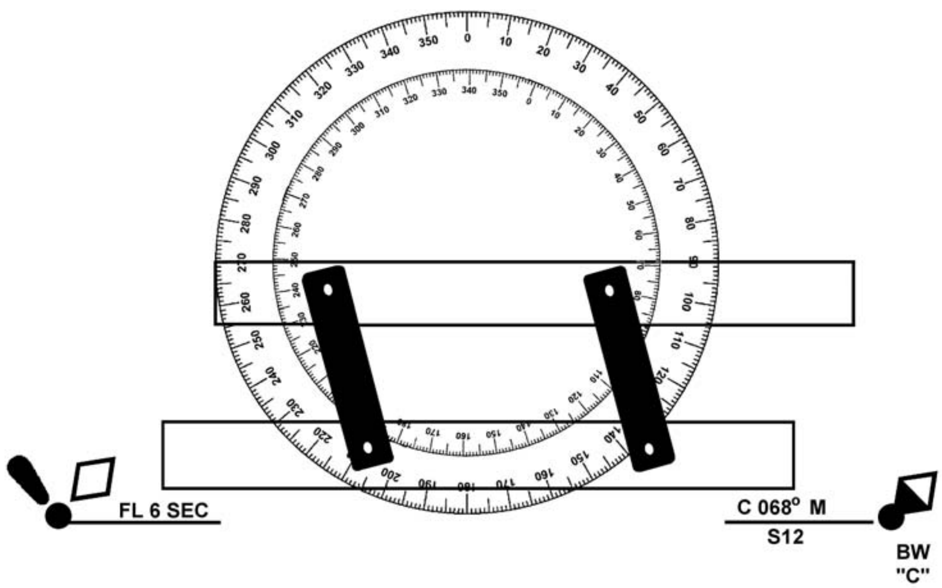

Figure 14-24
068° M Course Between Two Buoys

Dead Reckoning (DR)

D.29. Description

Dead reckoning (DR) is widely used in navigation. It is the process of determining a boat's approximate position by applying its speed, time, and course from its last known position.

D.30. Key Elements of Dead Reckoning

The key elements of dead reckoning are the course steered and the distance traveled without consideration to current, wind or other external forces.

D.30.a. Course Steered

Only courses steered are used to determine a DR. Course for a boat is normally magnetic (M) since it usually does not carry a gyrocompass, which gives true (T) direction.

D.30.b. Distance Traveled

Distance traveled is obtained by multiplying speed (in knots) by the time underway (in minutes).

D = S x T/60

(On the western rivers, distance is in statute miles.)

D.31. Standardized Plotting Symbols

All lines and points plotted on a chart must be labeled. The symbols commonly used in marine navigation are standardized and summarized as follows:

- Labeling the fix: The plotter should clearly mark a visual fix with a circle or an electronic fix with a triangle. The time of each fix should be clearly labeled. A visual running fix should be circled, marked "R Fix" and labeled with the time of the second LOP. Maintain the chart neat and uncluttered when labeling fixes.
- DR position: A point marked with a semicircle and the time.
- Estimated position (EP): A point marked with a small square and the time.

See **Figure 14-25** for examples of the plotting symbols.

NOTE

> Only standard symbols should be used to make it possible for every crewmember to understand the plot.

D.32. Labeling a DR Plot

The DR plot starts with the last known position (usually a fix). The procedures for labeling a DR plot are given below. (see **Figure 14-25**)

Figure 14-25 shows a DR plot starting in the upper left corner from a 0930 fix. (The compass rose is shown for information purposes and is not always so obvious on the chart.) At 1015 a fix is taken and a new DR plot started. Also, at 1015, the course is adjusted to C 134° M to get to the intended destination at the 1200 DR plot. Then, the 1200 fix is plotted and the new DR plot (C 051° M and S 16) is started.

Step	Procedure
1	Plot the course line, label it clearly and neatly. • Course: Above the course line, place a capital C followed by the ordered course in three digits. • Speed: Below the course line, place a capital S followed by the speed
2	Use standard symbols to label a DR plot: • Circle for a fix. • Semicircle for a DR position. • Square for an estimated position.
3	Plot a DR position: • At least every half hour. • At the time of every course change. • At the time of every speed change.
4	Start a new DR plot from each fix or running fix (plot a new course line from the fix).
5	Time is written as four digits.

The course can be magnetic (M), true (T) or compass (C) and is always expressed in three digits. If the course is less than 100°, zeros are prefixed to the number, for example, 009°.

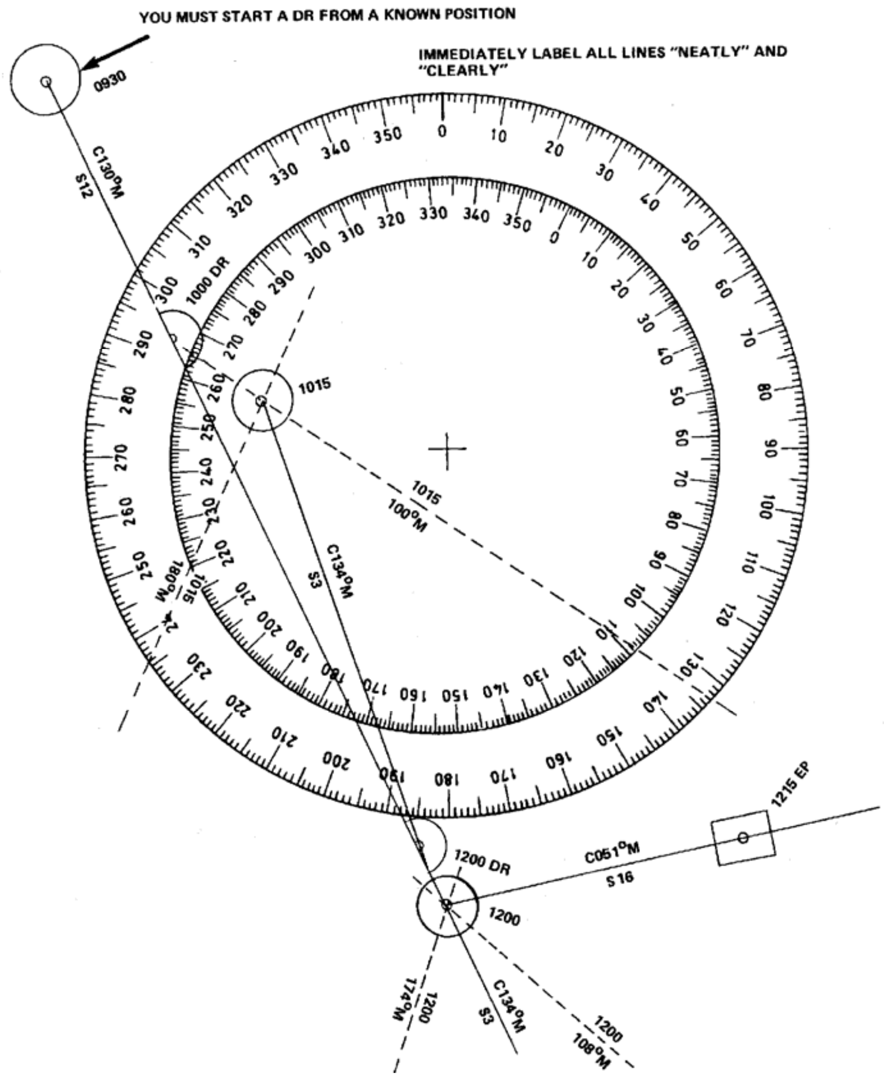

Figure 14-25
Labeling a DR Plot

Basic Elements of Piloting

D.33. Description Direction, distance, and time are the basic elements of piloting. With these elements, an accurate navigation plot can be maintained.

D.34. Direction Direction is the relationship of one point to another point (known as the reference point). Direction, referred to as bearing, is measured in degrees from 000 through 360°. The heading of 360° is always referred to or spoken 000°.

D.34.a. Reference Point/ Reference Direction

The usual reference point is 000°. The relationships between the reference points and reference directions are listed below:

Reference Direction	Reference Point
True (T)	Geographical North Pole
Magnetic (M)	Magnetic North Pole
Compass (C) *	Compass North
Relative (R) *	Boat's Bow

* Not to be plotted on a chart.

D.35. Bearings

Bearings are a direction, expressed in degrees from a reference point. Bearings may be true, magnetic, compass, or relative. All of the above reference directions may be used except relative direction to designate headings or courses. Relative direction, which uses the boat's bow as the reference direction, changes constantly.

In boat navigation, magnetic courses and bearings will usually be used, since true bearings are obtained from gyrocompasses, which are not normally found on boats.

D.35.a. Obtaining Bearings

Bearings are obtained primarily by using a magnetic compass (compass bearings) or radar (relative bearings). Bearings of fixed, known, objects are the most common sources for LOPs in coastal navigation. When using a compass to take bearings, the object should be sighted across the compass.

D.36. Compass Bearings

In the section on compass and compass error, how to convert from a compass course to magnetic and true courses by correcting the compass was discussed. A compass bearing must be corrected before it can be plotted.

NOTE

> Deviation always depends upon the boat's heading. The bearing (compass or relative) of any object is not the course. Enter the deviation table with the compass heading being steered to obtain proper deviation.

D.36.a. Obtaining Compass Bearings

The vessel is on a heading of 263° M. The compass bearing to Kays Pt. Light is 060°. Deviation from the deviation table on the boat's heading of 263° M is 7° W. To obtain magnetic bearing of Kays Pt. Light perform the following procedures: (see **Figure 14-26**)

Step	Procedure
1	Correct the compass bearing of 60° magnetic. Write down the correction formula in a vertical line. C = 060° compass bearing of light. D = 7° W (+E, -W) from deviation table for boat's heading M = What is the magnetic bearing of the light?
2	Compute information opposite appropriate letter in step 1.
3	Subtract 7° W deviation, the westerly error, from the compass bearing (060°) to obtain magnetic bearing (053°). M = 053°

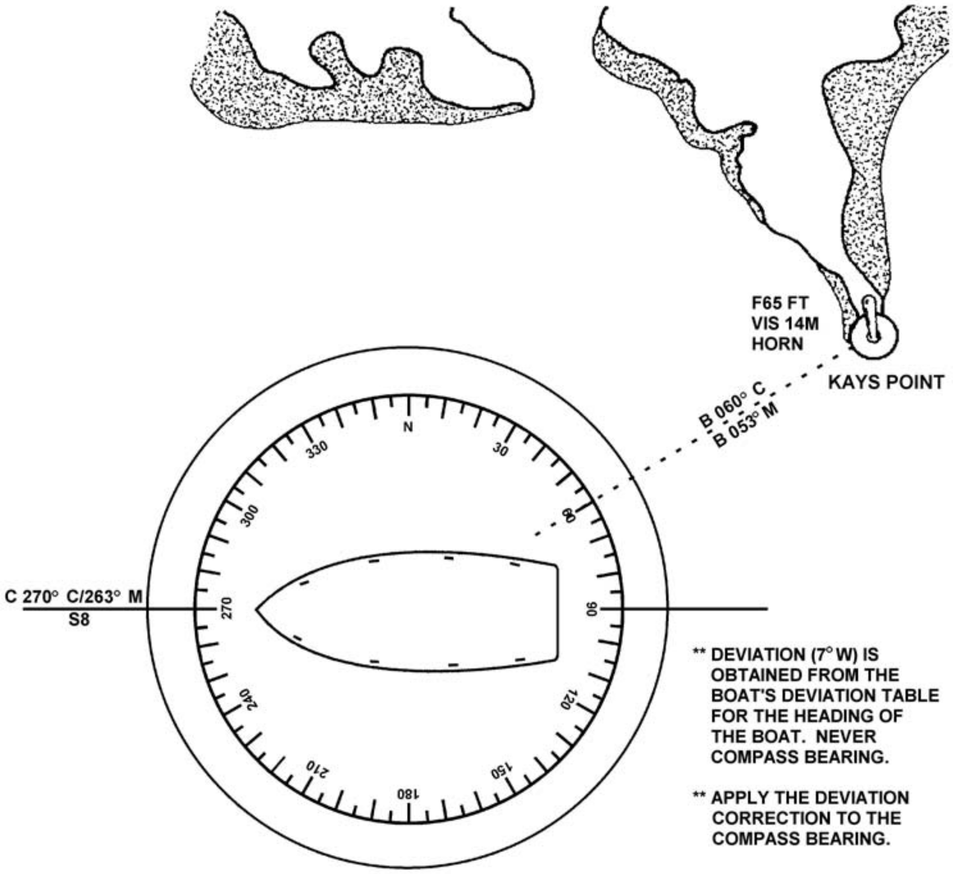

Figure 14-26
Converting Compass Bearing to Magnetic

D.37. Relative Bearings

Relative bearing of an object is its direction from the boat's bow at 000°, measured clockwise through 360°.

D.37.a. Converting to Magnetic Bearings

Relative bearings must be converted to magnetic bearings before they can be plotted. The procedures are as follows:

Step	Procedure
1	Convert heading to a magnetic course. Based on the boat's heading at the time the bearing was taken, use the deviation table to determine the deviation. (Deviation depends on the boat's heading, not that of the relative bearing.)
2	Add the relative bearing.
3	If this sum is more than 360°, subtract 360° to obtain the magnetic bearing.

Three examples follow to demonstrate these procedures.

D.37.a.1. Example #1

The boat is on a heading of 150°. The relative bearing to a standpipe is 125° relative. Deviation (from the boat's deviation table) on the boat's heading is 4° E. Obtain the magnetic bearing of the standpipe.

Step	Procedure
1	Correct heading of 150° to magnetic. Write down the correction formula in a vertical line. C = 150° D = 4° E (+E, -W) M = 154° V = Not applicable in this problem T = Not applicable in this problem
2	Compute information opposite appropriate letter in step 1.
3	Add the easterly error, 4° E deviation from the compass heading to obtain magnetic heading (154°).
4	Add the observed relative bearing (125°) and the magnetic heading (154°) to obtain magnetic bearing (279° M) of the standpipe.

D.37.a.2. Example #2

The boat is on a heading of 285°. The relative bearing to Williams Island Rock Light is 270° relative. The relative bearing to another light is 030° relative. Deviation (from the boats deviation table) on the boat's heading is 5° W. Obtain magnetic bearing of both lights. (see **Figure 14-27**)

Step	Procedure
1	Correct your heading of 285 to the magnetic heading. Write down the correction formula in a vertical line. C = 285° D = 5° W (+E, -W) M = 280° V = not applicable to this problem T = not applicable to this problem
2	Compute information opposite appropriate letter in step 1. Subtract the westerly error, 5° W deviation from the compass heading (285°) to obtain magnetic heading (280°).
3	Add each of the observed relative bearings (270° relative and 030° relative) to the magnetic heading (280°) to obtain the magnetic bearings. WILLIAMS IS ROCK 280° M + 270° relative bearing 550° (greater than 360°) -360 190° magnetic bearing OTHER LIGHT 280° M + 030° relative bearing 310° magnetic bearing

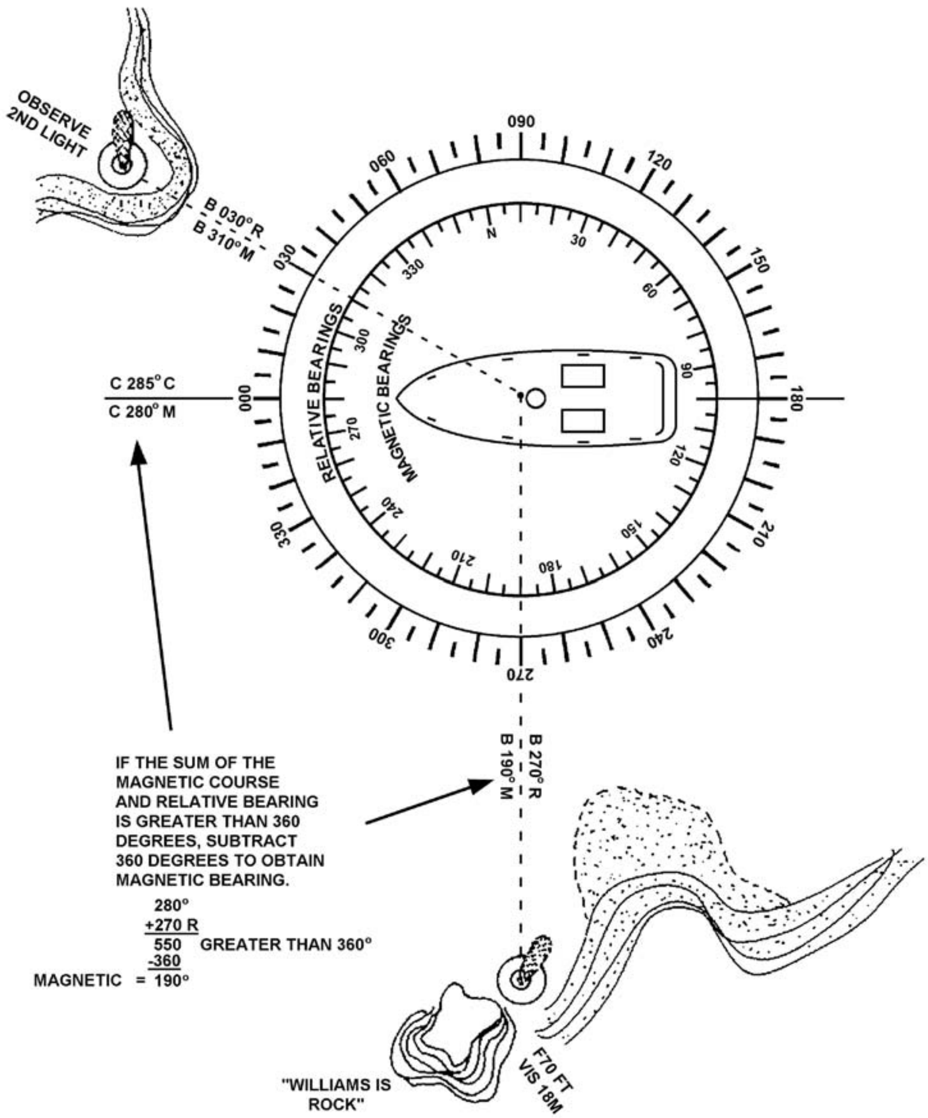

Figure 14-27
Converting Relative Bearings to Magnetic; Sums Greater than 360°

D.38. Distance

The second basic element in piloting is the special separation of two points measured by the length of a straight line joining the points without reference to direction. In piloting, it is measured in miles or yards. There are two different types of miles used:

- Nautical miles.
- Statute miles.

D.38.a. Nautical Mile

The nautical mile is used for measurement on most navigable waters. One nautical mile is 6076 feet or approximately 2000 yards and is equal to one minute of latitude.

D.38.b. Statute Mile

The statute mile is used mainly on land, but it is also used in piloting inland bodies of water such as the Mississippi River and its tributaries, the Great Lakes and the Atlantic and Gulf Intracoastal waterways.

CAUTION ! The longitude scale is never used for measuring distance.

D.38.c. Measuring Distance

Measure the distance by performing the following procedures:

Step	Procedure
1	Place one end of a pair of dividers at each end of the distance to be measured, being careful not to change the span of the dividers.
2	Transfer them to the latitude scale closest to the latitude being measured. Read the distance in minutes. (see **Figure 14-28**)
3	When the distance to be measured is greater than the span of the dividers, the dividers can be set at a minute or number of minutes of latitude from the scale and then "stepped off" between the points to be measured.
4	The last span, if not equal to that setting on the dividers, must be separately measured. To do this, step the dividers once more; closing them to fit the distance.
5	Measure this distance on the scale and add it to the sum of the other measurements.
6	The latitude scale nearest the middle of the line to be measured should be used.

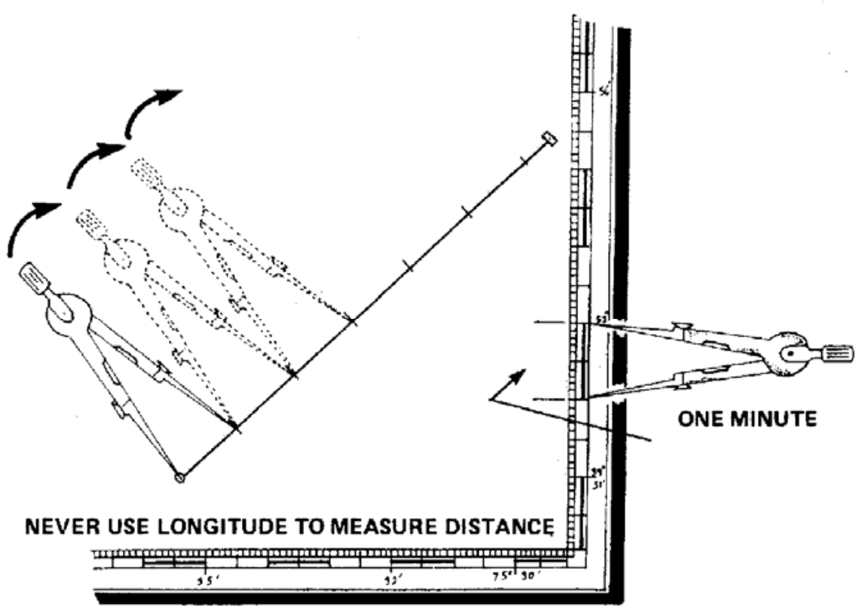

Figure 14-28
Measuring Distance, Latitude

To measure short distances on a chart, the dividers can be opened to a span of a given distance, then compared to the NM or yard scale on the chart. (see **Figure 14-29**)

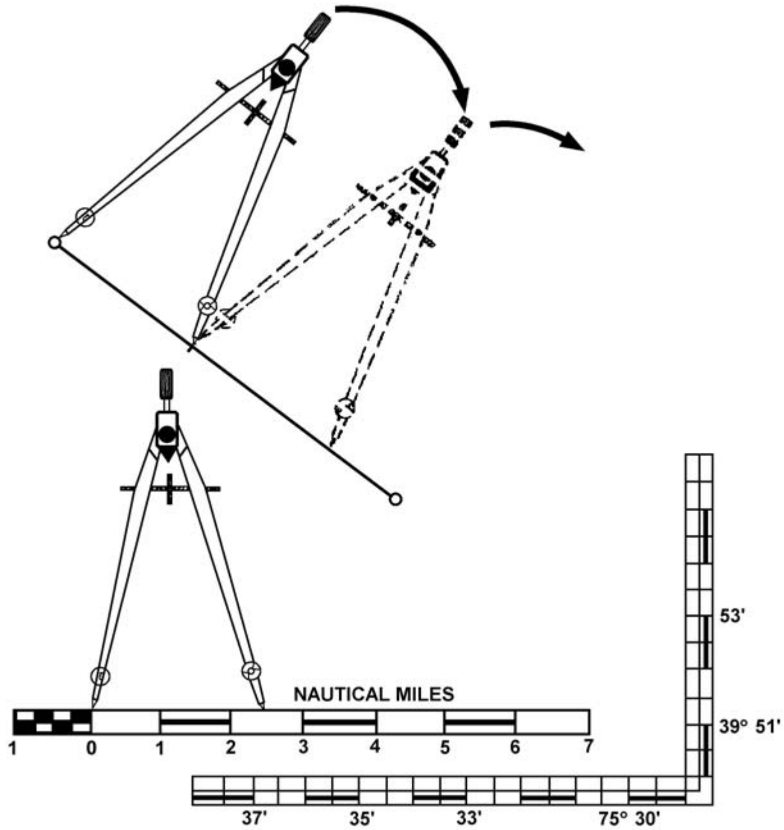

Figure 14-29
Measuring Distance, Nautical Miles

D.39. Time

Time is the third basic element in piloting. Time, distance, and speed are related. Therefore, if any two of the three quantities are known, the third can be found. The basic equations for distance, speed, and time; the speed curve; and nautical slide rule and their use have been discussed earlier.

Plotting Bearings

D.40. Description

A bearing or series of bearings can be observed as compass (C), magnetic (M), true (T), or as a relative bearing (visual or radar). The compass bearing reading usually needs to be converted for plotting and then drawn on the chart as a line of position (LOP).

D.41. Parallel

One common method of plotting bearings on a chart is using parallel rulers or a course plotter. Follow the example below for plotting the bearing onto the chart.

D.41.a. Example

The boat is on a heading of 192° compass. At 1015, a bearing of 040° relative on a water tower is obtained. Deviation (from the boat's deviation table) on the boat's heading is 3° W.

Step	Procedure
1	Correct the compass heading of 192° to the magnetic heading. Write down the correction formula in a vertical line. C = 192° D = 3° W (+E, -W when correcting) M = 189° V = not applicable to this problem T = not applicable to this problem
2	Compute the information opposite the appropriate letter in step 1. Subtract the westerly error, 3° W deviation from the compass heading (192°) to obtain magnetic heading (189°).
3	Add the relative bearing (040°) to the magnetic heading (189°) to obtain the magnetic bearing (229°). 189° (M) + 040° 229° magnetic bearing
4	Place the parallel rulers with their edge passing through the crossed lines at the center of the compass rose and the 229° mark on the inner ring (magnetic) of the compass rose. (see **Figure 14-30**)
5	Walk the parallel rulers to the dot marking the exact position of the water tower.
6	Draw a broken line and intersect the course line (C 189° M).
7	Label a segment of line with the time of the bearing along the top. The segment is drawn near the course line, not the entire length from the water tower.
8	Below the line, label the magnetic bearing 229° M.

At 1015, the boat was somewhere along the LOP. A single line of bearing gives an LOP but the boat's location cannot be accurately fixed by a single LOP.

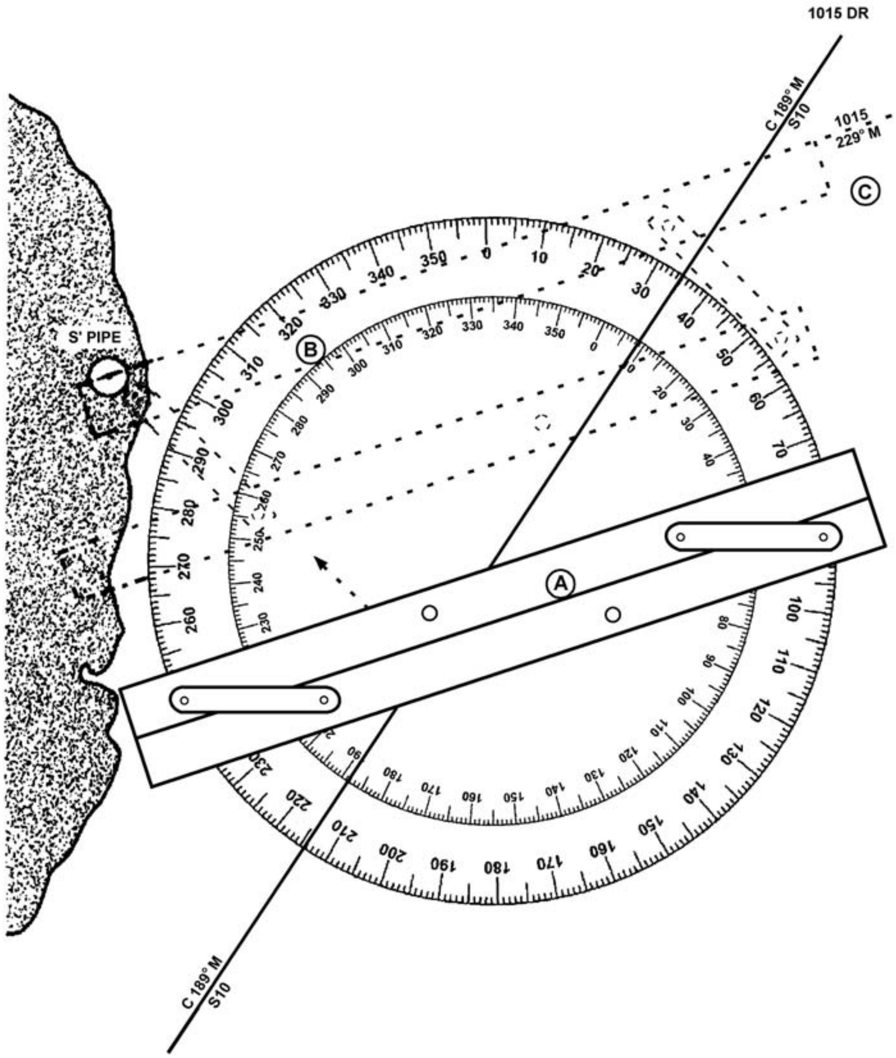

Figure 14-30
Plotting Bearings

Line of Position (LOP)

D.42. Description

The position of a boat can be determined by many methods of piloting. The LOP is common to all methods of piloting. For example, if a standpipe and a flagstaff in a line are observed, the boat is somewhere on the line drawn from the standpipe through the flagstaff and towards the boat. This line is called a range or a visual range.

If the bearing is taken on a single object, the line drawn is called a bearing LOP. The observed bearing direction must be corrected to magnetic or true direction and plotted. The compass rose can be used to provide the direction.

A single observation gives an LOP, not a position. The boat is located somewhere along that LOP. (see **Figure 14-31**)

NOTE A boat's position is somewhere along the line of position.

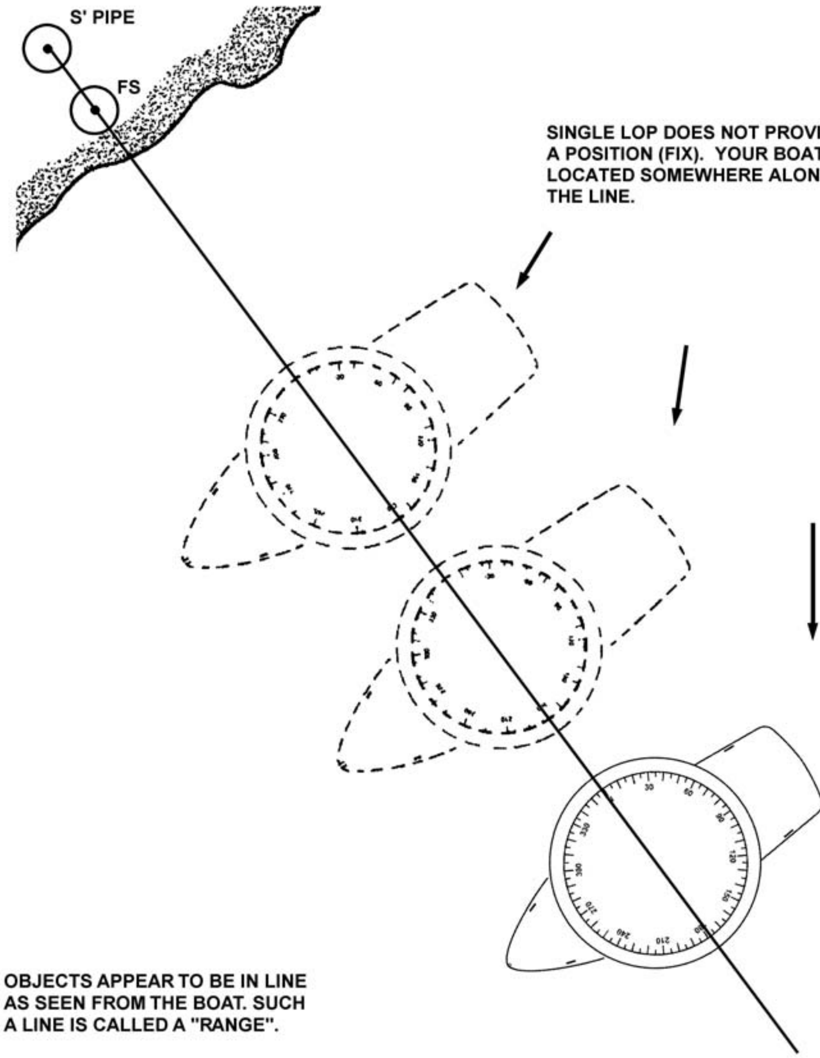

Figure 14-31
Visual Range LOP

D.43. Selecting Objects to Obtain a Fix

The primary consideration in selecting charted objects to obtain a fix is the angle between the bearings. Also, attempts should always be made to take bearings on objects as close as possible to the boat because minor errors in reading are magnified when increasing distance from the object.

NOTE An error of 1 degree at 1 mile will result in an error of 100 feet.

D.43.a. Two Lines of Position

When there are only two LOPs for a fix, the quality of the fix will be best when there is a 90° difference in the lines. Serious error in position could result if a difference of less than 60° or more than 120° between the two lines exist. Therefore, two LOPs should intersect at right angles or near right angles wherever possible.

D.43.b. Three Lines of Position

An ideal fix has three or more LOPs intersecting at a single point and the LOPs have a separation of at least 60°, but not more than 120°.

D.44. Obtaining Fixes

A single line of bearing gives an LOP, and the boat is somewhere along that LOP. Position cannot accurately be fixed by a single LOP. Two or more intersecting LOPs or radar ranges must be plotted to obtain an accurate fix. The greater the number of LOPs or radar ranges intersecting at the same point, the greater the confidence in the fix. For a fix to be accurate, LOPs must be observed at the same time. However, in navigation two or more bearings taken, one after the other, are considered to be observed at the same time (simultaneous).

NOTE

For a fix to be accurate, LOPs must be from simultaneous observation (exact same time). Two or more bearings taken one after the other are considered simultaneous.

D.44.a. Obtaining Bearings

Bearings are obtained by visual sightings across a compass, hand-held bearing compass, relative bearings (dumb compass) or by radar. Then, the direction to the object sighted is recorded, converted to magnetic or true direction, and plotted.

D.44.b. Using Cross Bearings

When using cross bearings, the fix is obtained by taking bearings on two well-defined objects and plotting the observed bearings on the chart. A more accurate fix can be obtained by taking a third bearing on a well-defined object. The three LOPs should form a single point or a small triangle. The boat's position is then considered to be on the point or in the center of the small triangle.

A large triangle is an indication than an inaccurate bearing was taken. Measurements should be double-checked.

CAUTION !

> Do not use the hand-held bearing compass on a steel boat. Deviation cannot be determined accurately. Each change in position on deck results in an undetermined amount of deviation.

D.44.b.1. Example

On a compass heading of 330°, a lookout tower and a standpipe are sighted and the crew decides to take a fix. The lookout tower bears 030° (compass) and the standpipe bears 005° (compass). Deviation from the deviation table, on the boat's compass heading (330° C), is 5° E. Plot the fix. (see **Figure 14-32**)

<table>
<tr><th>Step</th><th>Procedure</th></tr>
<tr><td>1</td><td>Correct compass bearing (030°) and (005°) to magnetic bearings.

Write down the correction formula in a vertical line.
<table>
<tr><th>Lookout Tower</th><th>Standpipe</th></tr>
<tr><td>C = 030°</td><td>C = 005°</td></tr>
<tr><td>D = 5° E (+E, - W)</td><td>D = 5° E (+E, -W)</td></tr>
<tr><td>M = 035°</td><td>M = 010°</td></tr>
<tr><td>V = not applicable</td><td>V = not applicable</td></tr>
<tr><td>T = not applicable</td><td>T = not applicable</td></tr>
</table>
</td></tr>
<tr><td>2</td><td>Compute information opposite the appropriate letter in step 1. Add the easterly error 5° E deviation to the compass bearings 030° and 005° to obtain magnetic bearings of 035° and 010°.</td></tr>
<tr><td>3</td><td>Plot the two magnetic bearings. The prudent sailor will recognize that the accuracy of this fix is doubtful due to the angle between the bearings being considerably less than the desired 60°-120°.</td></tr>
</table>

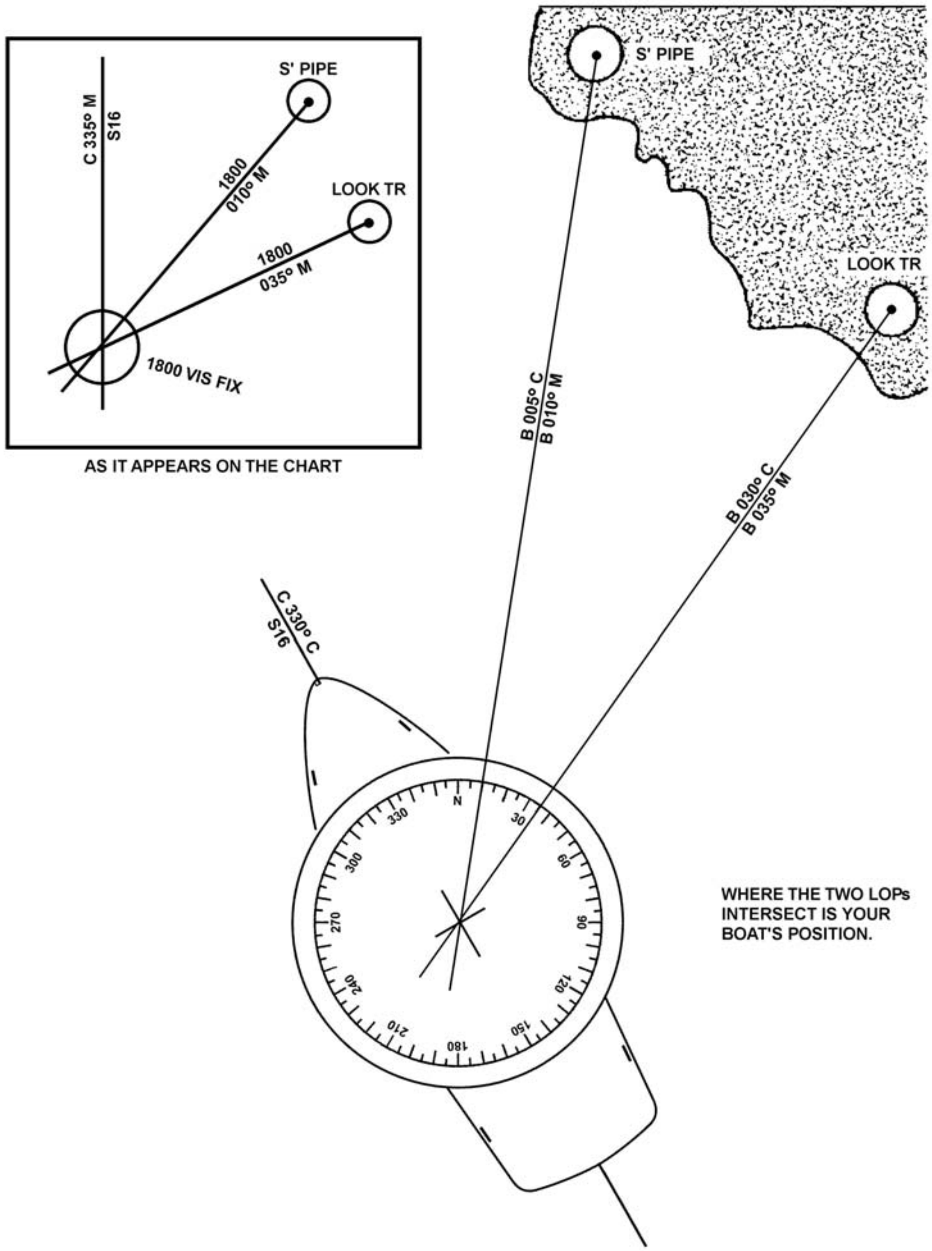

Figure 14-32
Two Ranges

NOTE Compass bearings are not plotted on the chart.

D.44.c. Ranges

When two charted objects are in range, as seen from a boat, the boat is located somewhere on a straight line through these objects. Frequently, a range will mark the center of a channel. The boat is steered so as to keep the range markers in line.

Ranges may be established navigational aids or natural ranges such as a church steeple and a water tower. When entering or leaving a harbor, it is often possible to fix the position by means of ranges.

D.44.c.1. Example

While steering on a range (keeping the bow lined up with the two range marks), the time is 0800 when two charted objects (for example, a water tank and smoke stack) line up on the starboard side. The boat's position is at the intersection of the lines drawn through each set of ranges. (see **Figure 14-33**) After having observed two sets of ranges that determined a fix, a magnetic course of 000° M is steered to stay in safe water.

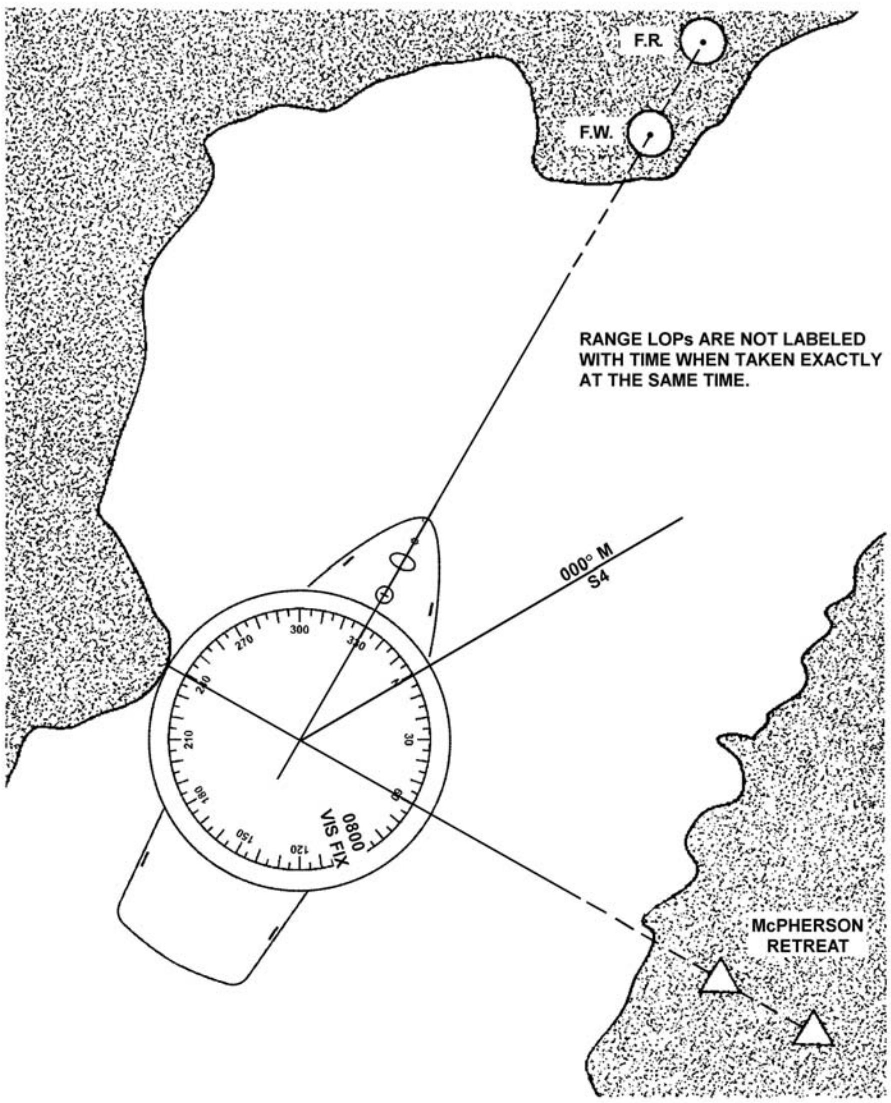

Figure 14-33
Fix by Two Ranges

D.44.d. Running Fix (R FIX)

Often it is impossible to obtain two bearing observations within a close enough interval of time to be considered simultaneous. A running fix (R Fix) can be obtained by using two LOPs acquired at different times. It is determined by advancing an earlier LOP by using dead reckoning calculations of the boats direction and distance traveled during an interval. (see **Figure 14-34**)

Plot a running fix by performing the following procedures:

NOTE The shorter the time interval between LOPs, the more accurate the running fix.

Step	Procedure
1	Plot the first LOP. Plot the second LOP.
2	Advance the first LOP along the DR plot to the time of second LOP. (The first LOP is advanced by moving it parallel to itself, forward along the course line for the distance the boat will have traveled to the time of the second bearing.)
3	Where the two LOPs intersect is the running fix.
4	Avoid advancing an LOP for more than 30 minutes.

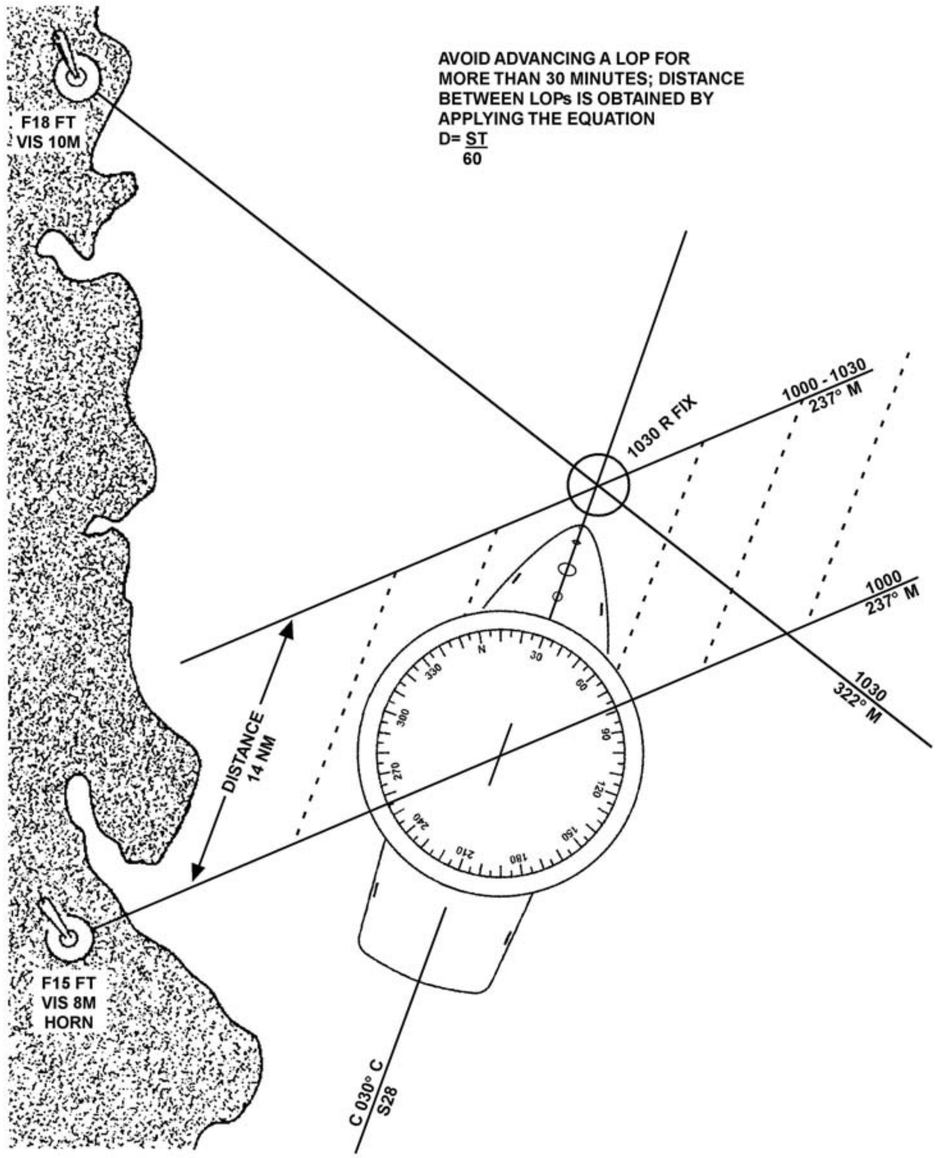

Figure 14-34
Running Fix

D.44.d.1. Example

At 1000, a compass bearing of 240° to a light is observed, which is corrected to 237° M. There were no other well-defined objects from which to obtain a bearing. Since plotting the first LOP the boat has run at 28 knots on a compass course of 030° C.

At 1030, the boat has a second compass bearing of 325° to the light is observed. Plot this as a second LOP and advance the first LOP. The position where they cross is the running fix.

Step	Procedure
1	Obtain the time interval and the distance the boat traveled since the 1000 LOP. (A nautical slide rule may be used) 10 hours 30 minutes <u>-10 hours 00 minutes</u> 30m - time interval Apply the equation for distance (nautical slide rule may be used). D = S x T/60 D= 28 x 30/60 D = 840/60 D = 14 nautical miles
2	Using dividers, measure the distance (14 NM) off of the latitude or nautical mile scale along the course line in the direction traveled.
3	Advance the first LOP, ensuring it is moved parallel to itself, forward along the course line for the distance traveled (14 NM). Draw the LOP labeling the new line (1000-1030) to indicate that it is an advanced LOP.
4	Correct the compass bearing of the second light (325° C) to obtain the magnetic bearing (322° M)
5	Plot the bearing. A running fix has been established by advancing an LOP.

D.44.e. Danger Bearings

Danger bearings are used to keep a boat clear of a hazardous area in the vicinity of the track. Danger bearings are the maximum or minimum bearing of a point used for safe passage. They indicate a charted object whose bearing will place the boat outside that hazardous area. Examples of such dangers are submerged rocks, reefs, wrecks and shoals. A danger area must be established in relation to two fixed objects, one of which is the danger area. The other object must be selected to satisfy three conditions:

- Visible to the eye.
- Indicated on the chart.
- Bearing from the danger area should be in the same general direction as the course of the boat as it proceeded past the area.

Plot a danger bearing by performing the following procedures: (see **Figure 14-35**)

Step	Procedure
1	On a chart, draw a line from the object selected (the leading object) to a point tangent to the danger area closest to the intended passing point. The measured direction of the line from the danger area to the leading object is the danger bearing. **Figure 14-35** indicates that 311° M is a danger bearing.
2	Label the danger bearing with the abbreviation 'DB' followed by the direction (DB 311° M). Frequent visual bearings should be taken. If the bearings are greater than the danger bearing, the boat is in safe water.

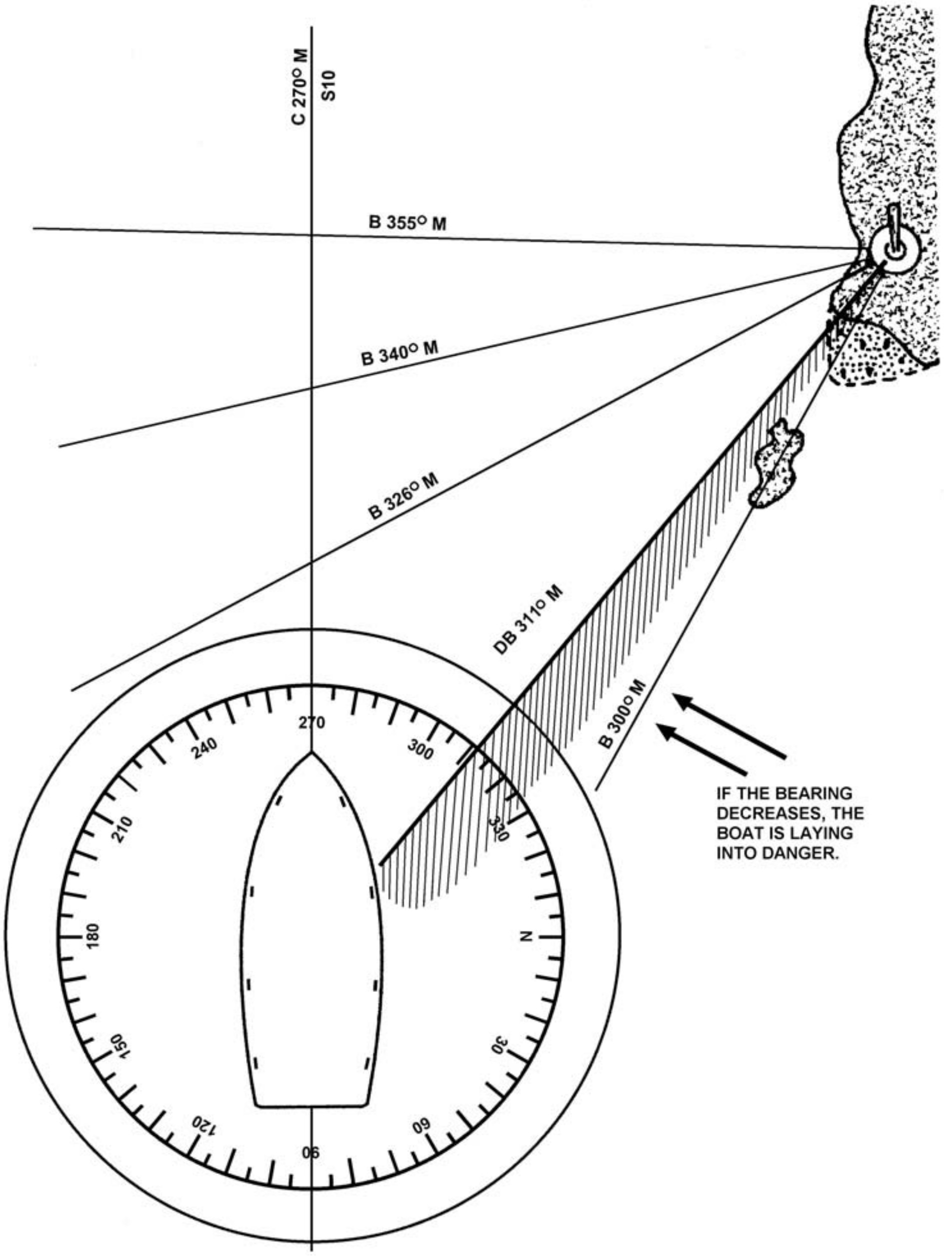

Figure 14-35
Danger Bearings

When a bearing is observed to be less than the danger bearing, such as 300° M, the boat is standing into danger. Danger bearings should have a series of short lines drawn on the danger side for easy identification as shown in **Figure 14-35**.

The label DB may be proceeded by the letters NMT (not more than) or NLT (not less than), as appropriate.

The coxswain should ensure that all crewmembers are aware of where the danger lies. That is, whether the danger includes all degrees less than the danger bearing or all the degrees greater than the danger bearing.

Set and Drift (Current Sailing)

D.45. Description

Current sailing is the method of computing course and speed through the water, considering the effects of current so that, upon arrival at the destination, the intended course (track) and the actual course made good are the same. The difference in position between a DR position and a fix taken at the corresponding time is due to various external forces acting on the boat. These forces are usually accounted for as set and drift.

D.46. Definition

Set is the direction of these forces and includes factors such as wind, current, and sea condition. Set is expressed in degrees. "Set 240° magnetic" means that the boat is being pushed towards 240° magnetic.

Drift is the strength of the set and is expressed in knots. "Drift 1.5 knots" means that the boat is being pushed in a given direction (set) at a speed of 1.5 knots.

D.47. Making Allowances

In working problems involving set and drift, allow for their effect upon the boat. This can be accomplished by comparing actual fix position information with the DR track and determining the difference. However, conditions do not always allow for this. Also, this can only be done after some portion of the voyage has already occurred.

D.48. Tidal Current Charts

Tidal Current Charts are available for certain bodies of water such as Boston Harbor or San Francisco Bay. They graphically indicate the direction and velocity of tidal currents for specific times with respect to the state of the current predictions for major reference Stations. These charts make it possible to visualize how currents act in passages and channels throughout the 12-hour cycle. By referring to the current charts, it is possible to plan a passage that is made quicker by either taking advantage of a favorable current or picking a track that reduces the effect of a head current.

D.49. Tidal Current Tables

Tidal Current Tables are used to predict tidal currents. Examples of how to apply predicted currents are found in the back of the publication. This makes it possible to apply the corrections well in advance so as to avoid the dangers along the way and safely arrive at the destination. This method involves the use of a vector diagram called a current triangle.

NOTE

> The tidal current directions are shown in degrees true and must be converted to magnetic before plotting the set and drift problem.

D.50. Current

The current triangle is a vector diagram indicating the course and speed the boat will make good when running a given course at a given speed. (see **Figure 14-36**) It can also be used to determine the course to steer and the speed necessary to remain on the intended track. This information may be obtained by using the chart's compass rose for constructing a current triangle to provide a graphic solution.

- The first line (AB) on a current triangle indicates the boat's intended direction and the distance to travel in a given period of time. The length of this line represents the boat's speed in knots.
- The second line, (CB) laid down to the destination end of the intended direction (the first line), shows the set (direction) of the current. The length of this line represents the drift (speed) of the current in knots.
- The third line (AC) provides the resulting corrected course to steer and the speed of advance to arrive safely at the destination. If any two sides of the triangle are known, the third side can be obtained by measurement.

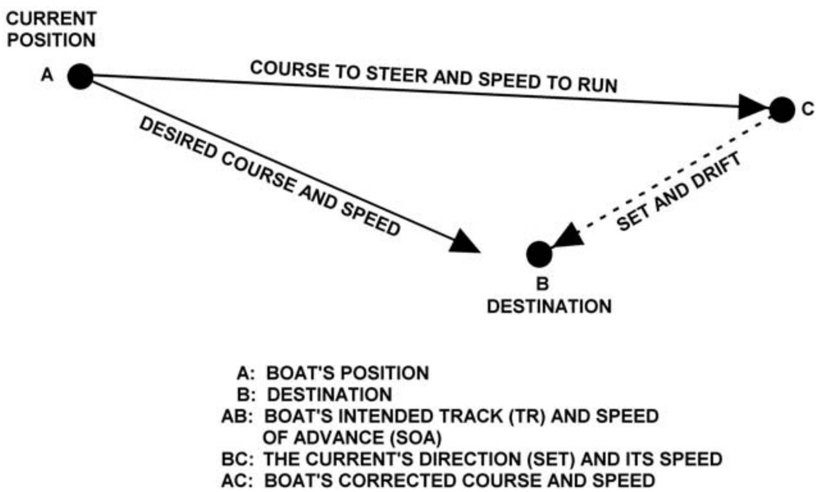

Figure 14-36
Current Triangle

D.50.a. Example

The intended track to the destination is 093° magnetic (093M), the speed is 5 knots, the *Tidal Current Table* for the operating area indicates that the current will be setting the boat 265° true (265T), drift (speed) 3 knots. The local variation is 4° (W). Obtain the corrected course to steer and SOA to allow for set and drift. (see **Figure 14-37**). The nautical miles scale, is provided as an example for measuring "units" of length.)

Step	Procedure
1	Lay out the chart. Think of the center of the compass rose as the departure point. Draw the boat's intended track (093° M) from the center of the compass rose. Make this line 5 units in length to represent 5 nautical miles from the center of the compass rose. Put a small arrowhead at this point. This is the desired course and speed vector.
2	Draw a line for the set and drift of the current from the center of the compass rose towards 261° magnetic (265° T + 4° W (variation) = 269° M).
	Set in the *Tidal Current Tables* is given in degrees true and must be converted to degrees magnetic to be used. Make this line three units long putting an arrowhead at the outer end. This is the set and drift vector.
3	Draw a straight line to connect the arrowheads of the desired course and speed vector and the set and drift vector. This line is the corrected course to steer and speed of advance.
4	Measure the length of this line to obtain the speed (8.7 knots) from the nautical miles scale.
5	Advance the line to the center of the compass rose and read the corrected magnetic course to steer (088° M) from the inner circle of the compass rose.

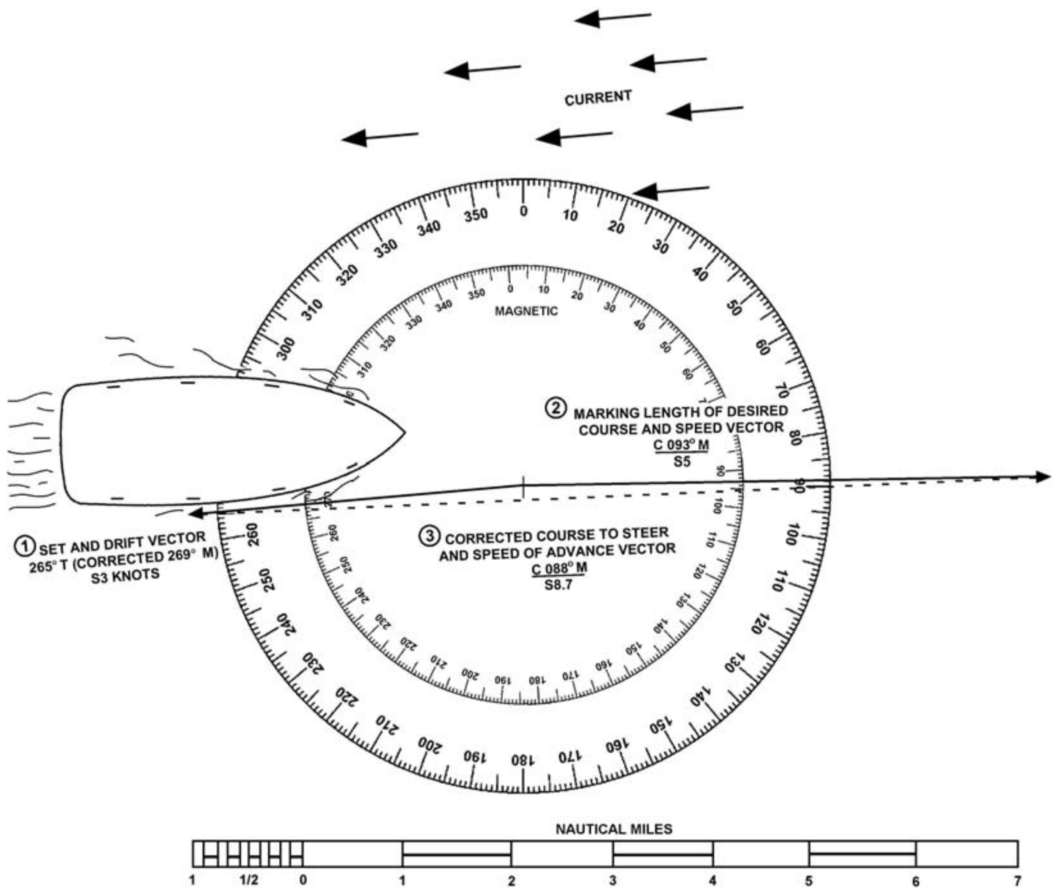

Figure 14-37
Plotting Set and Drift to Set Course to Steer

Using the same figures as shown in the above example, **Figure 14-38** shows what the effect would be if the set and drift is not corrected for by using a current triangle. (see **Figure 14-38**)

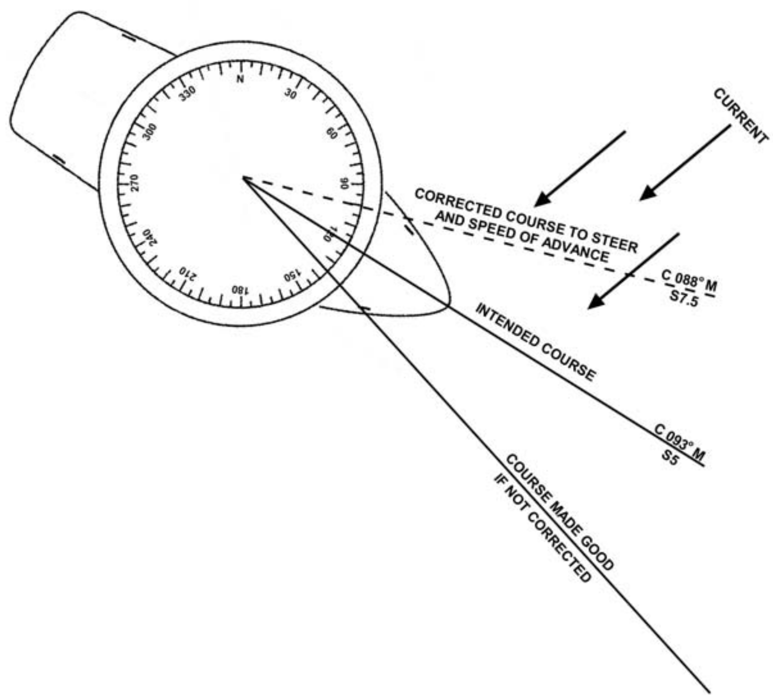

Figure 14-38
Compensating for Set and Drift

Radar

D.51. Description

Radar is an aid in navigation, but it is not the primary means of navigation. Boat navigation using radar in limited visibility depends on the coxswain's experience with radar operation. It also depends on the coxswain's knowledge of the local operating area and is not a substitute for an alert visual lookout.

D.52. Basic Principle

A radar radiates radio waves from its antenna to create an image that can give direction and distance to an object. Nearby objects (contacts) reflect the radio waves back and appear on the radar indicator as images (echoes). On many marine radars, the indicator is called the plan position indicator (PPI).

D.53. Advantages

Advantages of radar include:

- Can be used at night and in low visibility conditions.
- Obtains a fix by distance ranges to two or more charted objects. An estimated position can be obtained from a range and a bearing to a single charted object.
- Enables rapid fixes.
- Fixes may be available at greater distances from land than by visual bearings.
- Assists in preventing collisions.

D.54. Disadvantages

The disadvantages of radar include:

- Mechanical and electrical failure.
- Minimum and maximum range limitations.

D.54.a. Minimum Range

The minimum range is primarily established by the radio wave pulse length and recovery time. It depends on several factors such as excessive sea return, moisture in the air, other obstructions and the limiting features of the equipment itself. The minimum range varies but is usually 20 to 50 yards from the boat.

D.54.b. Maximum Range

Maximum range is determined by transmitter power and receiver sensitivity. However, these radio waves are line of sight (travel in a straight line) and do not follow the curvature of the earth. Therefore, anything below the horizon will usually not be detected.

D.54.c. Operational Range

The useful operational range of a radar on a boat is limited mainly by the height of the antenna above the water.

D.55. Reading the Radar Indicator

Interpreting the information presented on the indicator takes training and practice. The radar indicator should be viewed in total darkness, if possible, for accurate viewing of all echoes. Also, charts do not always give information necessary for identification of radar echoes, and distance ranges require distinct features.

It may be difficult to detect smaller objects (e.g., boats and buoys) in conditions such as:

- Heavy seas.
- Near the shore.
- If the object is made of nonmetallic materials.

D.56. Operating Controls

Different radar sets have different locations of their controls, but they are basically standardized on what function is to be controlled. The boat crew should become familiar with the operation of the radar by studying its operating manual and through the unit training program.

D.57. Reading and Interpolating Radar Images

The PPI is the face or screen of the Cathode Ray Tube (CRT), which displays a bright straight radial line (tracer sweep) extending outward from the center of a radar screen. It represents the radar beam rotating with the antenna. It reflects images on the screen as patches of light (echoes).

In viewing any radar indicator, the direction in which the boat's heading flasher is pointing can be described as up the indicator. The reciprocal of it is a direction opposite to the heading flasher, or down the indicator. A contact moving at right angles to the heading flasher anywhere on the indicator would be across the indicator.

The center of the radar screen represents the position of the boat. The indicator provides relative bearings of a target and presents a map-like representation of the area around the boat. The direction of a target is represented by the direction of its echo from the center, and the target's range is represented by its distance from the center. (see **Figure 14-39**)

The cursor is a movable reference and is controlled by the radar cursor control. The cursor is used to obtain the relative bearings of a target on the indicator.

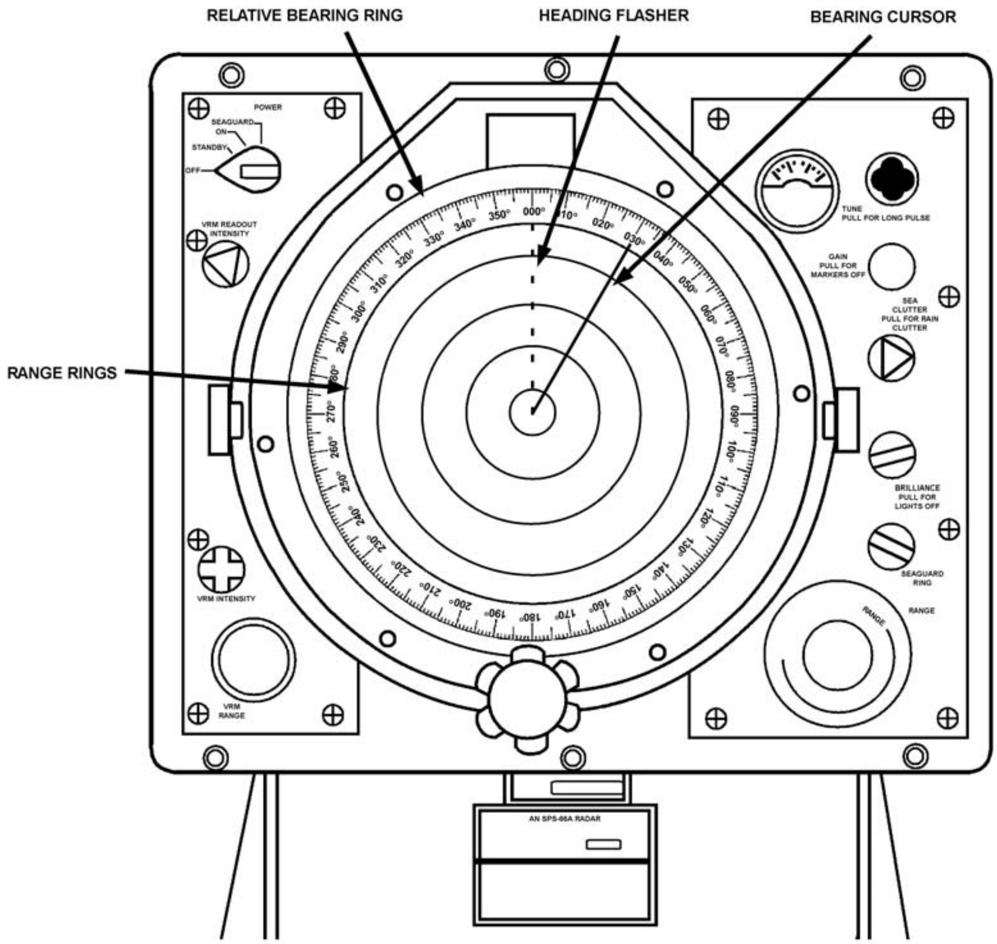

Figure 14-39
Radar Range Rings, Relative Bearing Ring, Heading Flasher, and Bearing Cursor

D.57.a. Radar Bearings	Radar bearings are measured in relative direction the same as visual bearings with 000° relative being dead ahead. (see **Figure 14-39**) In viewing any radar indicator, the dot in the center indicates the boat's position. The line from the center dot to the outer edge of the indicator is called the heading flasher and indicates the direction your boat is heading. To obtain target relative bearings, the cursor control should be adjusted until the cursor line crosses the target. The radar bearing is read from where the cursor line crosses the bearing ring.

NOTE Like visual observations, relative bearing measurements by radar must be converted to magnetic bearing prior to plotting them on the chart.

D.57.b. Target Range	Many radars have a variable range marker. Crewmembers should dial the marker out to the inner edge of the contact on the screen and read the range directly. Other radars may have distance rings. If the contact is not on a ring, the distance is estimated (interpolated) by its position between the rings.

D.57.b.1. Example

The radar is on the range scale of 2 nautical miles, and has 4 range rings. Range information is desired for a target appearing halfway between the third and fourth rings.

- Range rings on the two-mile scale are ½ mile or 1000 yards apart (4 rings for 2 miles means each ring equals ¼ of the total range of 2 miles).
- Range is calculated as 1000 + 1000 + 1000 + ½ x 1000 or 3500 yards.

D.58. Radar Contacts

Even with considerable training it may not always be easy to interpret a radar echo properly. Only through frequent use and experience will a crewmember be able to become proficient in the interpretation of images on the radar screen.

Knowledge of the radar picture in the area is obtained by using the radar during good visibility and will eliminate most doubts when radar navigating at night and during adverse weather. Images on a radar screen differ from what is seen visually by the naked eye. This is because some contacts reflect radio waves (radar beams) better than others.

D.58.a. Common Radar Contacts

A list of common radar contacts and reflection quality follows:

Contact	Integrity
Reefs, shoals, and wrecks	May be detected at short to moderate ranges, if breakers are present and are high enough to return echoes. These echoes usually appear as cluttered blips.
Sandy spits, mud flats, and sandy beaches	Return the poorest and weakest echoes. The reflection, in most cases, will come from a higher point of land from the true shoreline such as bluffs or cliffs in back of the low beach. False shorelines may appear because of a pier, several boats in the area, or heavy surf over a shoal.
Isolated rocks or islands off shore	Usually return clear and sharp echoes providing excellent position information.
Large buoys	May be detected at medium range with a strong echo; small buoys sometimes give the appearance of surf echoes. Buoys equipped with radar reflectors will appear out of proportion to their actual size.
Piers, bridges, and jetties	Provide strong echoes at shorter ranges.
Rain showers, hail, and snow	Will also be detected by radar and can warn of foul weather moving into the area. Bad weather appears on the screen as random streaks known as ‘clutter’.

D.59. Radar Fixes

Radar navigation provides a means for establishing position during periods of low visibility when other methods may not be available. A single prominent object can provide a radar bearing and range for a fix, or a combination of radar bearings and ranges may be used. Whenever possible, more than one object should be used. Radar fixes are plotted in the same manner as visual fixes.

NOTE

> If a visual bearing is available it is more reliable than one obtained by radar.

D.59.a. Example

On a compass heading of 300°, a radar contact (image) bearing 150° relative is observed. Deviation, from the deviation table, for the boat's compass heading (300° C) is 3'E.

Obtain the magnetic bearing of the contact by performing the following procedures:

Step	Procedure
1	Correct compass heading of 300° to magnetic heading. Write down the correction formula in a vertical line. C = 300° D = 3° E (+E, -W when correcting) M = 303° M V = not applicable in this problem T = not applicable in this problem
2	Compute information opposite appropriate letter in step 1. Add the easterly error 3° E deviation to the compass heading (300° C) to obtain the magnetic course of 303° M.
3	Add the radar relative bearing (150° relative) to the magnetic heading (303° M) to obtain magnetic bearing of the radar contact (093° M). 303° +150° 453° (greater than 360°) 453° -360° 093° M bearing of contact

D.59.b. Range Rings

Radar range rings show up as circles of light on the screen to assist in estimating distance. Major range scales are indicated in miles and are then subdivided into range rings. Typical range scales for a boat radar are ½, 1, 2, 4, 8, and 16 NM. Typical number of range rings for a particular range scale are shown as follows:

Scale/Miles	Rings	NM Per Ring
½	1	½
1	2	½
2	4	½
4	4	1
8	4	2
16	4	4

D.59.c. LOPs

Radar LOPs may be combined to obtain fixes. Typical combinations include two or more bearings, a bearing with distance range measurement to the same or another object, or two or more distance ranges. Radar LOPs may also be combined with visual LOPs.

Care should be exercised when using radar bearing information only since radar bearings are not as precise as visual bearings. A fix obtained by any radar bearing or by distance measurement is plotted on the chart with a dot enclosed by a triangle to indicate the fix and labeled with time followed by "RAD FIX", such as, 1015 RAD FIX.

D.59.d. Distance Measurement Example

At 0215, the boat is on a course of 300° (303° M). The radar range scale is on 16 miles. Two radar contacts (land or charted landmark) are observed. The first has a bearing of 330° relative at 12 NM. This target is on the third range circle. The second target is bearing 035° relative at 8 NM. This target is on the second range circle. Obtain a distance measurement fix by performing the following procedures: (see **Figure 14-40**)

NOTE Radar ranges are usually measured from prominent land features such as cliffs or rocks. However, landmarks such as lighthouses and towers often show up at a distance when low land features do not.

Step	Procedure
1	Locate the objects on the chart.
2	Spread the span of the drawing compass to a distance of 12 NM (distance of first target), using the latitude or nautical mile scale on the chart.
3	Without changing the span of the drawing compass, place the point on the exact position of the object and strike an arc towards the DR track, plotting the distance.
4	Repeat the above procedures for the second object (distance of 8 NM). Where the arcs intersect is the fix (position). Label the fix with time and 'RAD FIX' (0215 RAD FIX).

NOTE The arcs of two ranges will intersect at two points. In some cases, a third LOP may be needed to determine which intersection represents the fix position.

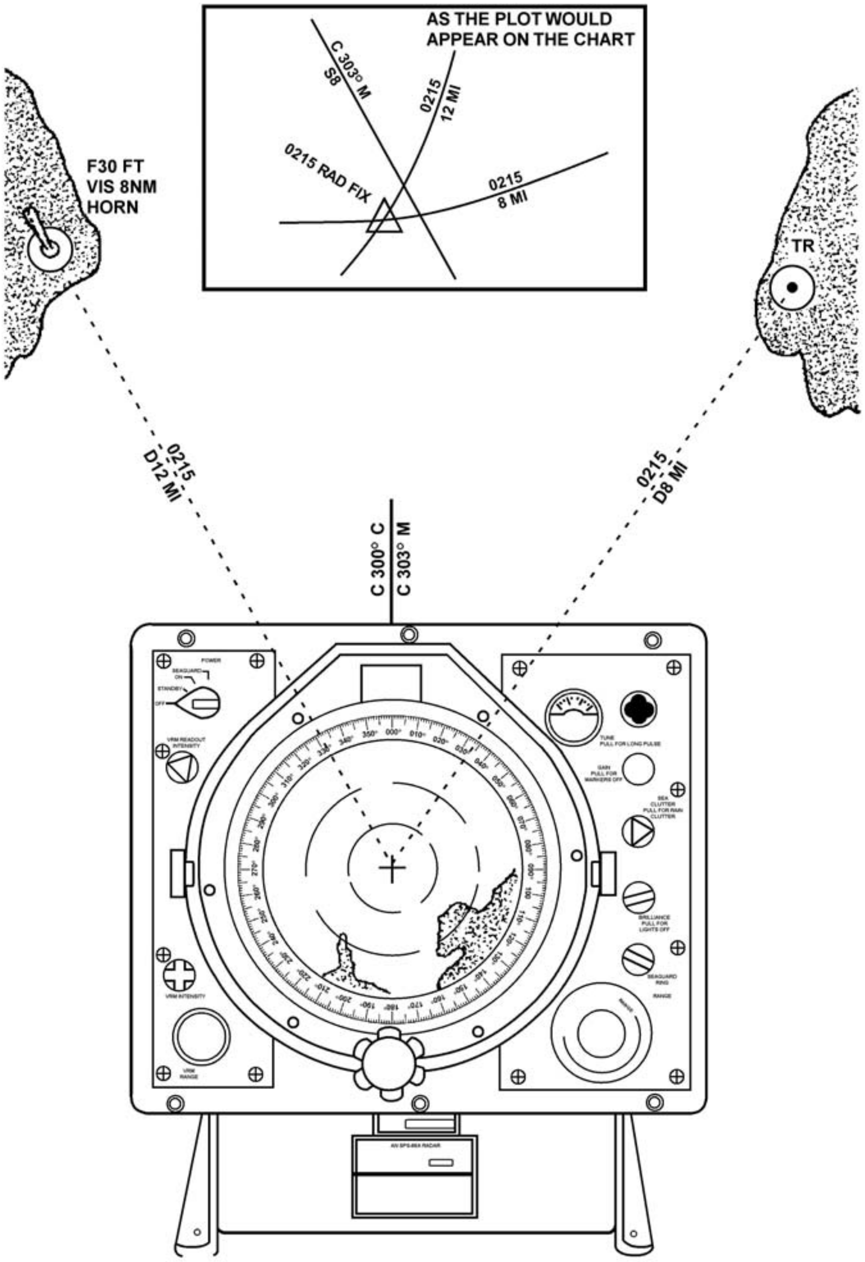

Figure 14-40
Obtaining a Radar Fix Using Two Distance Measurements

D.59.e. Sample DR Plot	A DR plot typically includes many types of LOPs and fixes. **Figure 14-41** is provided as an example of what could appear on a properly maintained DR plot. Some of the fixes within the figure have not been discussed within the text.

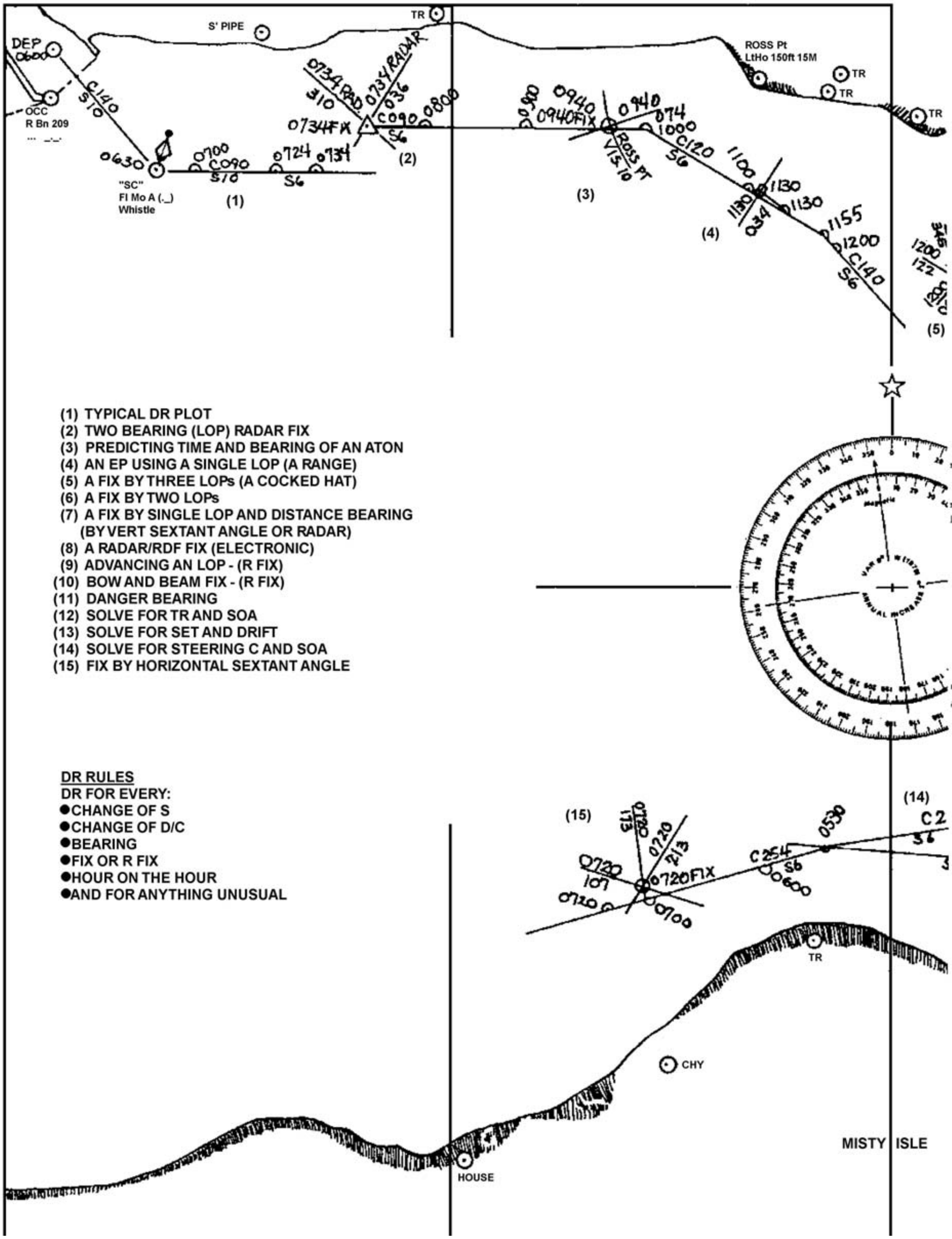

Figure 14-41
Sample DR Plot

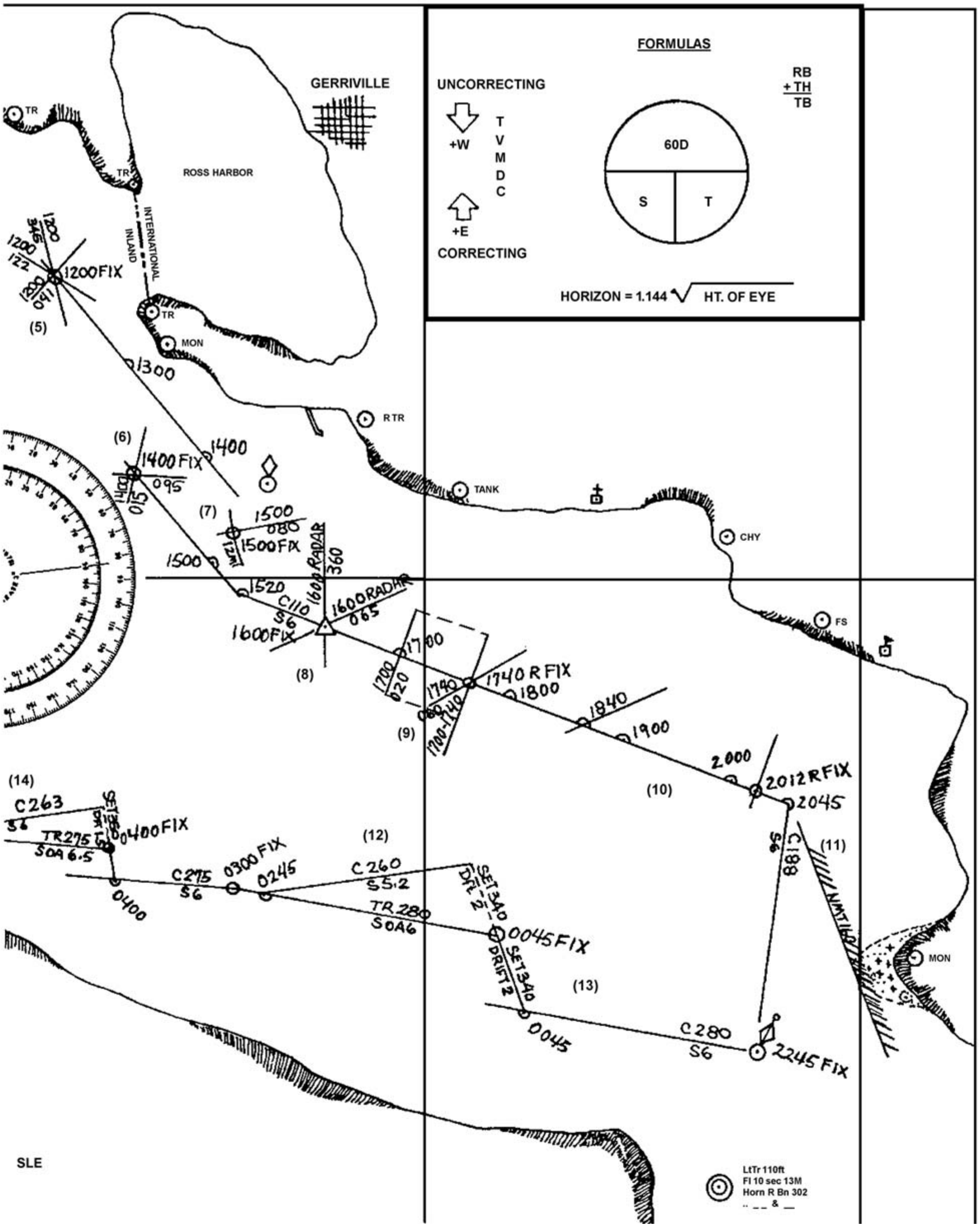

Figure 14-41 (continued)
Sample DR Plot

LORAN-C

D.60. Description

As previously discussed in *Chapter 13, Section D*, LORAN-C is a navigation system network of transmitters consisting of one master station and two or more secondary stations. LORAN-C is a pulsed, hyperbolic (uses curved lines) system. LORAN-C receivers measure the TD between the master transmitter site signal and the secondary transmitter site signal to obtain a single LOP. A second pair of LORAN-C transmitting stations produces a second LOP. Plotting positions using TDs requires charts overprinted with LORAN-C curves. However, most LORAN-C receivers convert LORAN-C signals directly into a readout of latitude and longitude. The mariner then can use a standard nautical chart without LORAN-C curves. It is accurate to better than .25 nautical mile (NM).

D.61. Receiver Characteristics

Different LORAN-C receivers have different locations of their controls, but they are basically standardized on what function is to be controlled. The boat crew should become familiar with the operation of the LORAN-C receiver by studying its operating manual and through the unit training program.

NOTE LORAN-C is not accurate enough for precise navigation, such as staying within a channel.

D.62. Determining Position

Many LORAN-C receivers give a direct readout of latitude and longitude position that can be plotted on the chart. Depending on the receiver, the conversion of LORAN-C signals to latitude and longitude may lose some accuracy. The readout typically goes to two decimal places (hundredths) but plotting normally only goes to the first decimal place (tenths).

Older LORAN-C receivers display only a TD for each pair of stations. By matching these TD numbers to the LORAN-C grid, overprinted on a chart, an LOP can be determined. Intersecting two or more of these LOPs gives a fix.

TDs represent specific intersecting grid lines on a LORAN-C chart. (see **Figure 14-42**) Each line is labeled with a code such as SSO-W and SSO-Y that identifies particular master-secondary signals. Following the code is a number that corresponds to the TDs that would appear on a LORAN receiver on a boat located along the line. Crewmembers should note the TDs and find the two intersecting grid lines; one on the SSO-W axis, the other on the SSO-Y Axis that most nearly match the readings on the boat's receiver.

The first step in plotting a LORAN-C position is to match the numbers on the receiver with the LORAN-C grid on the chart. The point where the two lines meet gives a fix of the position.

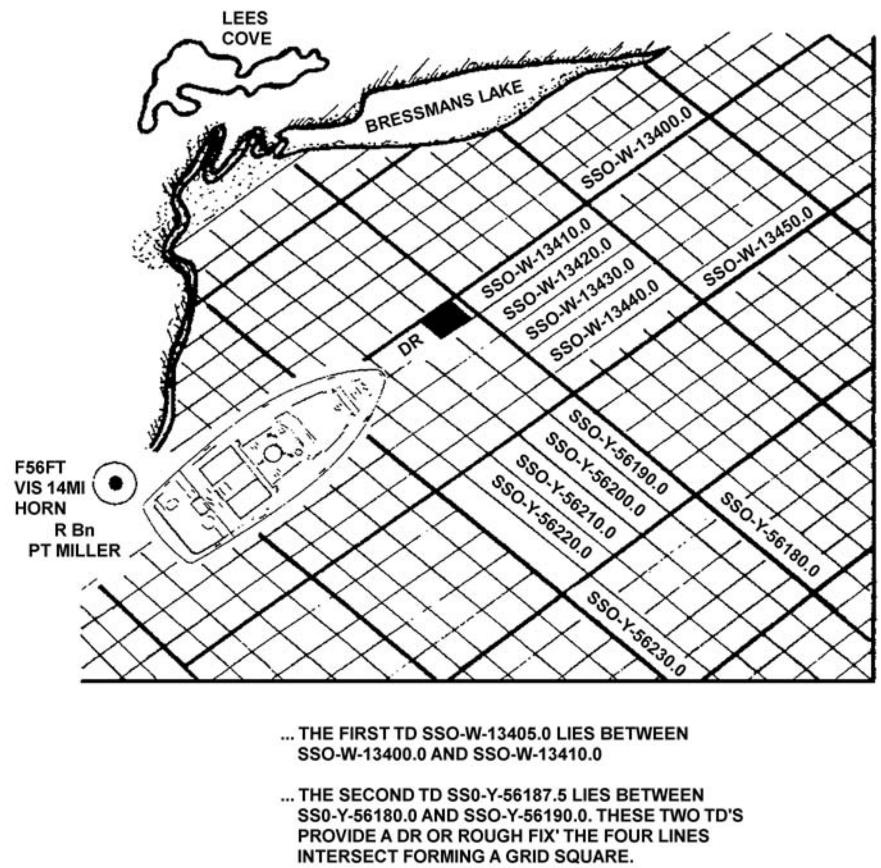

Figure 14-42
Matching LORAN-C TDs with LORAN-C Grids on a Chart

D.63. Refining a LORAN-C Line of Position

Two LORAN-C readings are given as: SSO-W-13405.0 and SSO-Y-56187.5. The first axis lies between SSO-W-13400.0 and SSO-W-13410.0 and the second axis lies between SSO-Y-56180.0 and SSO-Y-56190.0.

Refine the LORAN-C fix by performing the following procedures: (see **Figure 14-43**)

Step	Procedure
1	Use dividers and measure the exact distance between the LORAN-C LOPs SSO-W-13400.0 and SSO-W-13410.0 on the chart. (see **Figure 14-43**)
2	Without changing the span of the dividers, find the points where the distance between the base of the wedge-shaped interpolator scale on the chart and the topmost sloping edge of the interpolator matches the span of the dividers. Connect these two points with a vertical line. (see **Figure 14-43**)
3	Along the vertical edge of the interpolator are the numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10. Beginning at the base, read UP. Each number makes an immediate sloping line on the interpolator. The difference between SSO-W-1 3405.0 and SSO-W-18410.0 is five. Select line five of the interpolator and follow it to the vertical line drawn in step 2.
4	Take the dividers and measure the distance between line five and the base of the interpolator. Without changing the span of the dividers, measure the same distance, away and perpendicular to the line SSO-W-13400.0 on the chart nearest the DR. Measure the direction toward the line SSO-W-13410.0. Take parallel rulers and draw a line parallel to SSO-W- 1 8400.0 at this point. The SSO-W- 1 3405.0 TD is now plotted.
5	Plot the SSO-Y-56187.5 between SSO-Y-56180.0 and SSO-Y-56190.0 using the above procedures.

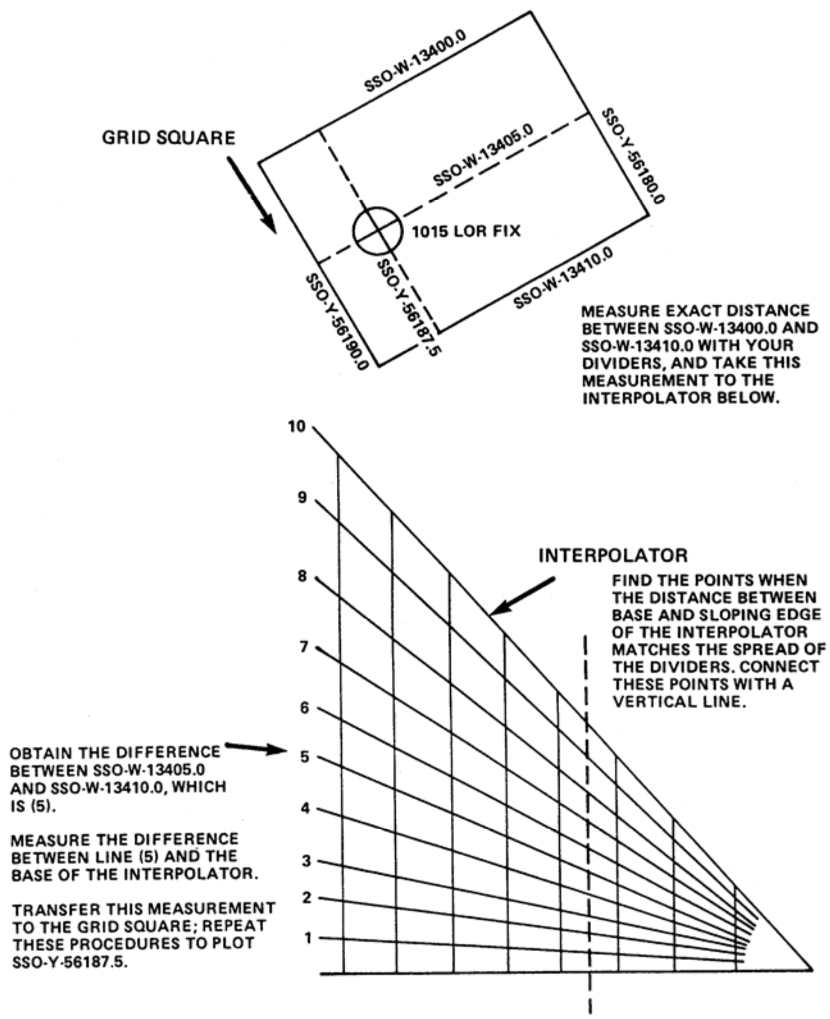

Figure 14-43
Obtaining a LORAN-C Fix on a Grid Square

Global Positioning System (GPS)

D.64. Description

As previously discussed in *Chapter 13, Section D*, the GPS is a radionavigation system of 24 satellites operated by the DoD. It is available 24 hours per day, worldwide, in all weather conditions. Each GPS satellite transmits its precise location, meaning position and elevation. In a process called “ranging,” a GPS receiver on the boat uses the signal to determine the distance between it and the satellite. Once the receiver has computed the range for at least four satellites, it processes a three-dimensional position that is accurate to about 33 meters. GPS provides two levels of service - SPS for civilian users, and PPS for military users.

D.65. Standard Positioning Service

The civilian SPS is available on a continuous basis to any user worldwide. It is accurate to a radius within 33 meters of the position shown on the receiver about 99% of the time.

D.66. Precise Positioning Service

PPS provides position fixes accurate to within 10 meters. This service is limited to approved U.S. Federal Government, allied military, and civil users.

D.67. Equipment Features

GPS receivers are small, have small antennas, and need little electrical power. Hand-held units are available. Positional information is shown on a liquid crystal display (LCD) screen as geographical coordinates (latitude and longitude readings). These receivers are designed to be interfaced with other devices such as autopilots, EPIRBs and other distress alerting devices, to automatically provide positional information. Navigational features available in the typical GPS receiver include:

- Entry of waypoints and routes in advance.
- Display of course and speed made good.
- Display of cross-track error.
- Availability of highly accurate time information.

Differential Global Positioning System (DGPS)

D.68. Description

As previously discussed in *Chapter 13, Section D,* the Coast Guard developed the DGPS to improve upon SPS signals of GPS. It uses a local reference receiver to correct errors in the standard GPS signals. These corrections are then broadcast and can be received by any user with a DGPS receiver. The corrections are applied within the user's receiver, providing mariners with a position that is accurate within 10 meters, with 99.7% probability. While DGPS is accurate to within 10 meters, improvements to receivers will make DGPS accurate to within a centimeter, noise-free and able to provide real-time updates.

The Coast Guard uses selected marine radiobeacons to send DGPS corrections to users. DGPS provides accurate and reliable navigational information to maritime users in HEA, along U.S. coastal waters, the Great Lakes, navigable portions of the western rivers, Puerto Rico, Hawaii, and Alaska.

Section E. River Sailing

Introduction

The section provides general information for operating on rivers, with emphasis on the western rivers. The western rivers (Mississippi River system) pose navigational concerns that often are not seen in harbor, coastal, or high seas sailing. Local knowledge is very important. Navigational techniques and the language both have differences that must be learned to become a competent river sailor.

E.1. Major Piloting Differences

Some of the special considerations for river navigation include:

- Charts.
- Mile marks.
- Fixed aids.
- Buoyage.
- Compass.
- DR plot.

E.1.a. Charts

Charts are simple, line drawn "maps" that show the main geographical features of the waterway, the channel or sailing line, prominent man-made objects, and the various aids. River charts do not show landmarks such as stacks, water towers, or antennas. These charts do not always show the geographical names for areas along the bank. River charts only show structures immediately on the banks by symbol and footnote. **Figure 14-44** provides a good example.

NOTE A road map of the operating area is a good supplement for identifiable geographical names.

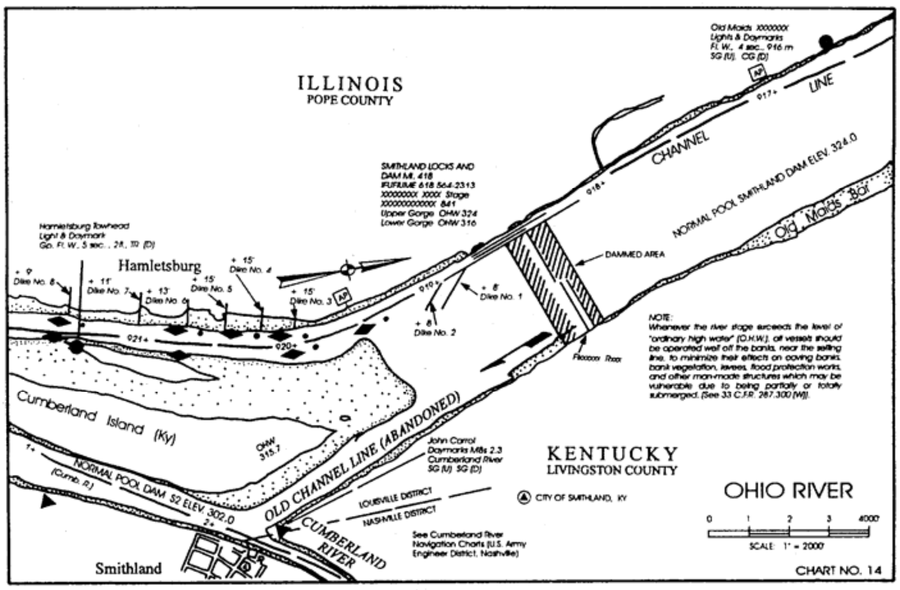

Figure 14-44
Sample River Chart

E.1.b. Mile Marks

The Western Rivers have mile marks (beginning at the mouth or at the headwaters of the stream).

E.1.c. Fixed Aids

Fixed aids (daymarks and lights) display the mile, usually as statute miles, on a "mile" board for that point of the river. Where no aid exists, landmarks such as bridges, creeks, islands, and overhead power lines provide the mile-mark reference.

E.1.d. Buoyage

The U.S. lateral system of buoyage has differences when used on these rivers.

E.1.e. Compass

Compasses are not normally very useful on western rivers because there are no plotting references on the chart and that many rivers meander. However, boat-mounted compasses must be installed. There will be situations where the use of a compass can help determine a position. For example, on a meandering river with no prominent landmarks, comparing the compass heading with the north arrow on the chart will help identify the bend or reach where the boat is operating.

E.1.f. DR Plot

As in coastal sailing, a boat's approximate position is determined by dead reckoning, applying its speed, time, and course from its last known position. However, because many rivers have numerous bends, it often is not possible to maintain a complete DR plot with precise course changes.

E.2. Conditions and Effects

Surface and bottom conditions of a river are unpredictable and can change quickly. Some of the unique situations to deal with include:

- Silting and shoaling.
- Drift.
- Flood or drought.

E.2.a. Silting and Shoaling

Silt is a mass of soil particle carried in water. It can clog boat cooling water intakes and wear out strut bearings and shafts. Silt settles on the bottom as shoaling, either adding to or creating sand bars or mud banks.

E.2.b. Drift

Drift, or driftwood, is floating debris carried by the river flow and washed or lifted from the banks. Running drift can damage a boat.

E.2.c. Flood or Drought

Tides affect rivers near the coast, but a flood or a drought will greatly affect the vertical level (depth) of the entire river.

E.2.c.1. Flood

A flood is created by runoff or drainage from heavy rains or melting snow. Navigating outside the riverbanks requires caution and local knowledge. During a flood condition, some dangers may include:

- Currents are much stronger.
- Channels can shift.
- Obstructions can be hidden under the water.
- Drift hazards (trees and other debris) increase.
- AtoN can be broken.
- Bridge clearances are reduced.

E.2.c.2. Drought

A drought is low water level. This can result in the closing of channels. Snags and obstructions that once were cleared easily become hazards to navigation. Also, sandbars and mud flats will appear where it was once safe to operate.

NOTE

Refer to *Chapter 10, Boat Handling* for information on operating boats in narrow channels.

E.3. Locks and Dams

Locks and dams provide a navigable channel for river traffic. Navigation dams release water, as necessary, to maintain a navigable channel during the navigation season. Locks release water as a part of their normal operation. Both of these can be a safety problem for boats. Knowledge of locks and dams, including location, use and associated hazards, is essential for safe boat operations.

E.3.a. Construction and Operation

The navigation dams on the Mississippi, Illinois, and Ohio rivers can be of different construction. Two types of dam construction are the Tainter gate and the Roller gate. Also, some dam releases are controlled remotely. This is the kind of local knowledge that the boat crew needs to check before operating in that area.

Most people know that water released from a dam can create a powerful, turbulent current going downstream. However, an upstream water current can exist close to the lower or downstream side of a dam. Operating too close to the downstream side of a dam can result in the boat being drawn into the dam.

A strong suction is created by the rush of water underneath the upper side of a roller-gate dam. (see **Figure 14-45**) A boat drifting into the dam on the upper side may not be in immediate danger on the surface but it is possible for boats to be drawn into the gates. These areas are usually marked by danger buoys upstream of the dam and should be avoided as much as possible. If entering this area is a must, the lockmaster should be contacted before entering. If the boat enters this area, crewmembers should not go into the water.

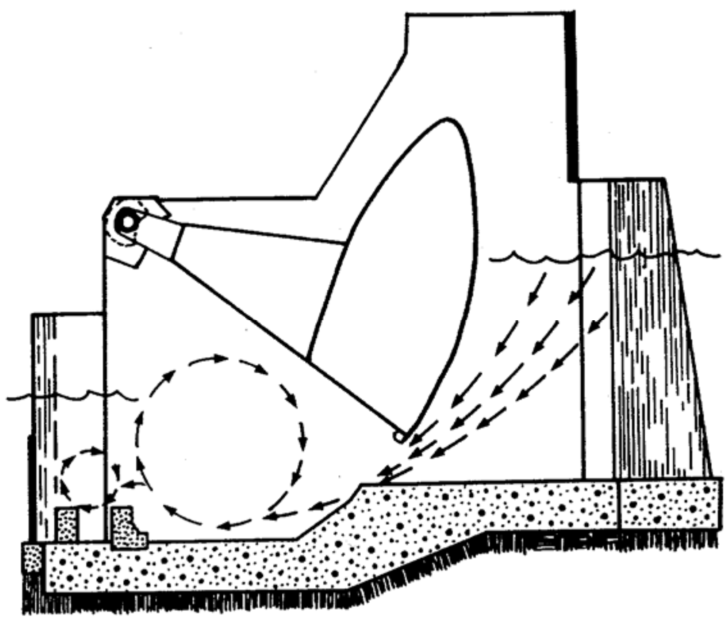

Figure 14-45
Roller Gate Dam

E.3.b. Navigation Displays

When locks at fixed dams and moveable dams have their dams up, they will show navigation lights during hours of darkness. These lights are green, red, or amber and in groups of one, two or three. A circular disc may also be shown. The significance of these displays is explained in local guidance.

E.3.c. Lock Operations

The purpose of a lock is to raise or lower the boat to the level of the channel that it wants to continue to navigate. Locks come in all shapes and sizes, but they all operate on the principle that water seeks its own level. A lock is an enclosure with accommodations at both ends (generally called gates) to allow boats to enter and exit. The boat enters, the gates are closed, and by a system of culverts and valves, the water level in the lock aligns with the pool level of the upstream or downstream side of the lock. The gate then opens and the boat can continue on its way.

E.3.d Locking Procedures

There are many common locking procedures but local regulations can vary. The boat crew must check local guidance for correct locking procedures of each lock. Standard locking signals are shown in **Figure 14-46**. Precautions to take in locking include:

- Do not come closer than 400 feet of the lock wall until the lockman signals to enter.
- Moor to the side of the lock wall as directed.
- If using own mooring lines, they should be at least 50 feet long with a 12-inch eye splice.
- Do not tie mooring lines to the boat; tend the lines as the water level changes.
- Be prepared to cast off lines in an emergency; a small hand axe or hatchet should be available.
- Use fenders.
- Do not moor to ladder rungs embedded in the lock walls.
- Wait for the lockman’s signal (an air horn) to depart.
- Depart in the same order of entering the lock with other boats.
- Steer for the channel and keep a sharp lookout for craft approaching from the other direction.

At locks with “small craft signals”, signal the lockman the desire to pass. After signaling, stand clear and wait for instructions. Many locks are radio-equipped. Consult the appropriate navigation charts for radio-equipped locks, their frequency and call sign.

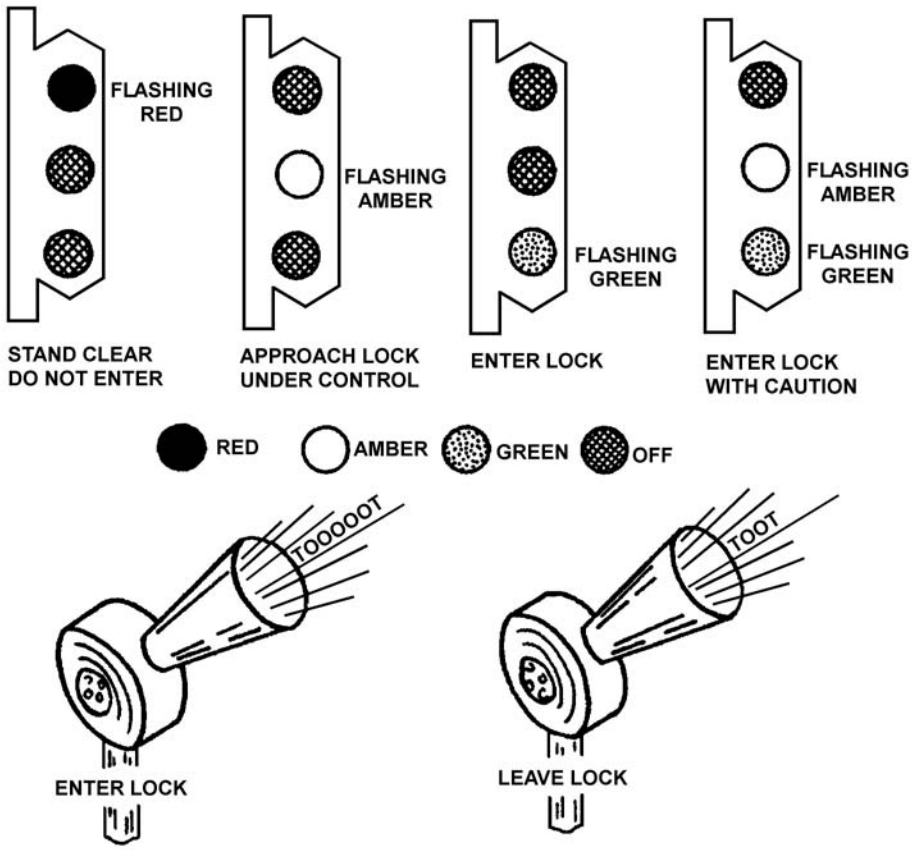

Figure 14-46
Standard Locking Signals

E.3.e. General Considerations

General considerations around locks include:

- The Secretary of the Army sets the priorities for safe and efficient passage of the various types of craft on inland waterways. Priorities, listed in descending order with the highest priority on top, are:
  - U.S. military craft.
  - Vessels carrying U.S. mail.
  - Commercial passenger craft.
  - Commercial tows.
  - Commercial fisherman.
  - Recreational craft.
- Under certain conditions, boats may be locked through with other crafts having a higher priority. This occurs only when there is no delay and neither craft is placed in jeopardy.
- Lockmen have the same authority over a boat in a lock as the traffic police have over a car at an intersection. For safety purposes, obey the lockman's instructions.
- Every boat should carry a copy of, and the crew should be familiar with the regulations governing navigation on the rivers in its AOR.

E.4. Safety Considerations Around Navigation Dams

General safety considerations include:

- Stay clear of danger zones - 600 feet above and 100 feet below dams.
- Approach dams at reduced speed, along the shore at the lock.
- Be "dam" conscious:
  - During the filling process, it is dangerous to approach near the intake ports in the lock walls above the upstream lock gates. The filling process creates a powerful suction as water rushes into the culverts. Boats must stay clear of the locks until signaled to approach.
  - During the emptying process, a strong undercurrent and suction is created in the lock chamber. This suction occurs next to the lock walls and is created by the water rushing into the filling and emptying ports of the lock.
  - Wearing a PFD may not keep a person from being pulled under the water in these circumstances.

E.5. Common River Sailing Terms

Table 14-6 provides terms and their definitions, commonly used in river sailing.

Table 14-6
River Sailing Terms

Term	Description
Auxiliary Lock	A small secondary lock next to the main lock.
Backwater	The water backed up a tributary system.
Bar	A deposit of sand or gravel in or near the channels that, at times, prevents boat traffic from passing.
Bend	A bend of the river, similar to a curve in a highway.
Berm	The sharp definitive edge of a dredged channel, such as in a rock cut.
Bight of a Bend	Sharpest part of a curve in a river or stream.
Bitts, Floating	Part of a lock system for securing a boat waiting in a lock, recessed in lock walls.
Boil	Turbulence in the water resulting from deep holes, ends of dikes, channel changes, or other underwater obstructions.
Caval or Kevel	A steel cleat of special design on barges and towboats for making aft mooring and towing lines.
Chute	Section of river that is narrower than ordinary and through which the river current increases. It is also the passage behind an island that is not the regular channel.
Deadhead	A water soaked wooden pile, tree, or log that floats at the surface of the water (barely awash), usually in a vertical position.
Dike	A structure of pilings or stone that diverts the current of a river.
Down Draft	The natural tendency of a river current to pull the boat downstream when making a river crossing.

Table 14-6 (continued)
River Sailing Terms

Term	Description
Draft	A crosscurrent that is usually designated as an out draft, or as a left- or right-handed draft.
Draw Down	The release of water through one dam before the arrival of a significant increase in water from the upper reaches of the river.
Drift	Debris floating in or lodged along the banks of the river. (Also known as driftwood.)
Flat Pool	The normal stage of water in the area between two dams. It is maintained when little or no water is flowing; therefore the pool flattens out.
Flood Stage	A predetermined level or stage along the main river bank where flooding will occur or may overflow in the particular area.
Foot of _____	The downstream end or lower part of a bend or island.
Gauge	A scale graduated in tenths of a foot that shows the water level or river stage. A lower gauge is one that shows the downstream side of a dam and an upper gauge is one on the upstream side.
Head of _____	The upstream end or beginning of a bend or island.
Left Bank	The left bank of a river when going downstream, properly termed left bank descending.
Levee	An embankment or dike constructed for flood protection.
Lock	A chamber built as part of a river dam to raise or lower boat traffic that wants to pass the dam.
Lock Gate	A moveable barrier that prevents water from entering or leaving a lock chamber.
Mile Board	A 12" x 36" board above a river aid and with the river mileage at that point from a given location.
Open River	Any river having no obstructions such as dams, or when the river stage is high enough to navigate over movable dams.
Pool Stage	The stage of water between two successive dams. It is usually at the minimum depth to maintain the depth in the channel at the shallowest point.
Reach	Usually a long, straight section of a river.
Right Bank	The right bank of a river when going downstream, properly termed as right bank descending.
Slack Water	A location where there is a minimum current.
Snag	Tree or log embedded in the river bottom.
Tow	One or more barges made up to be transported by a boat.
Towboat	A riverboat that pushes barges ahead.

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