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 a 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 VO 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 Division vessel is a VO-in-training. A crewmember must learn all landmarks, charts, maps, 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.

Most of Utah's lakes are fairly small and do not require a lot of navigational skills to be able to safely boat or perform SAR/Patrol missions. But Utah does have some very large bodies of water where navigation skills are imperative. This chapter goes into some depth in how to read a chart. Most lakes in Utah have a map that can be used for dead reckoning purposes. But Great Salt Lake is the only bod of water in Utah that has been charted. This does not mean the skills taught in this chapter are not necessary. Many of the same skills that apply to charts can also be applied to maps and should be understood for the purpose of charting a proper and successful SAR mission. And with the recent advancement of electronic charts we may well see charting software companies producing electronic charts for more of Utah's waters.

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 navigation problems are based on the earth being a perfect sphere. Charts are drawn to include the 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.

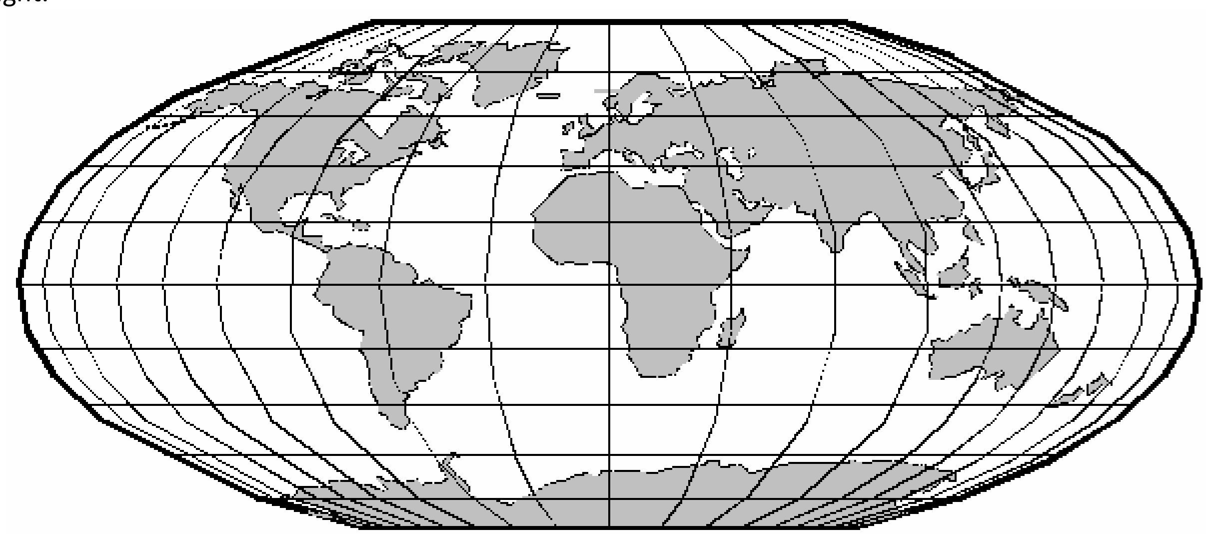

Figure 14-1
Earth with Reference Lines

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 360º 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 360º of arc. In every degree of arc in a circle, there are 60 minutes. Sixty (60) minutes is equal to 1º of arc, and 360º are equal to a complete circle. When degrees are written, the symbol l(º) 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 14º 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 1º 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; 24º45'15".

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 10.0'

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

Circle =	360º
1 degree (º) =	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, minuets, and seconds, in a north and south direction, from the equator. (0º at each pole).

The North Pole is 90º north latitude, and the South Pole is 90º 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.**

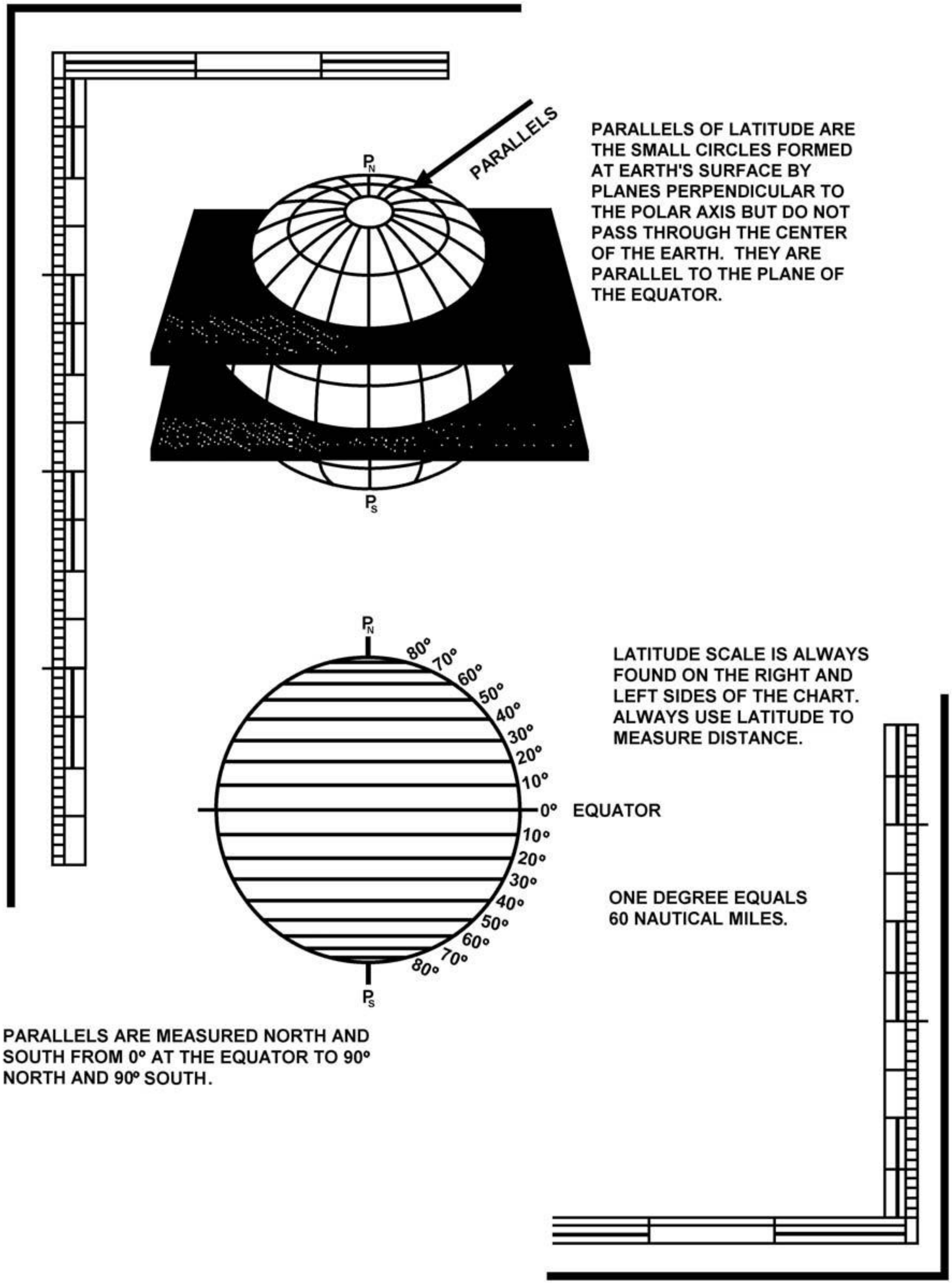

Figure 14-2
Parallels of Latitude

A.3.a. Measuring Latitude

To measure 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 dividers on the object
3	Move the dividers to the nearest latitude, 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 000º and is called the Prime Meridian. From this point, longitude is measured both east and west for 180º.

The 180º meridian is on the exact opposite side of the earth from the 000º 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**).

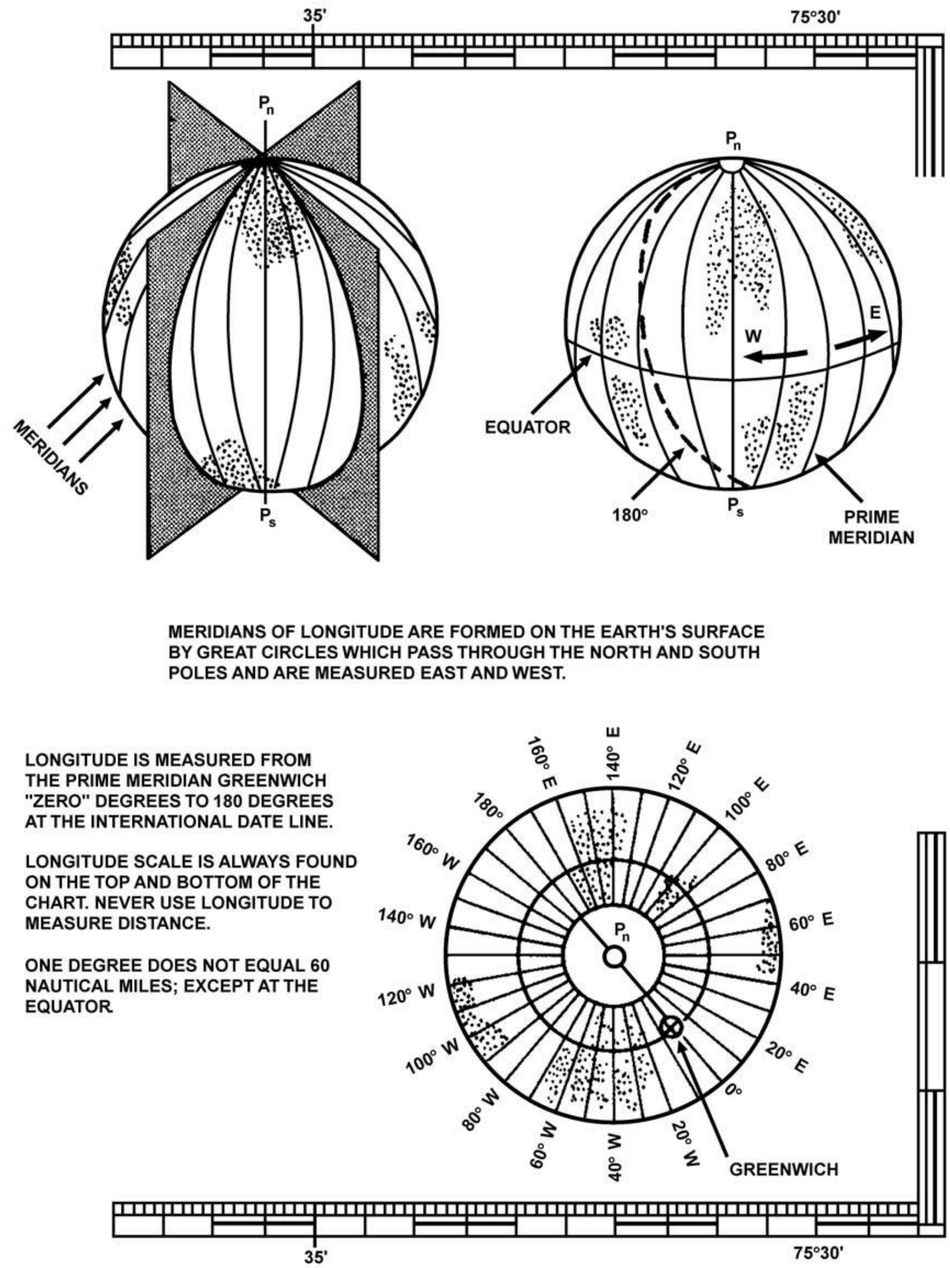

Figure 14-3
Meridians of Longitude

A.4.a. To Measure Longitude

To measure 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 a 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 **Figure 14-4**)

NOTE: Only the latitude scale is used for measuring distance.

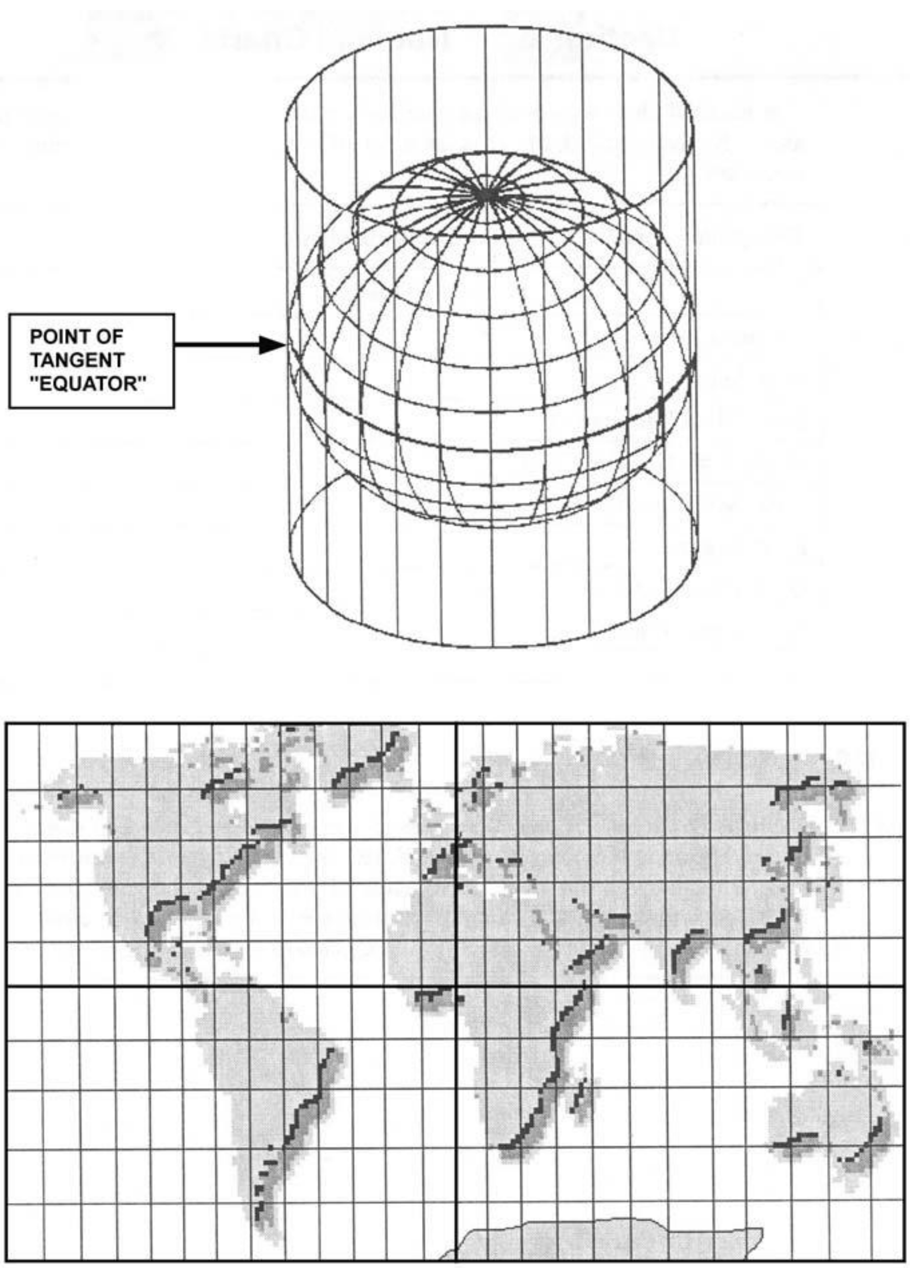

Figure 14-4
Mercator Projection

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 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 VO.

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.

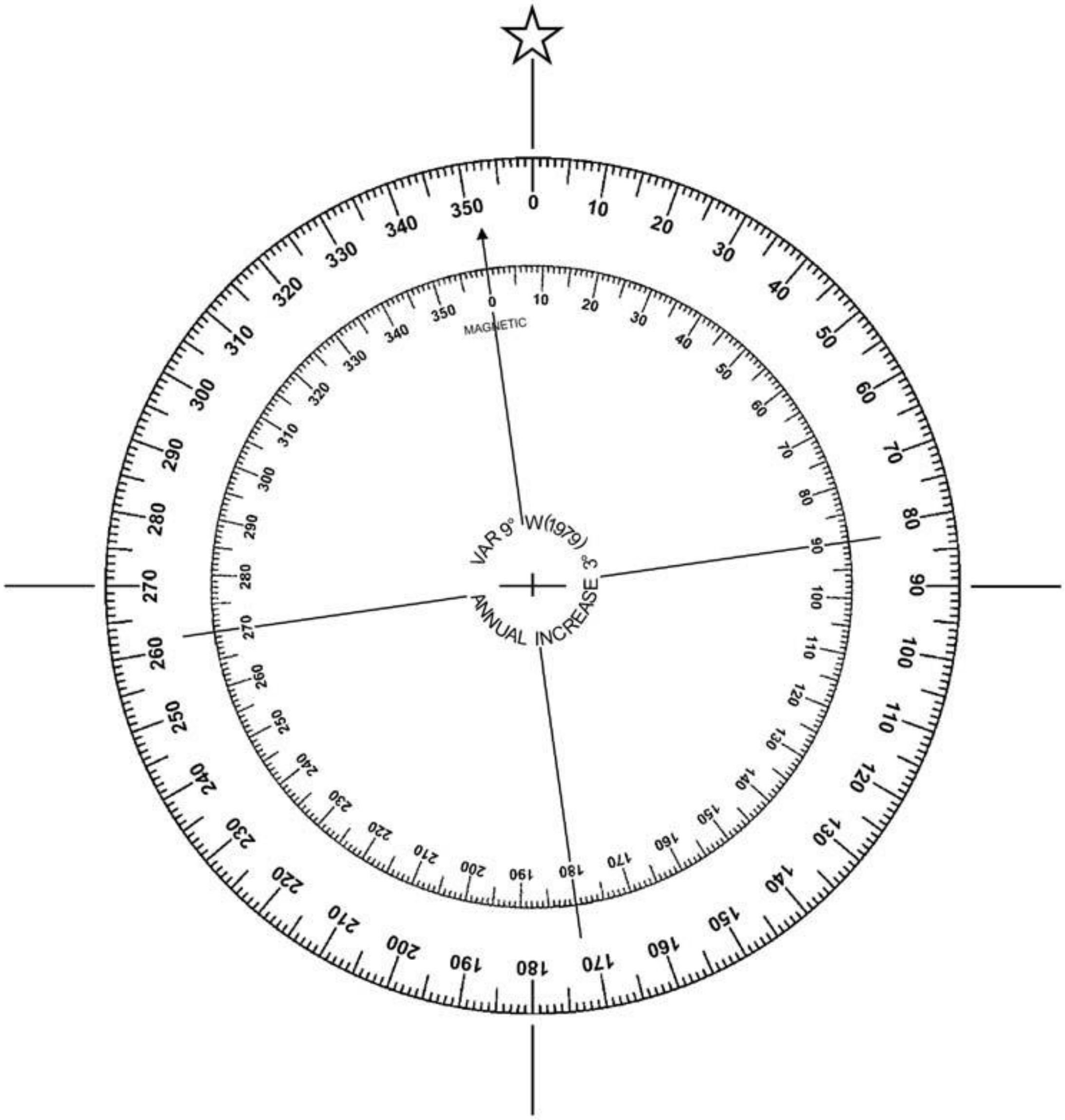

Figure 14-5
Compass Rose

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. The chart of the Great Salt Lake is based on a lake level of 4200 feet above sea level. Soundings on the chart must be added or subtracted based on the actual lake level at the time of plotting a course. Example: If the sounding read 25' but the lake level was only 4195' for that day the true sounding would only be 20 feet.

For more information on Mean Low Tide, Mean Low Water, Average Low Tide, Mean Lower Low Water, see *USCG Boat Crew Seamanship Manual, Chapter 14*.

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. The chart of Great Salt Lake has soundings in feet but no contour lines. The Bathymetric Map of Great Salt Lake has contour lines represent depth in feet.

Basic Chart Information

B.9. Description
The nautical chart shows channels, depths of water buoys, lights, 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 liens are the east and west reference points with the prime meridian as their zero reference point.

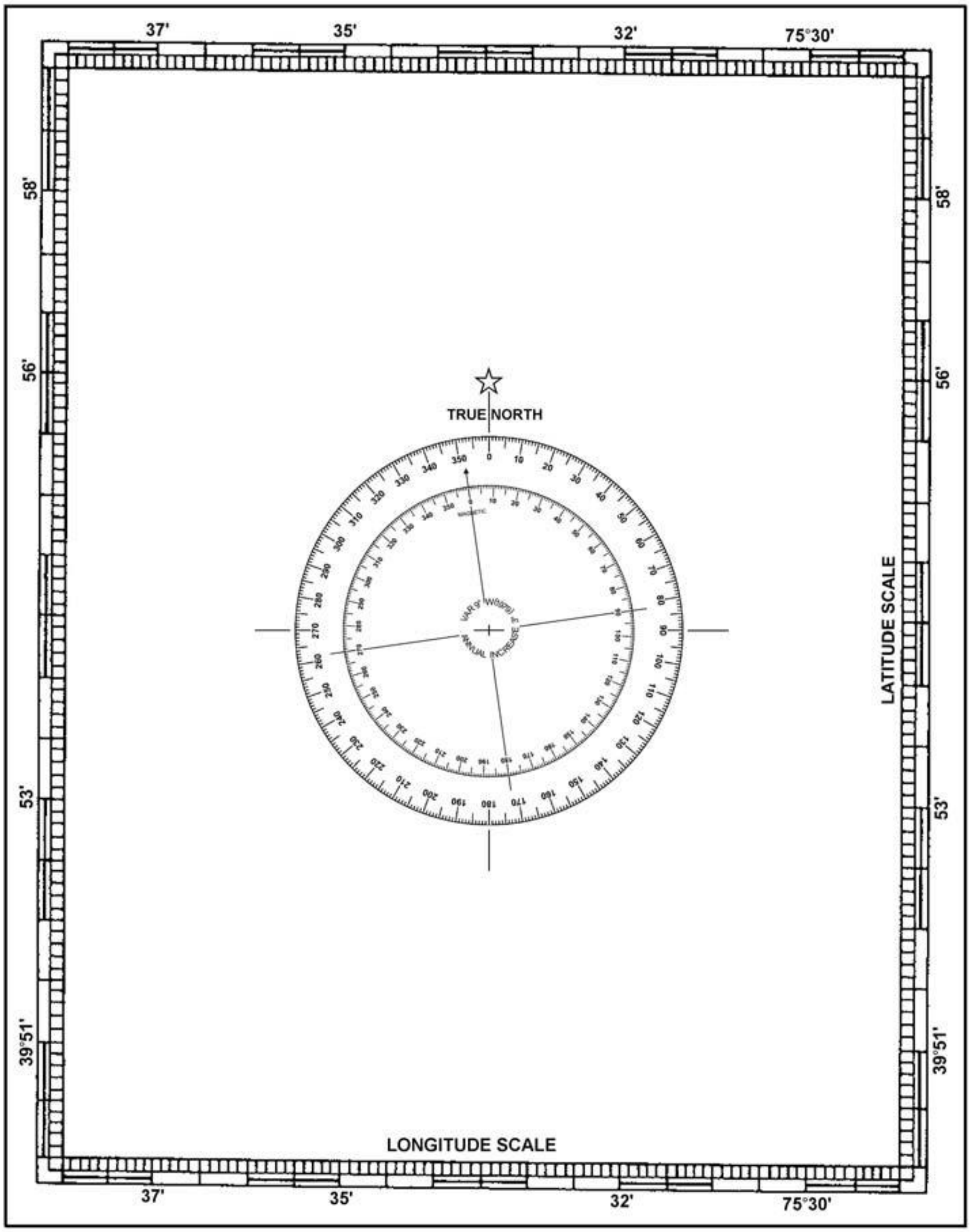

Figure 14-6
Chart Orientation

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 a 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 Numbers
The edition number of a chart and the 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
Scales of charts come in various sizes. Since the only chart in Utah is of the Great Salt Lake this chapter will not go into depth on scales. For a more in-depth discussion on scales of charts see *USGS Boat Crew Seamanship Manual, Chapter 14.*

Chart Symbols and Abbreviations

B.14 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 size. 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.15. Color

Nearly all charts employ color to distinguish various categories of information such as shoal water, deep-water, 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.16. 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 or 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**)

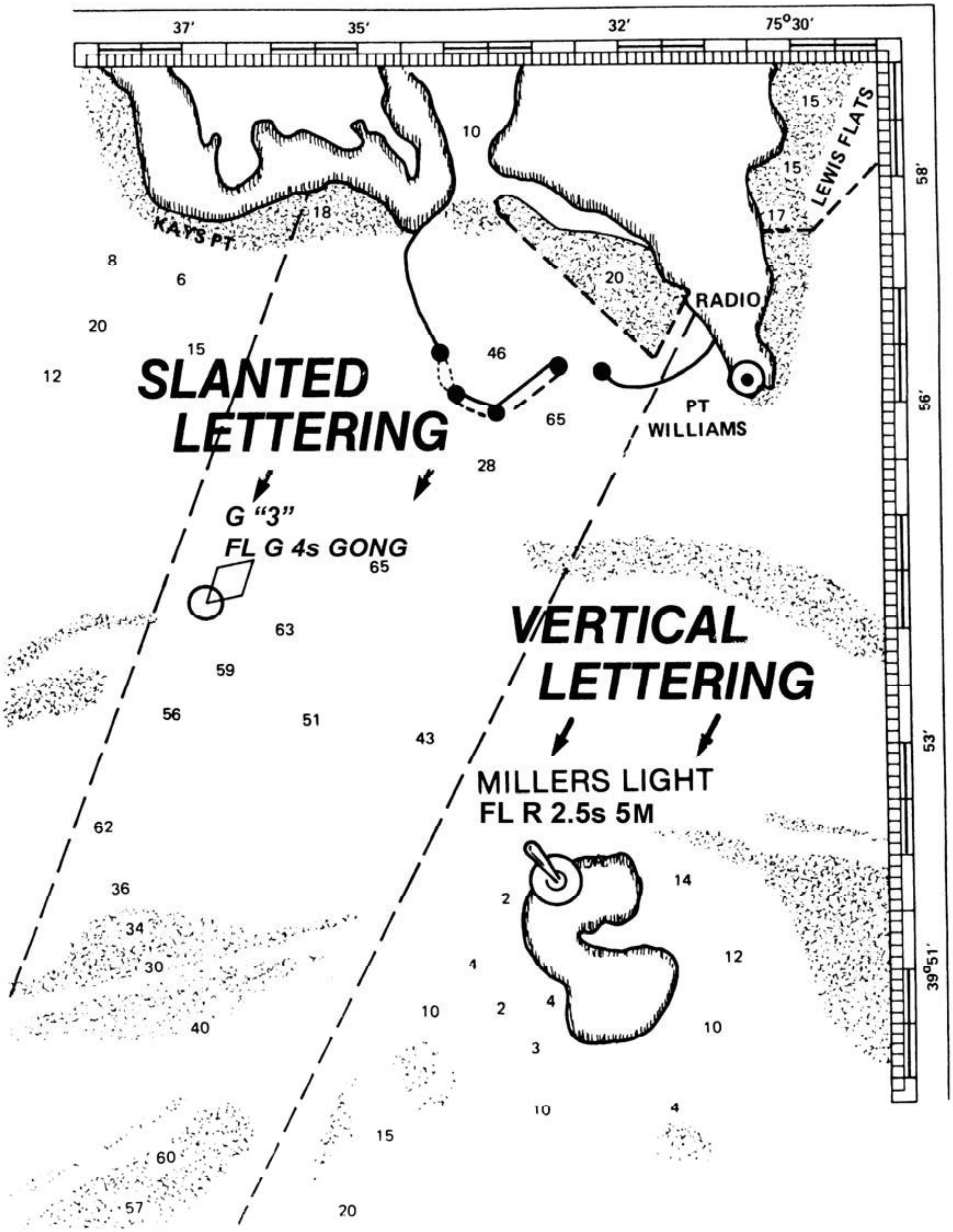

Figure 14-8
Chart Lettering

Buoy Symbols

B.17. 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.18. 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**)

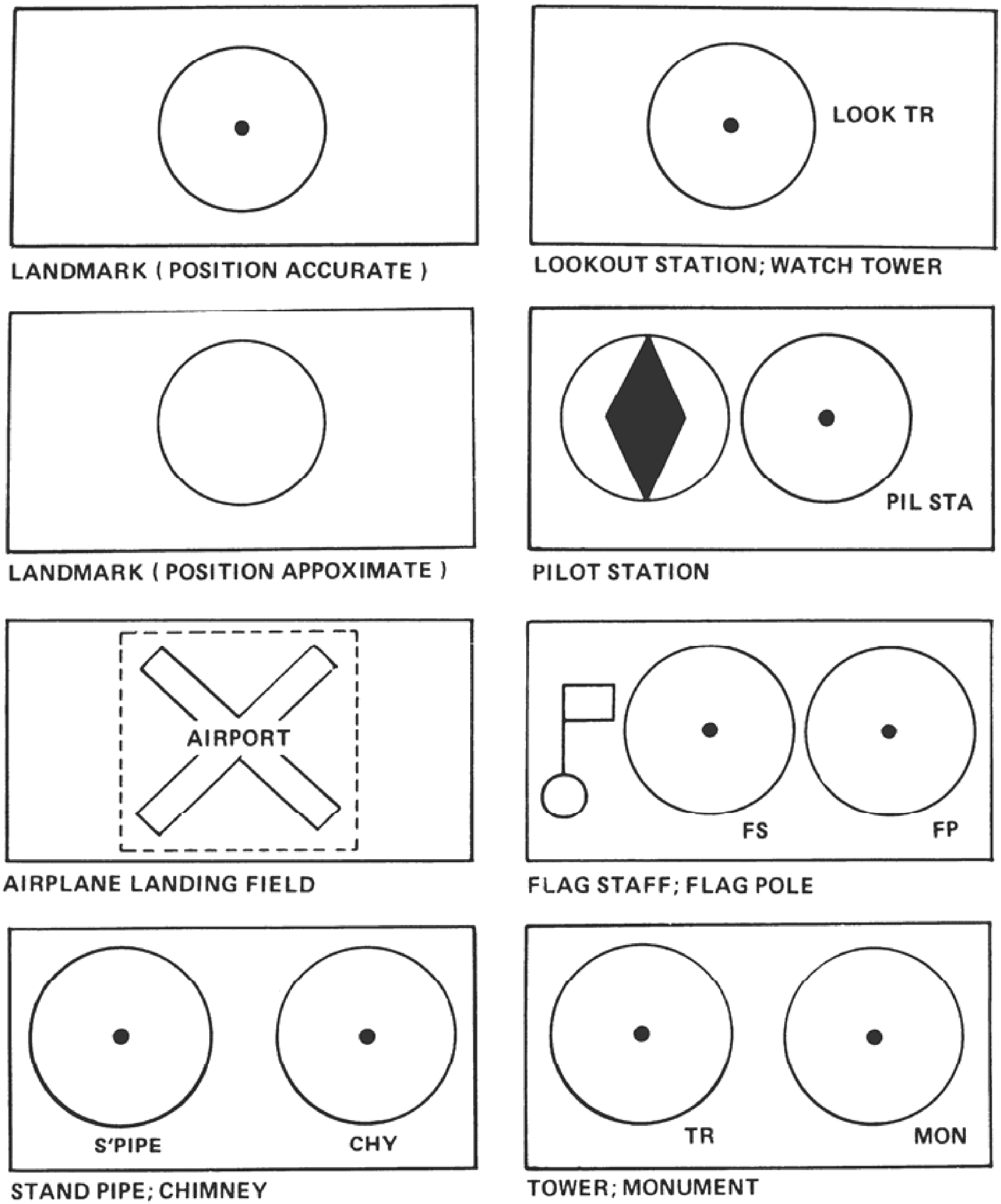

Figure 14-9
Symbols for Prominent Landmarks

B.19. 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**)

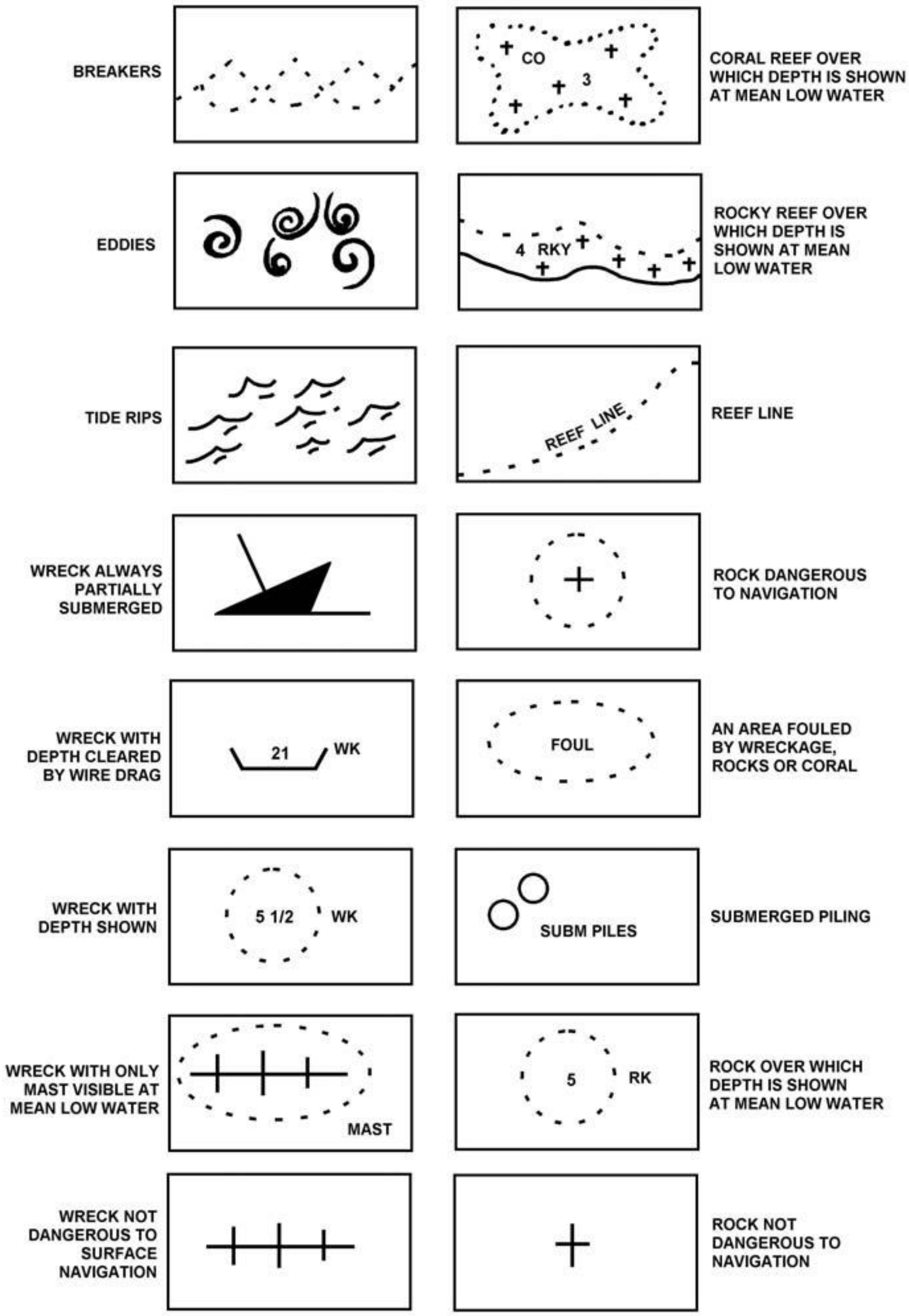

Figure 14-10
Breakers, Rocks, Reefs, Pilings

B-20. 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 or for anchoring warning or navigation buoys.

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.21. 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**)

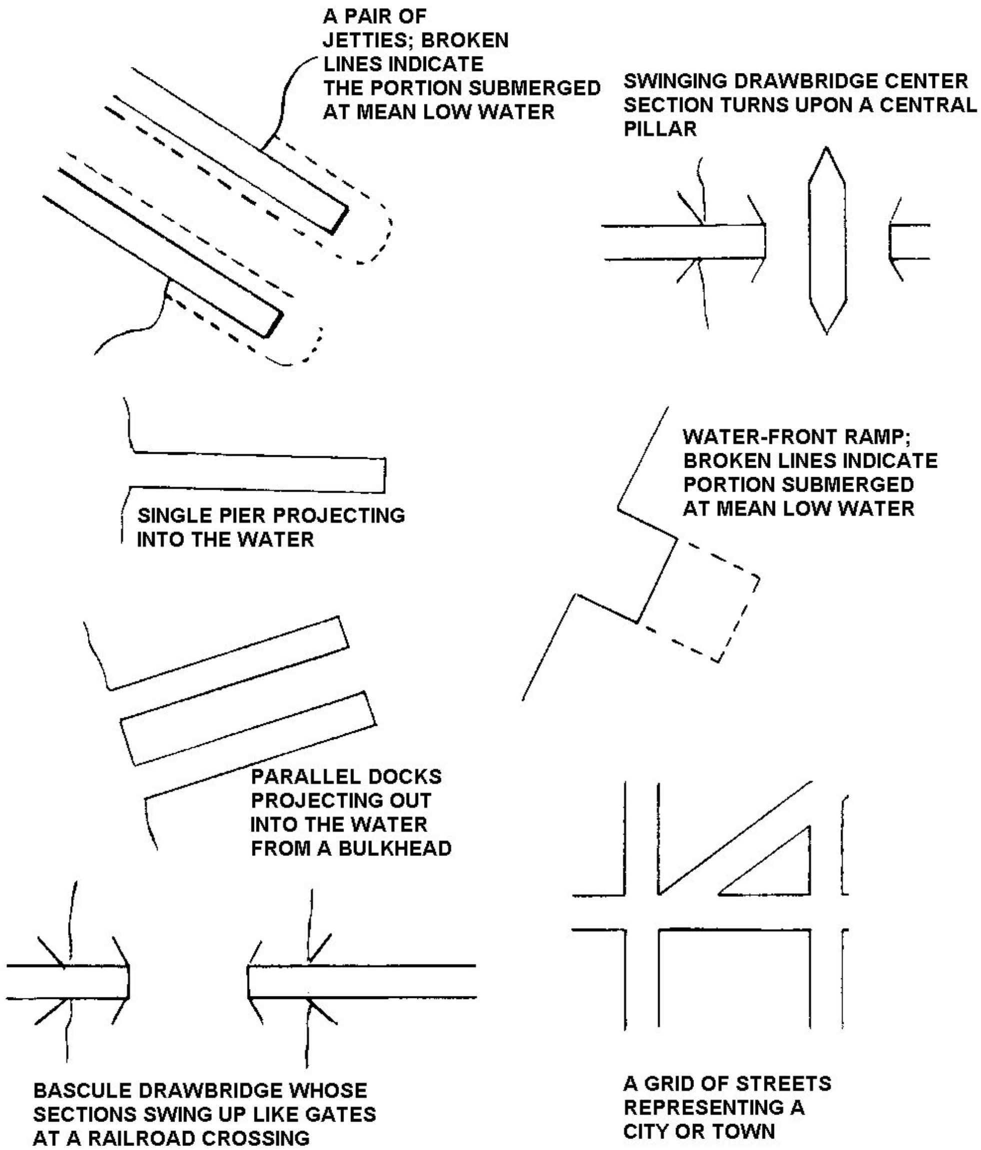

Figure 14-11
Structures

B.22. Coastlines

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

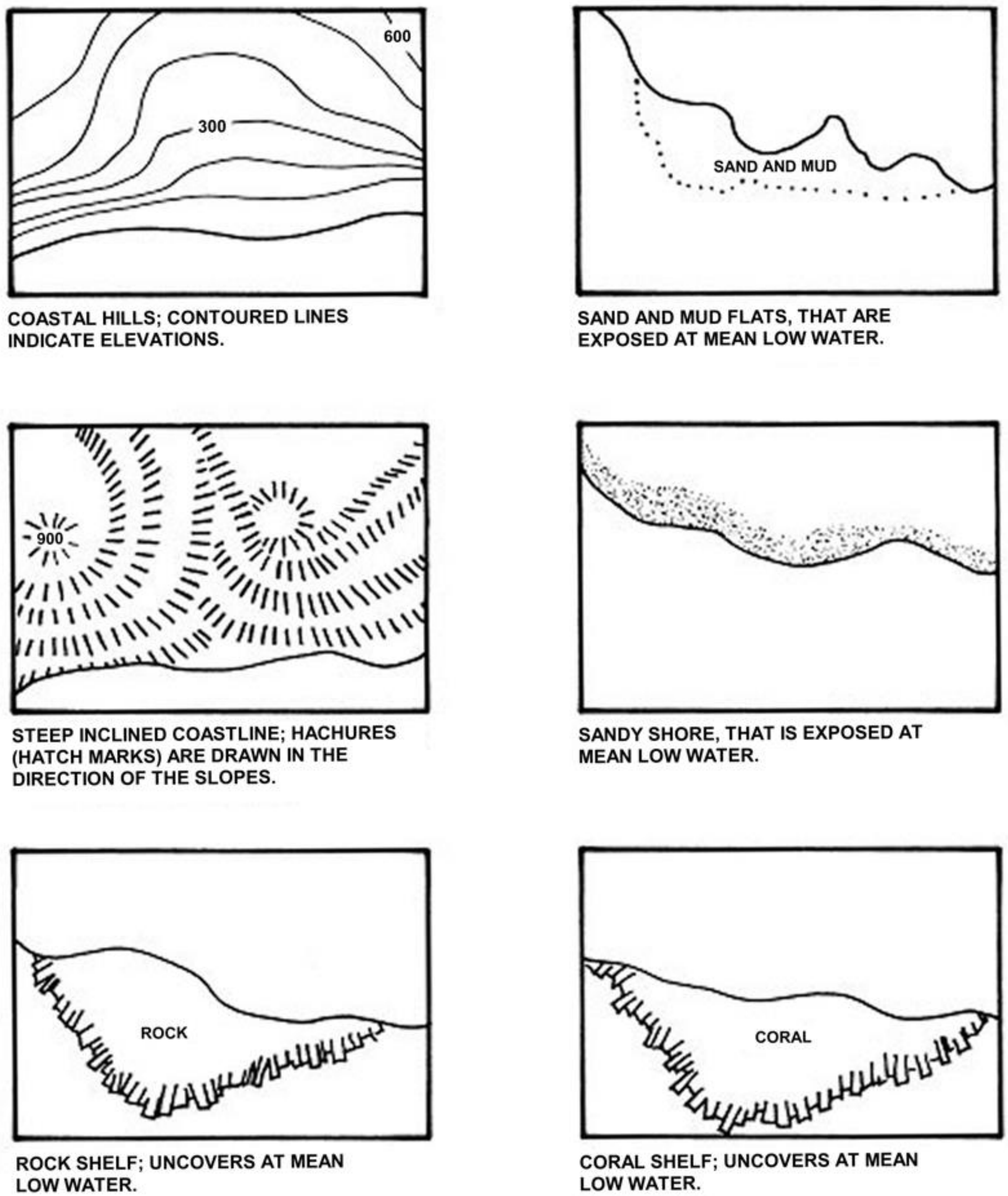

Figure 14-12
Coastlines

Accuracy of Charts

B.23. 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. Storm surge on Great Salt Lake can be so significant that depths on the south half can drop as much as a foot in pre-frontal conditions and climb as much as three feet in post frontal conditions. Also, the chart of Great Salt Lake does not give as accurate a representation of the bottom as the Bathymetric Map does.

B.24. Determining Accuracy
Compromise is something 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 soundings

B.24.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.24.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. This will be especially the case as more companies make more electronic charts of Utah's waters.

B.24.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 shores. These areas should be given wide berth.

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.

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 Division vessels except RIB's. 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 form magnetic materials aboard the vessel. 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 is divided into 360 degrees (º) and is numbered all the way around the card from 000º through 359º 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**)

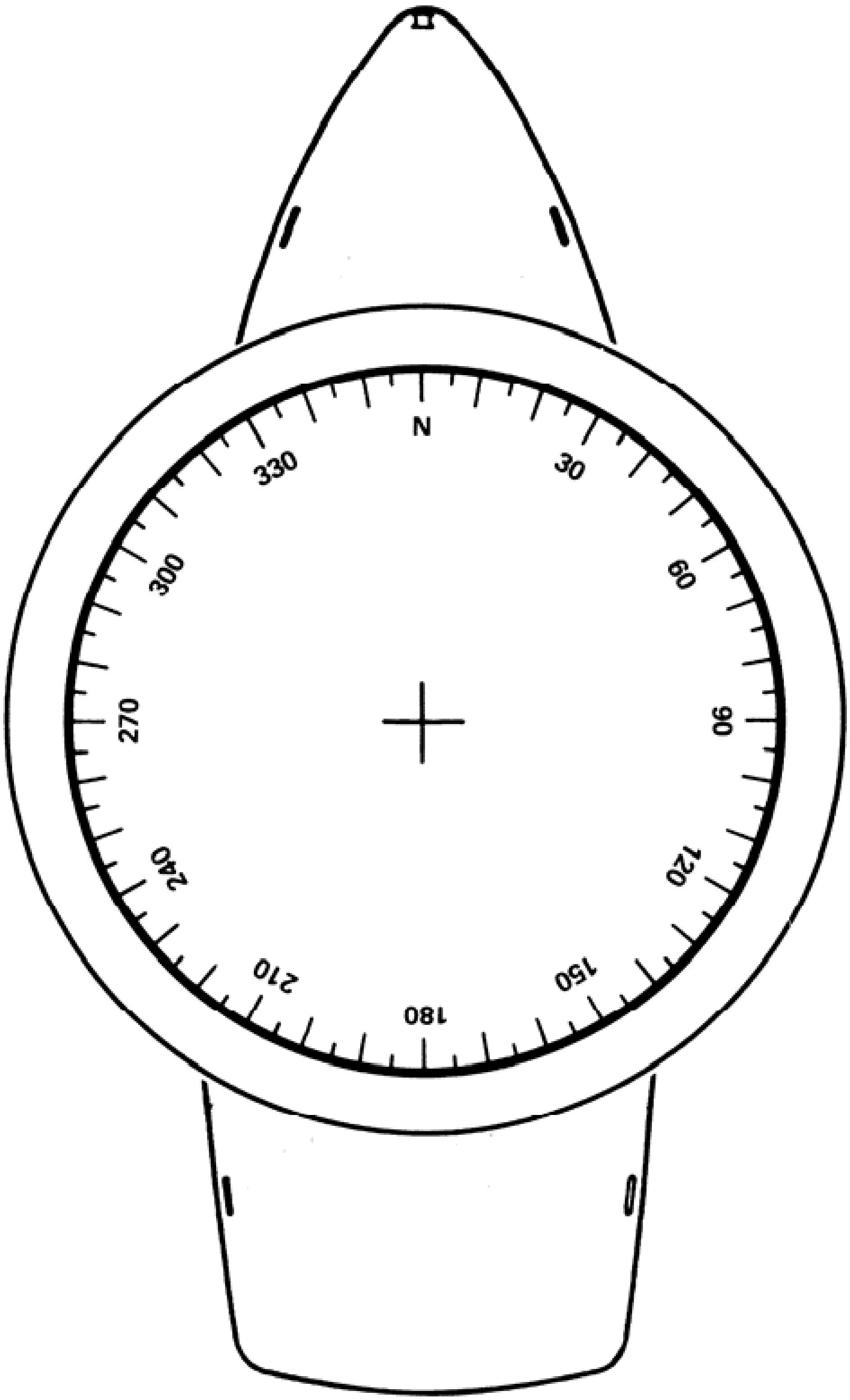

Figure 14-13
Compass Card

C.3. Lubbers 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 line of the boat's centerline and parallel to its keel (See **Figure 14-14**)

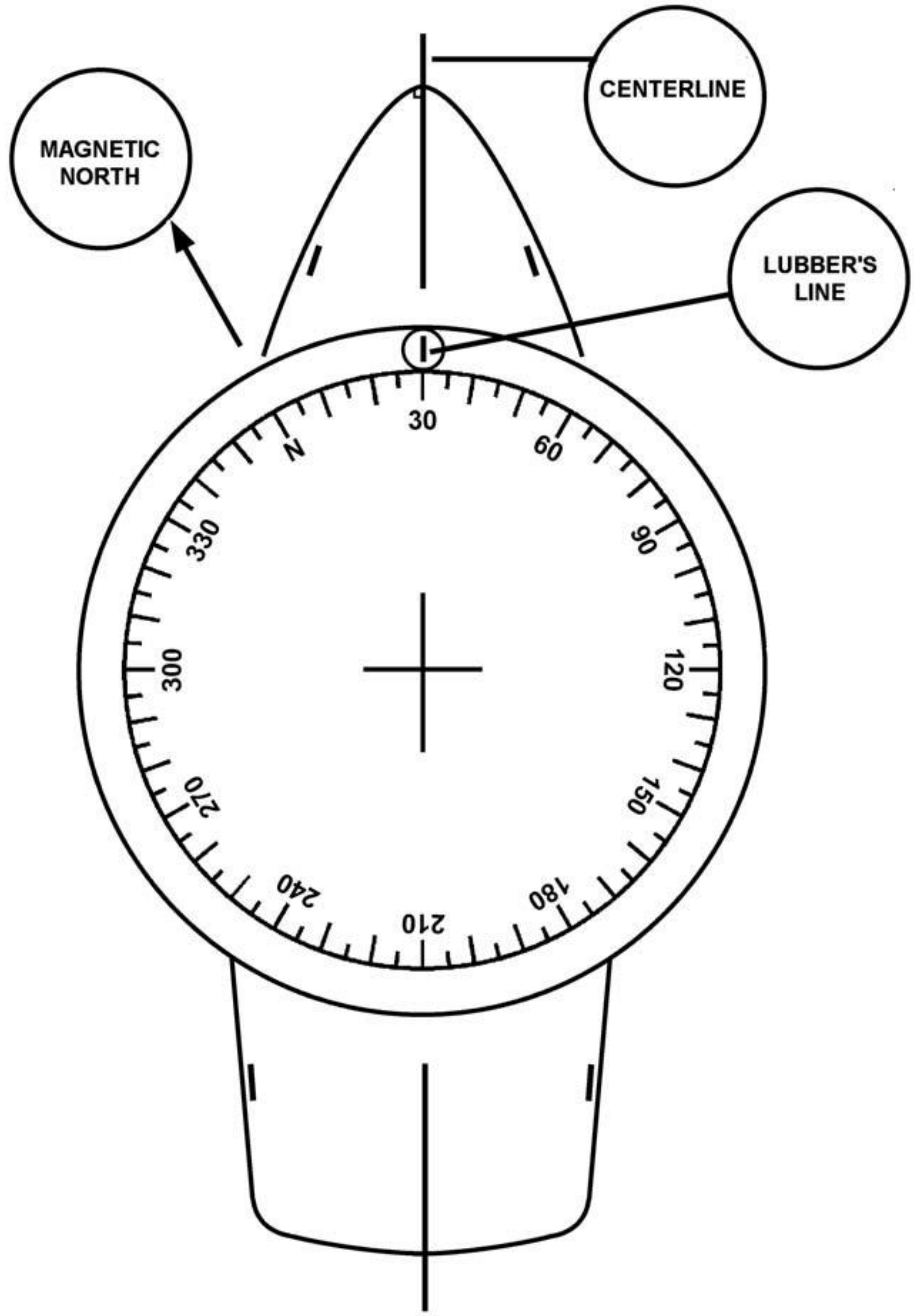

Figure 14-14
Lubber's Line and Magnetic North

Direction

C.4. Description
Direction is measured clockwise from 000º to 359º. When speaking of degrees in giving course heading, three digits should always be used, such as 270º or 057º. The heading of 360º is always referred to or spoken as 000º.

C.5. True and Magnetic
Directions measured on a chart are in true degrees or magnetic degrees as follows:

- True direction uses 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.

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

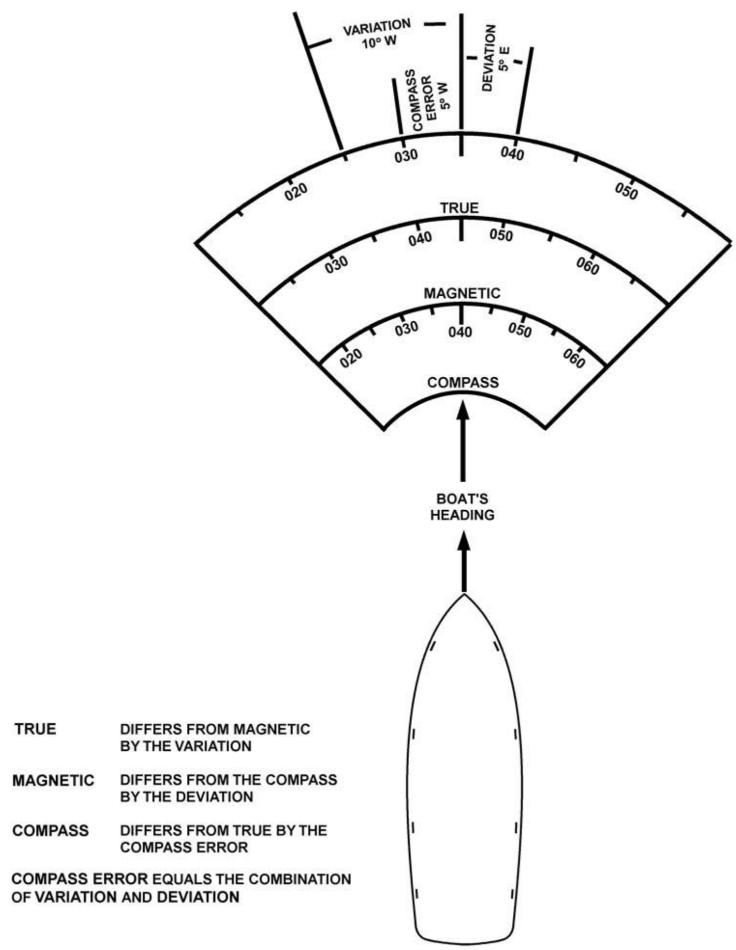

Figure 14-15
True, Magnetic, and Compass Courses

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, which 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 procedures for determining the amount of annual increase or decrease of variation:

Step	Procedure
1	Locate the compass rose nearest the 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 by the annual increase or decrease
6	Add or subtract the amount form 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 defection 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
It is recommended that VO's 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 should be completed annually, and after addition or deletion of equipment or structural alterations that would affect the magnetic characteristics of the boat.

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 15º 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 a Bearing of a Range
When obtaining the deviation, a position that will not interfere with normal boating traffic should be selected. To find the magnetic bearing of a 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 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 180º 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 272º. The bearing of the range read off the magnetic compass © is 274º. (See **Figure 14-16**)

Answer: 2ºW is the deviation.

The amount of deviation is the difference between C and M; this is 2º. 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 errors; and westerly errors.

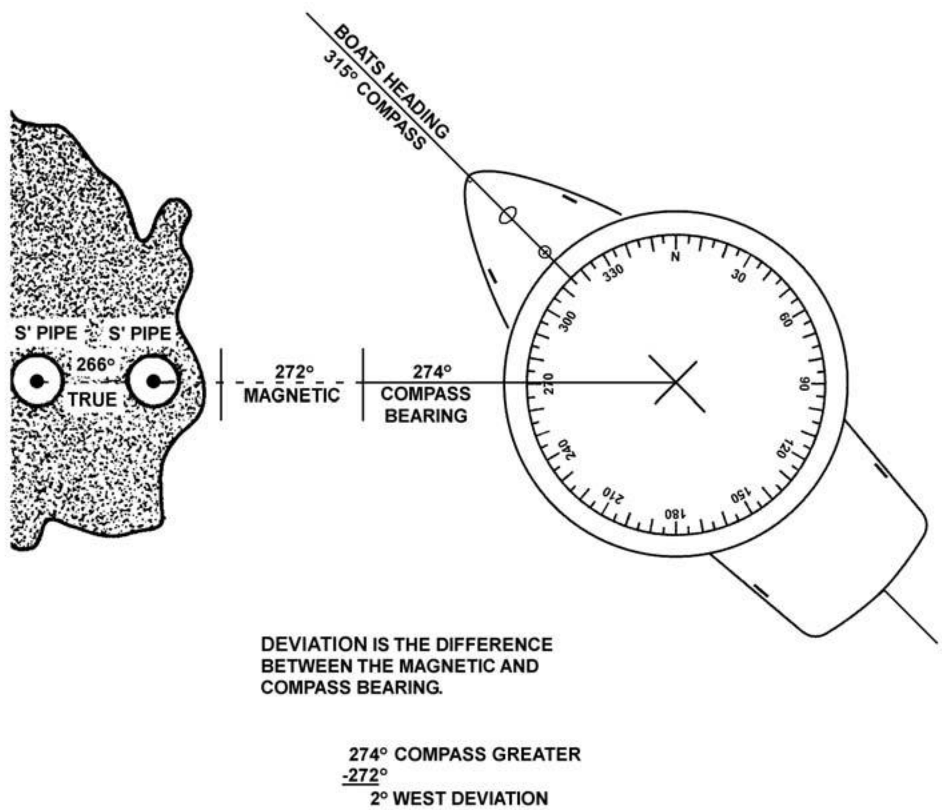

Figure 14-16

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 15º in the first column
2	Enter the range's magnetic bearing as measured on the chart (272º) 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 000º. Steer a steady heading and cross the range
4	Observe the compass bearing of the range at the instant the range is crossed. Use 266º for the exercise. Enter the range's bearing by compass in the second column on the same line as the boat's compass heading of 000º
5	Come around to the boat's compass heading of 030º. Steer a steady heading and cross the range.
6	Observe the compass bearing of the range at the instant the range is crossed. Use 265º 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 015º
7	Come around to the boat's compass heading of 030º. Steer a steady heading and cross the range.
8	Observe the compass bearing of the range at the instant the range is crossed. Use 265º 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 030º
9	Continue changing course by 15º 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
000º	266º	272º	6º E	006º
015º	265º	272º	7º E	022º
030º	265º	272º	7º E	037º
045º	267º	272º	5º E	050º
060º	270º	272º	2º E	062º
075º	269º	272º	3º E	078º
090º	271º	272º	1º E	091º

105º	272º	272º	0º	105º
120º	267º	272º	5º E	125º
135º	273º	272º	1ºW	134º
150º	268º	272º	4º E	154º
165º	275º	272º	3º W	162º
180º	274º	272º	2º W	178º
195º	277º	272º	5º W	190º
210º	272º	272º	6º W	204º
225º	279º	272º	7º W	218º
240º	275º	272º	3º W	237º
255º	279º	272º	7º W	248º
270º	279º	272º	7º W	263º
285º	277º	272º	5º W	280º
300º	270º	272º	2º E	302º
315º	274º	272º	2º W	313º
330º	269º	272º	3º E	333º
345º	266º	272º	6º E	351º

11	Prepare a smooth deviation table to be placed next to the boat's compass. The table must give a deviation for a magnetic course so the table may be used to correct courses. (See **Table 14-3**)

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
000º	6º E	006º
015º	7º E	022º
030º	7º E	037º
045º	5º E	050º
060º	2º E	062º
075º	3º E	078º
090º	1º E	091º
105º	0º	105º
120º	5º E	125º
135º	1º W	134º
150º	4º E	154º
165º	3º W	162º
180º	2º W	178º
195º	5º W	190º

210º	6º W	204º
225º	7º W	218º
240º	3º W	237º
255º	7º W	248º
270º	7º W	263º
285º	5º W	280º
300º	2º E	302º
315º	2º W	313º
330º	3º E	333º
345º	6º E	351º

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 15º apart. However, this is not necessary as long as a minimum of ten objects/bearings, evenly separated through the entire 360º, 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	013º	014.0º	1.0º W
Stack	040º	041.5º	1.5º W
R Tower	060º	062.0º	2.0º W
Lt. #5	112º	115.0º	3.0º W
Left Tangent Pier	160º	163.0º	3.0º W
Water Tower	200º	201.0º	1.0º W
Right Tangent Jetty	235º	235.0º	0.0º W
Light House	272º	271.0º	1.0º E
Flag Pole	310º	309.0º	1.0º E
Lookout Tower	345º	344.5º	0.5º 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**.

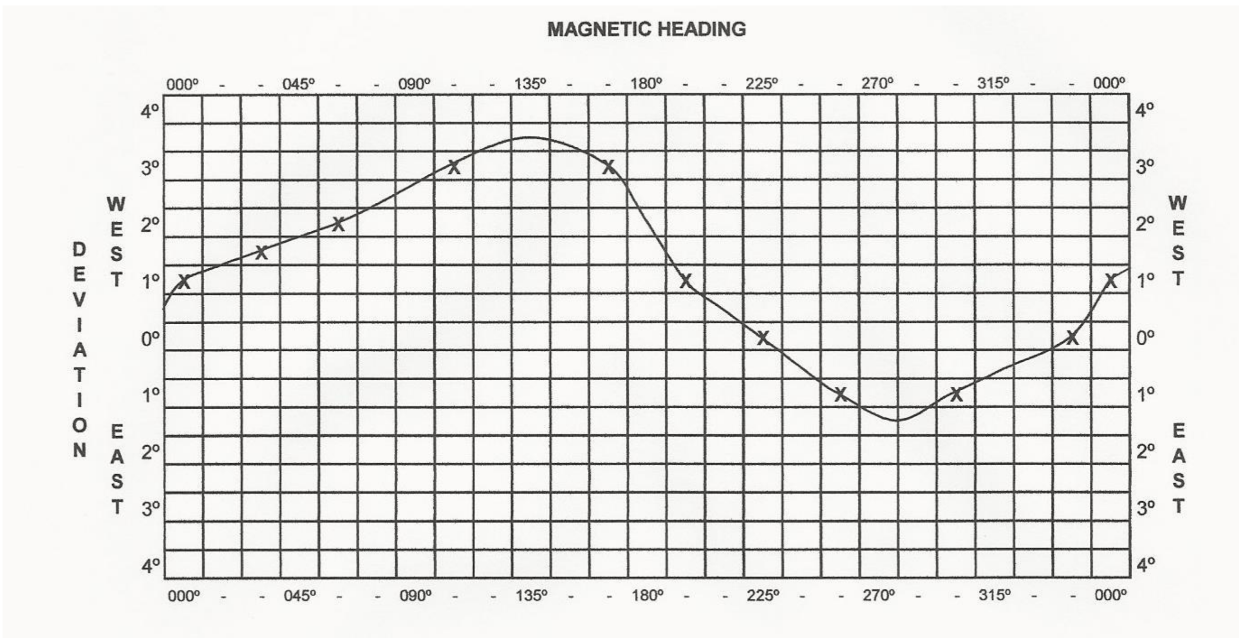

Figure 14-17
Example Deviation Curve

C.15.c. Determination
Deviation should be extracted from the deviation curve for any heading

NOTE: The graph is divided vertically in 15º 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 4º depicted. However, do not tolerate deviations of more than 3º. 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 (Ops) 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	015º/195º	014º/195º	1º E/0º
R. Tower – Tank	103º/293º	104º/282º	1º W/1º E
Flag Pole – Lt. #5	176º/356º	177º/282º	1º W/.5º E
Stack – Left Tangent Pier	273º/093º	272º/094º	1º E/1º W
End Channel Range	333º/153º	332º154.5º	1º E/1.5º W

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**)

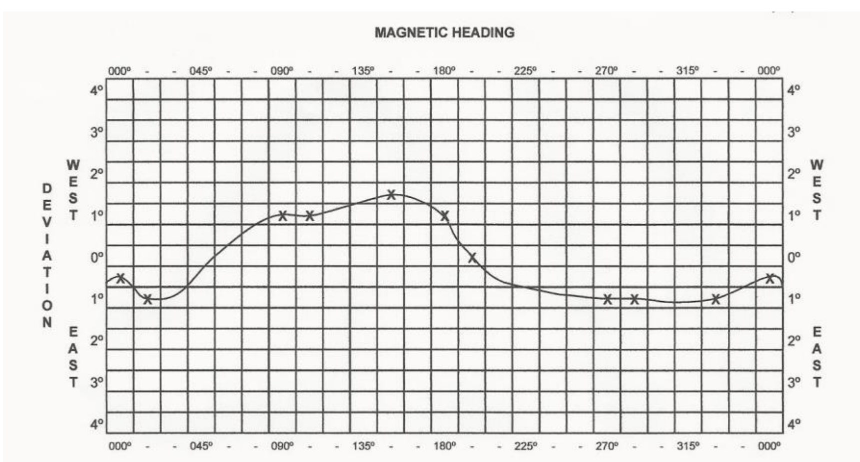

Figure 14-18
Example Deviation Curve

Compass Adjustment

C.17. Description
The following are 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 of 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 of the observed error.
3	Steer a course in an easterly direction. Adjust the E/W compensating magnet to remove half of 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 error to correct course or direction:

- Take the compass course.
- Apply deviation to obtain the magnetic course.
- Apply the 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 127º, variation from the compass rose is 4º W, and the deviation from the boat's deviation table is 5º E. Then, the true course (T) is obtained as follows:

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

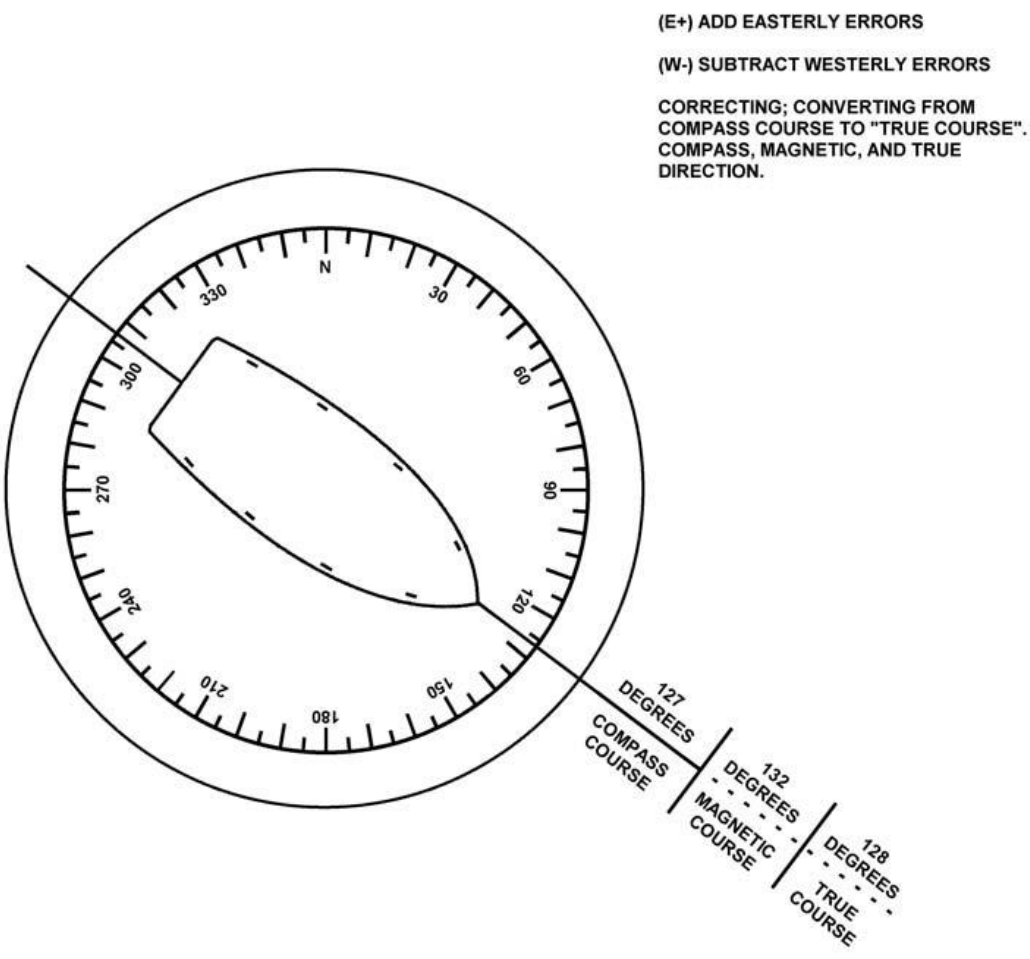

Figure 14-19
Applying Compass Error, Correcting

C.20. Converting True Course to Compass Course
Converting from true (T) direction to magnetic (M), or going form 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).

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 221º T, variation is 9º E and deviation is 2º W. Then, obtain the compass course (C) is obtained as follows:

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

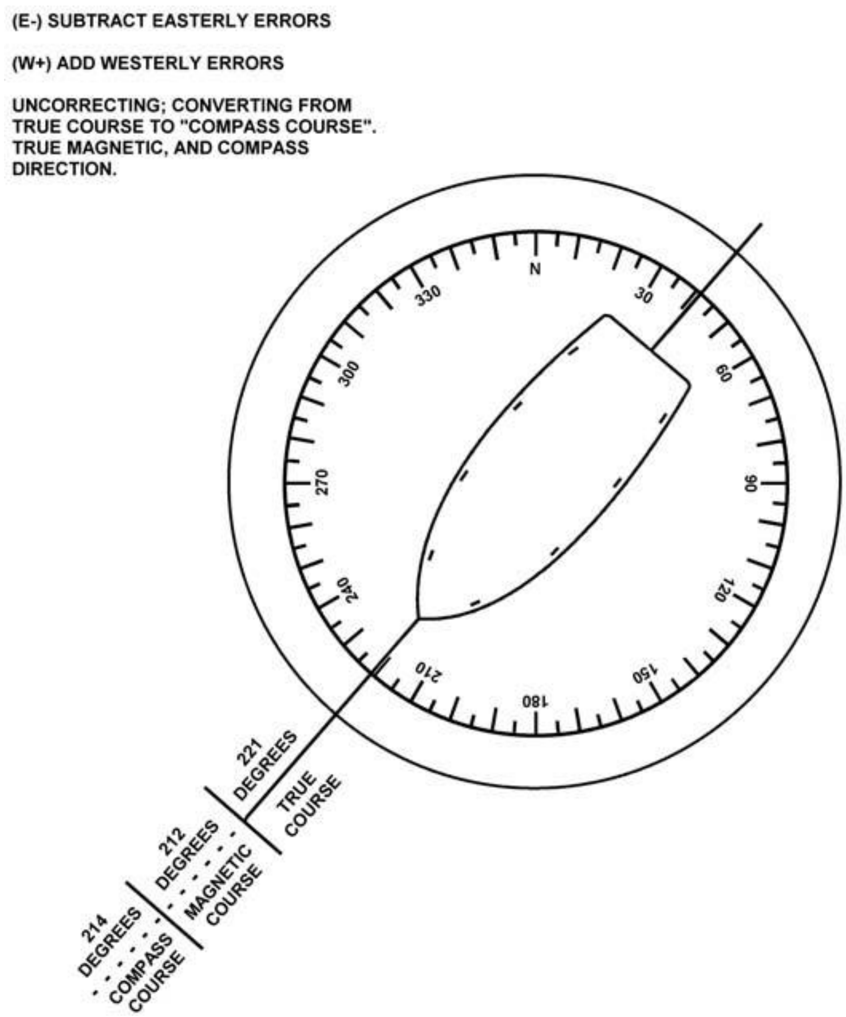

Figure 14-20
Applying Compass Error, Uncorrecting

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 VO 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**)

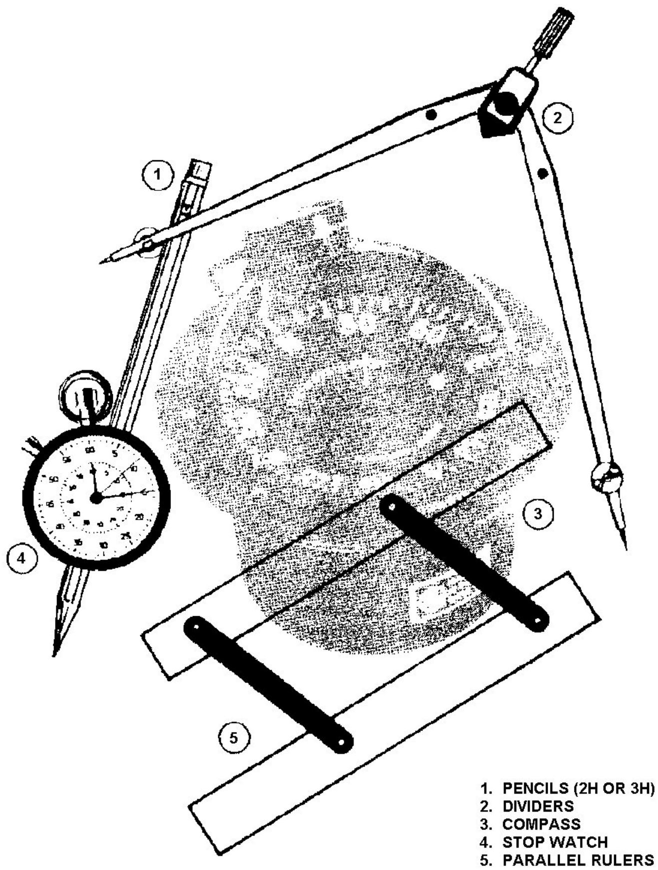

Figure 14-21
Basic Piloting Tools

D.2. Compass
For a boat, the magnetic compass is used:

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

A mark called a "lubber's line" is fixed to the inner surface of the compass housing. Similar marks, called 90º lubber's lines, are usually mounted at 90º intervals around the compass card and are used in determining when an object is bearing directly abeam or astern. Centered in 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 liens 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 semicircular 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 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 such as the Deep Channel buoys at Great Salt Lake. 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 **Table 14-4**)

Table 14-4
Sample Speed vs. RPMs Conversion

Speed, Kts. Calm Water	Approx. RPM	Fuel Gas/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
12.5	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 chart.

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. The salinity of Great Salt Lake can affect accuracy. Depth sounder accuracy is affected by salinity. In high salinity, the depth will indicate shallower that it is.

D.12.a. Transducer
The transducer is part of the depth sounder that transmits sound wave. The transducer is usually mounted through the hull and sticks out very 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.

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 depending on the instrument. But on most Division vessels it is a video display screen: The display is similar to a small television set with brightness on the bottom of the screen indicating the sea floor.

D.12.c. Bottom Conditions
With practice and experience, the bottom characteristics and conditions can be determined. Video display sounders may be generally interpreted as:

- Sharp, clear lines – hard bottom
- Broad, fuzzy lines – soft, muddy bottom

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 or feet and a lead weight of 7 to 14 pounds, hollowed at one end in which a 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 speeds.

NOTE: Always keep a lead line neatly stowed and ready for use in the event the depth sounder becomes inoperable. Lead lines should be wetted and stretched prior to marking. Lines should be checked periodically for accuracy of markings.

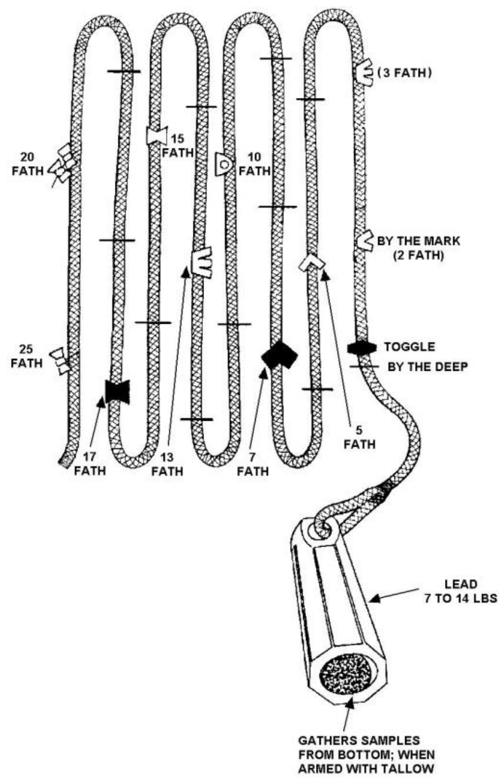

Figure 14-22
Handheld Lead Line

D.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 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.

Distance, Speed, and Time

D.15. 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.16. Expressing Distance, Speed, and Time
Units of measurement are:

- Distance in nautical miles (NM) (Great Salt Lake) or statute miles.
- 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.17. 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=SxT/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.17.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=SxT/60
2	D=10x20/60
3	D=200/60 D=3.3 NM

D.17.b. Example #2
At a speed of 10 knots, it took the boat 3 hours and 45 minutes to go from the Great Salt Lake Marina to the south end of Fremont Island. What is the distance to Fremont Island?

Step	Procedure
1	Convert the hours to minutes for solving the equation. First, multiply the 3 hours by 60 (60 minutes in an hour), add the remaining 45 minutes, that is: 3x60+45=225 minutes.

2	Write the equation. D=SxT/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.17.c. Example #3

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

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

D.17.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 2400hrs.

Step	Procedure
1	Calculate the time interval between 2030 and 2400. To determine the time interval, convert time to hours and minutes then subtract. 23 hours 60 minutes (2400) -<u>20 hours 30 minutes (2030)</u> 3 hours 30 minutes
2	Distance – speed – time equations are computed in minutes. Convert the 3 hours to minutes, add the remaining 30 minutes. 3x60=180 minutes <u>+30 minutes</u> 210 minutes
3	Write the equation. S=60D/T
4	Substitute information for the appropriate letter and calculate the speed. S=60D/T S=60x30 NM/210 minutes
5	S=1800/210 S=8.6 knots

D.17.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
2	T=60x12/15
3	T=720/15
4	T=48 minutes

D.18. 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 values on their opposite scales, the third is read from the appropriate index. See **Figure 14-23.**

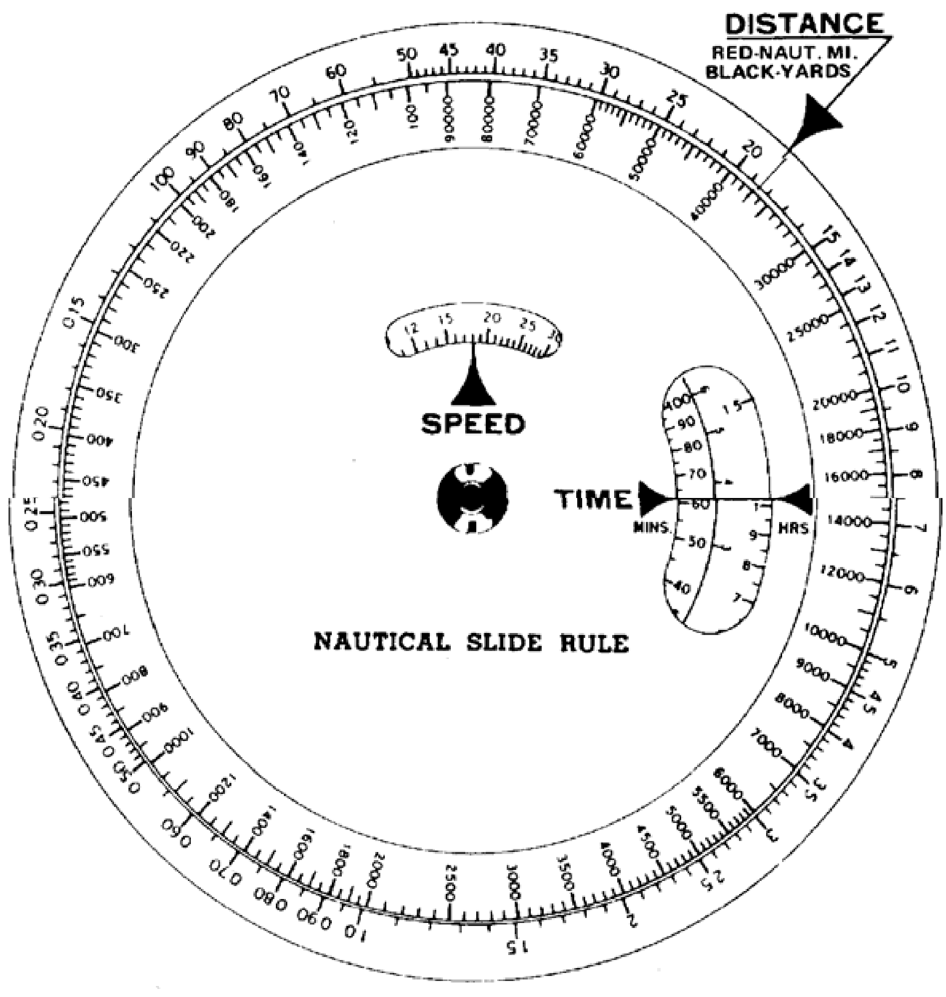

Figure 14-23
Nautical Slide Rule

Fuel Consumption

D.19. 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 the marina (or a refueling site). Many lakes the Division patrols in Utah are very small and fuel consumption is not a major issue. But this is not the case on some of the bigger lakes such as Utah Lake, Bear Lake, and especially Great Salt Lake.

D.20 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 (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 TxGPH=TFC
16	Calculate TFC for other selected RPM settings. (Change RPM setting and repeat step 6 through 15)

Luckily Division vessels located on the larger lakes of Utah have instruments that will calculate and display the GPH rate. It is important to pay close attention to GPH in mission planning so that enough fuel will be on the vessel to complete the sortie.

Terms Used in Piloting

D.21. 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 000º through 359º 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 000º through 359º. For marine navigation, the term applies to the direction to be steered. The heading of 360º is always referred to or spoken as 000º.
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	ETA	The ETA is the best estimate of predicted arrival time at a known

of arrival		destination.
Fix		A fix is a position determined form 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.
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. There are 1.51 statute miles in a nautical mile or 0.869 nautical miles in a statute mile.
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.22. 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 068º M **Figure 14-24** shows a course of 068º M between two buoys as measured by parallel rulers on a chart's compass rose.

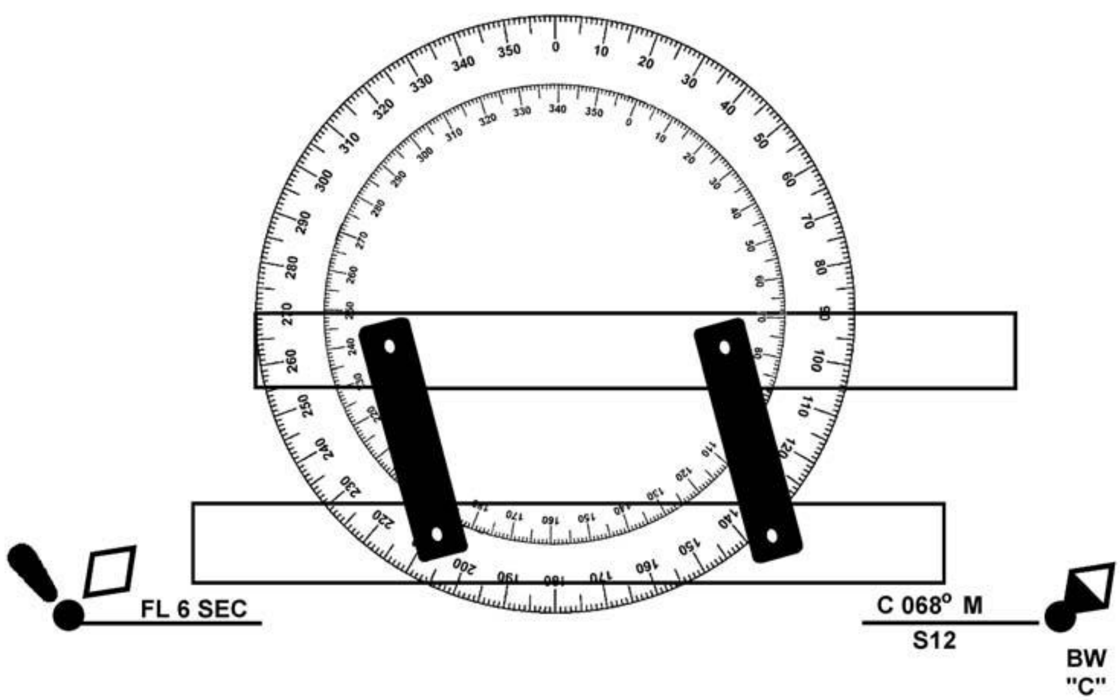

Figure 14-24
068º M Course Between Two Buoys

Dead Reckoning (DR)

D.23. Description
Dead reckoning (DRO 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.24. 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.24.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.24.b. Distance Traveled
Distance traveled is obtained by multiplying speed (in knots) by the time underway (in minutes)

D=SxT/60

D.25. 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.25. 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 134º to get the intended destination at the 1200 DR plot. Then, the 1200 fix is plotted and the new DR plot (C 051º M and S 16) is started.

Step	Procedure
1	Plot the course line, label it clearly and neatly.

	• Course: Above the course line, placed 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 form 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 100º, zeros are prefixed to the number, for example, 009º

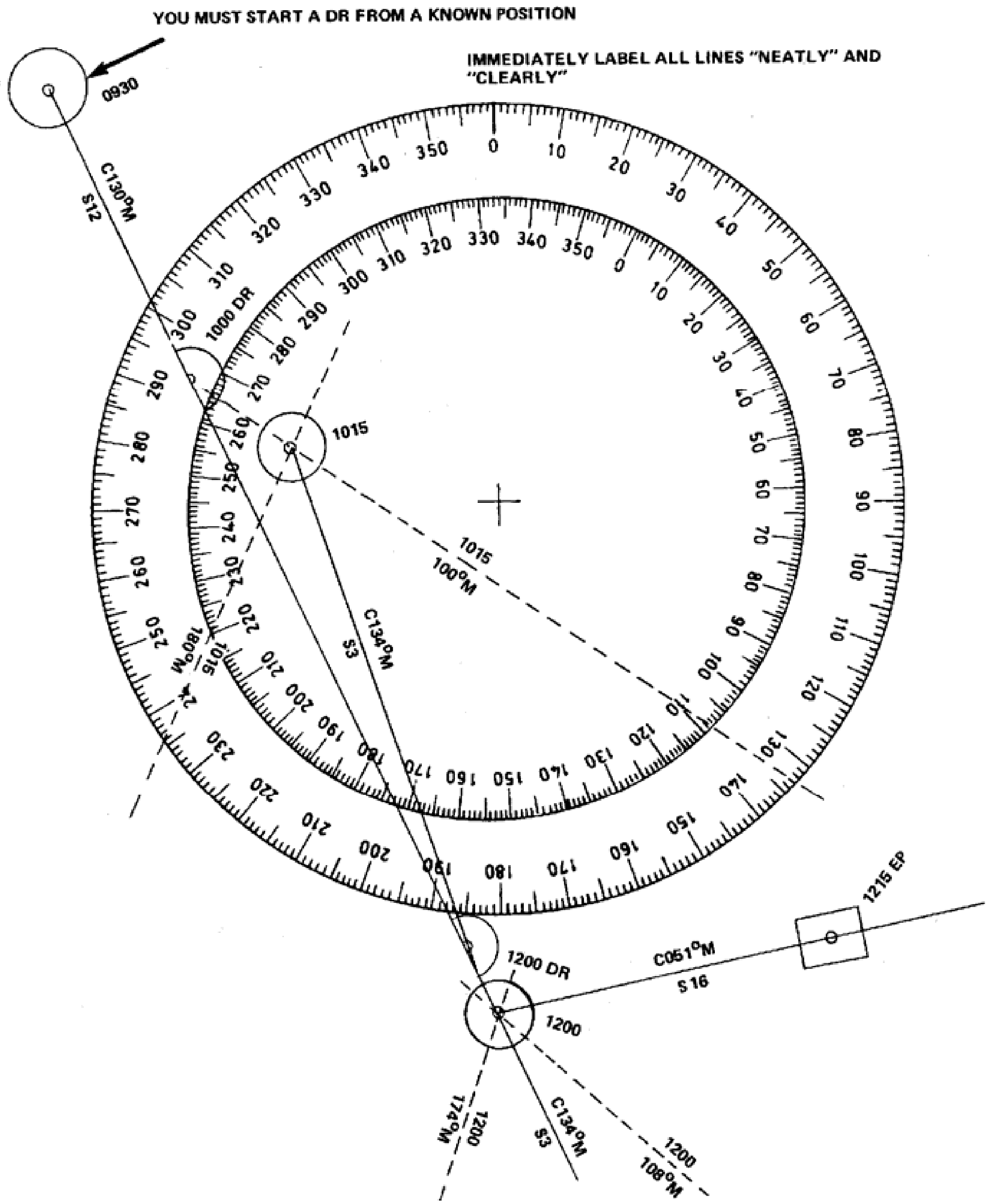

Figure 14-25
Labeling a DR Plot

Basic Elements of Piloting

D.26. Description
Direction, distance, and time are the basic elements of piloting. With these elements, an accurate navigation plot can be maintained.

D.27. 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 form 000º through 360º. The heading of 360º is always referred to or spoken 000º.

D.27.a. Reference Point/Reference Direction
The usual reference point is 000º. The relationship 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.28. 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 designated 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.28.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 navigation. When using a compass to take bearings, the object should be sighted across the compass.

D.29. Compass Bearings
In the section on compass and compass error, how to convert form 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.29.a. Obtaining Compass Bearing

The vessel is on a heading of 263º M. The compass bearing to Kays Pt. Light is 060º. Deviation from the deviation table on the boat's heading of 263º M is 7º 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 060º magnetic. Write down the correction formula in a vertical line C=060º compass bearing of light. D=7º 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 7º W deviation, the westerly error, from the compass bearing (060º) to obtain magnetic bearing (053º). M=053º

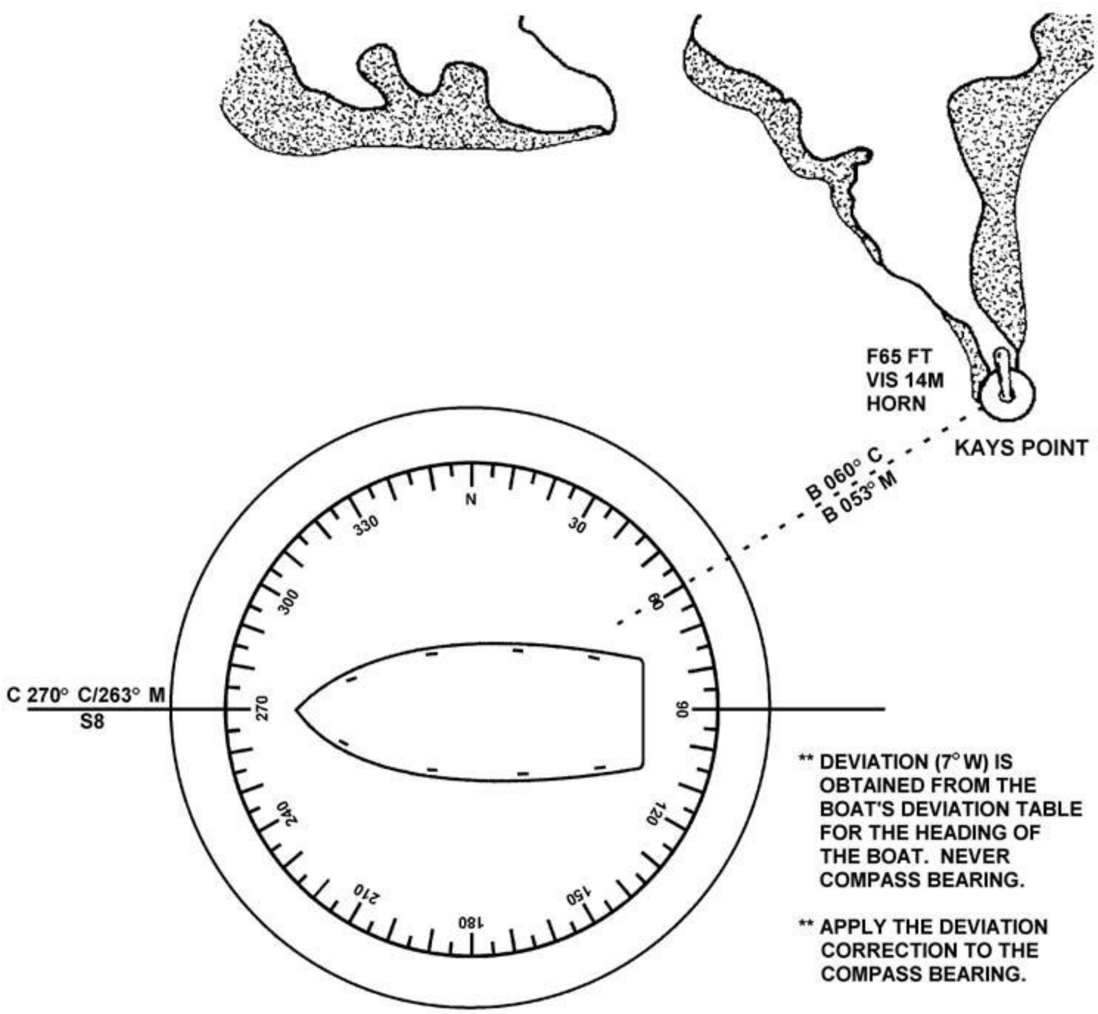

Figure 14-26
Converting Compass Bearing to Magnetic

B.30. Relative Bearing

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

B.30.a. Converting to Magnetic Bearing

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 360º, subtract 360º to obtain the magnetic bearing.

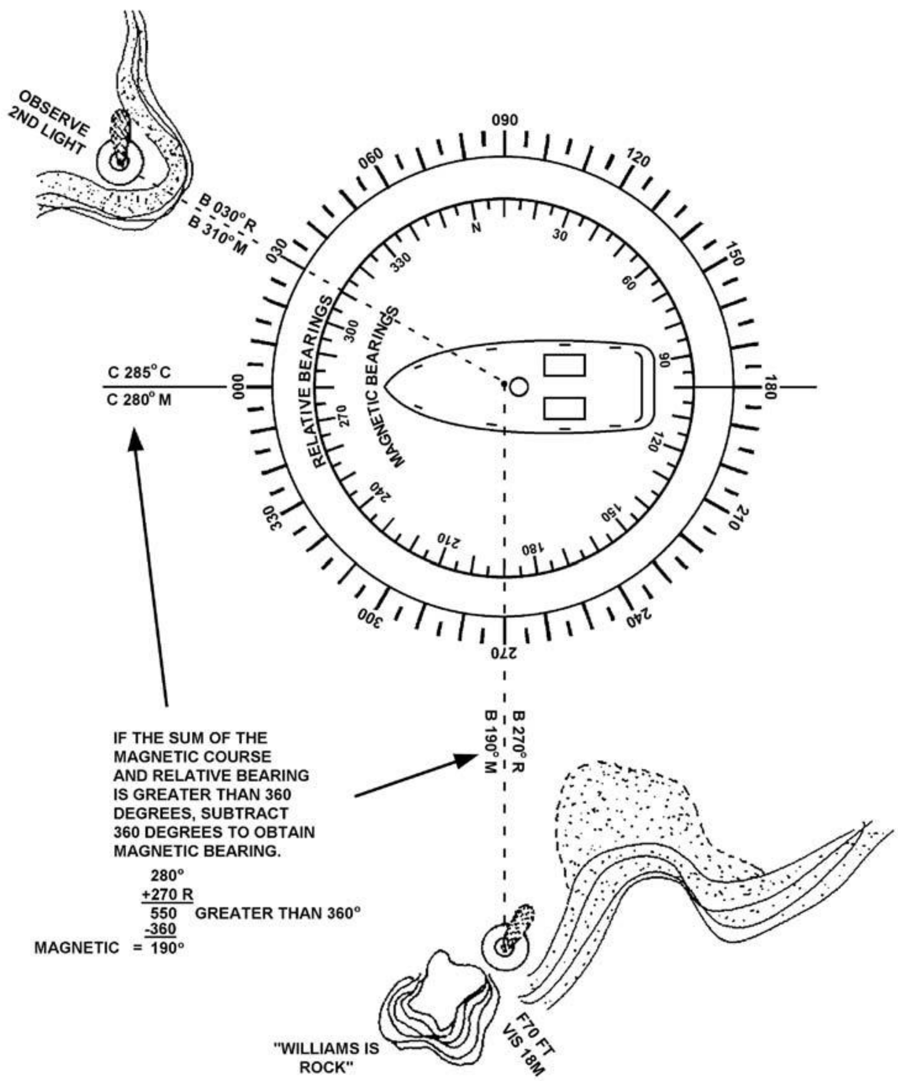

Figure 14-27
Converting Relative Bearings to Magnetic; Sums Greater than 360º

D.31. 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.31.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.31.b. Statute Mile
The statute mile is used mainly on land, but it is also used in piloting inland bodies of water such as Deer Creek.

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

D.31.c. Measuring Distance
Measure 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 the 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.

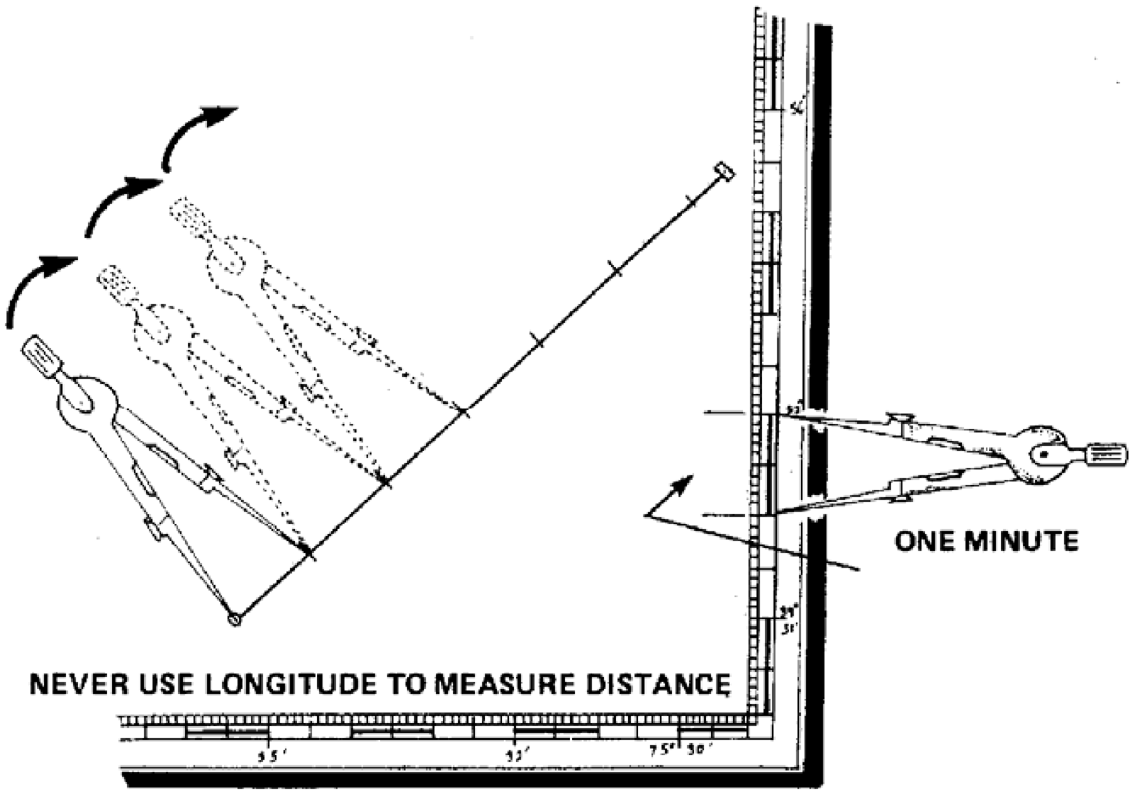

Figure 14-28
Measuring Distance, Latitude

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**)

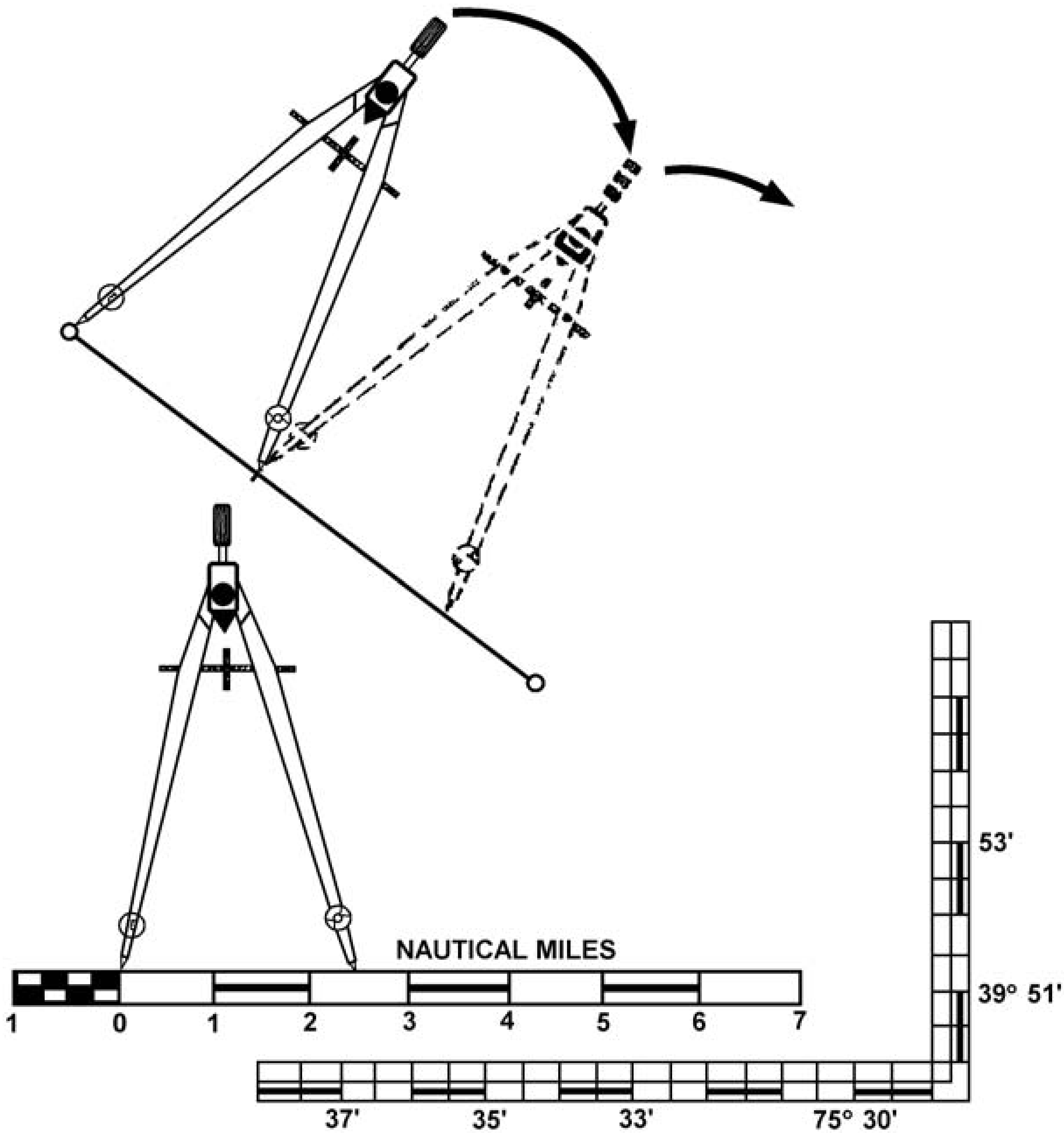

Figure 14-29
Measuring Distance, Nautical Miles

D.32. 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.33. 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.34. 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.34.a. Example
The boat is on a heading of 192º compass. At 1015, a bearing of 040º relative on a water tower is observed. Deviation (from the boat's deviation table) on the boat's heading is 3º

Step	Procedure
1	Correct the compass heading of 192º to the magnetic heading. Write down the correction formula in a vertical line. C=192º D=3º W (+ E, - W when correcting) M=189º 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, 3º W deviation from the compass heading (192º) to obtain the magnetic heading of (189º).
3	Add the relative bearing (040º) to the magnetic heading (189º) to obtain the magnetic bearing of (229º). 189º (M) <u>+40º</u> 229º magnetic bearing
4	Place the parallel rulers with their edge passing through the crossed lines at the center of the compass rose and the 229º 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 189º 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 229º

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.

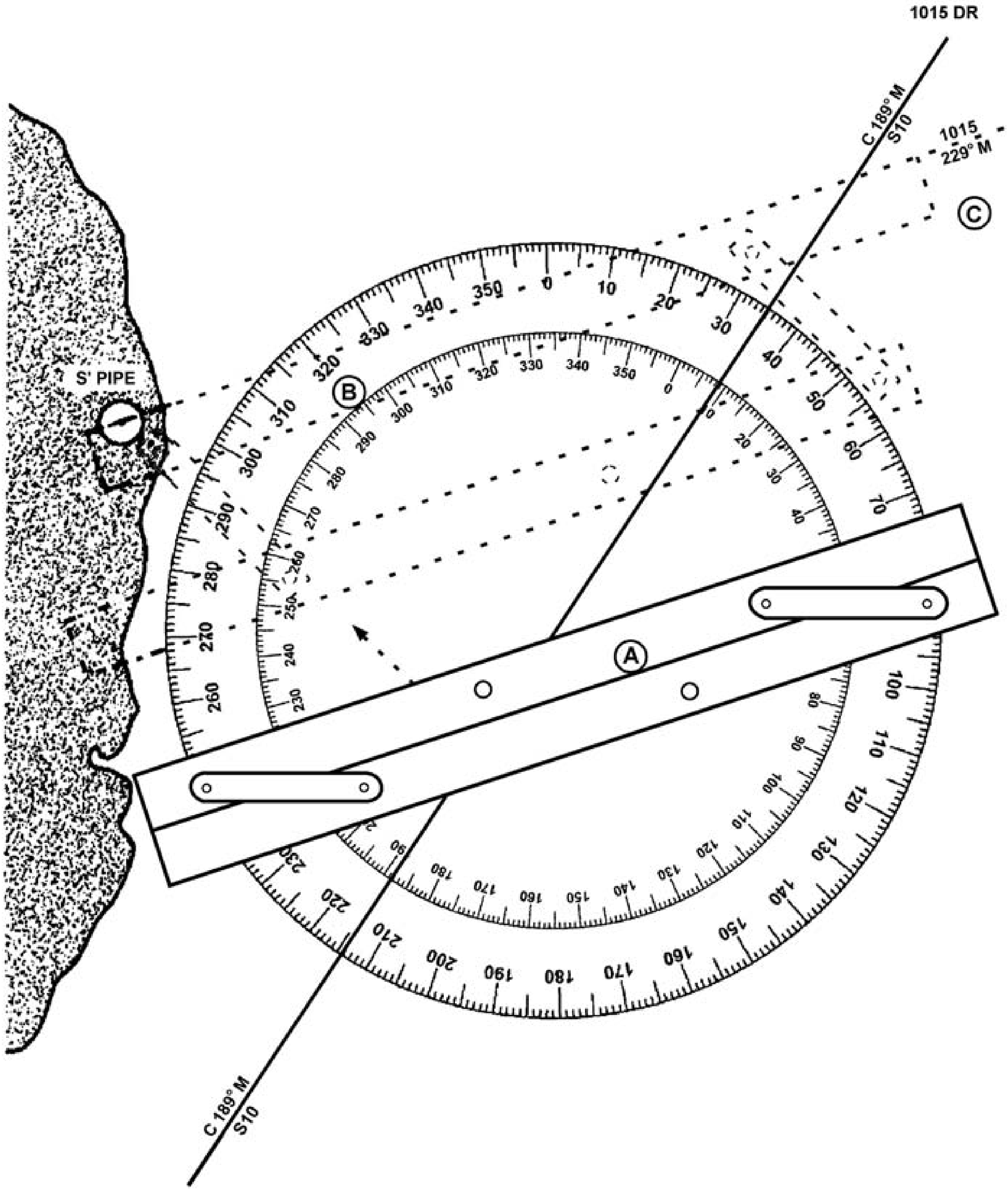

Figure 14-30
Plotting Bearings

Line of Position (LOP)

D.35. Description
The position of a boat can be determined by many methods of piloting. The LOP is common on 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 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 for 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**)

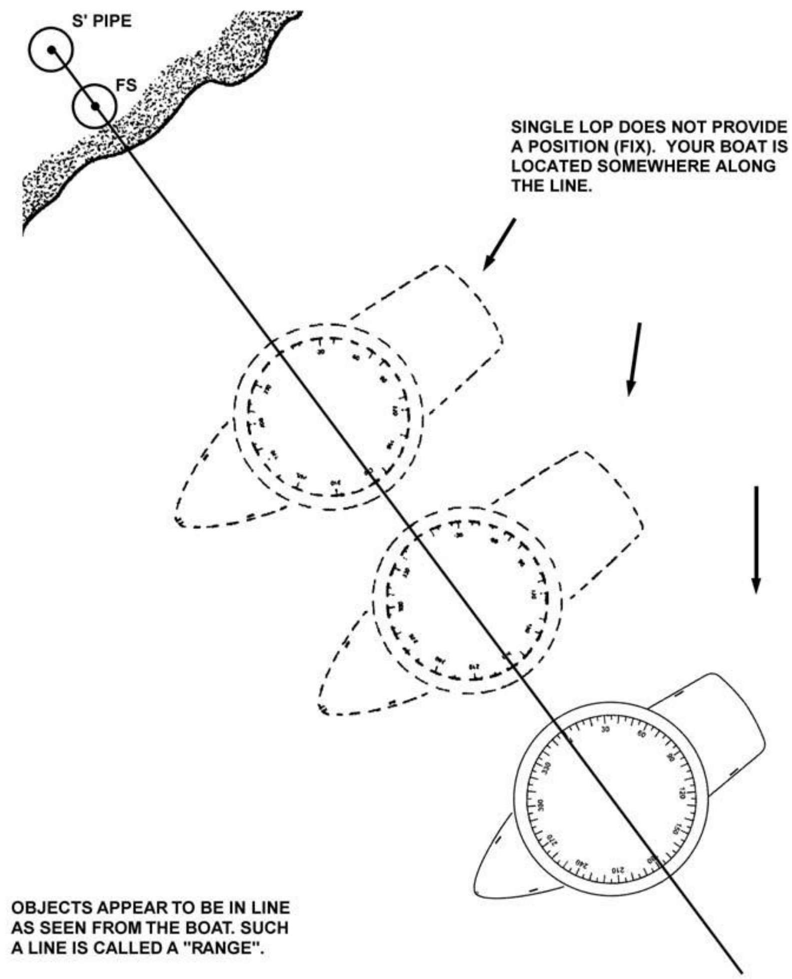

Figure 14-31
Visual Range LOP

D.36. 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.36.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 90º difference in the lines. Serious error in position could result if a difference of less than 60º or more than 120º between the two lines exist. Therefore, two LOPs should intersect at right angles or near right angles wherever possible.

D.36.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 60º, but not more than 120º.

D.37. 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.37.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.37.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 that 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.37.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.

D.37.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 liens 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 000º M is steered to stay in safe water.

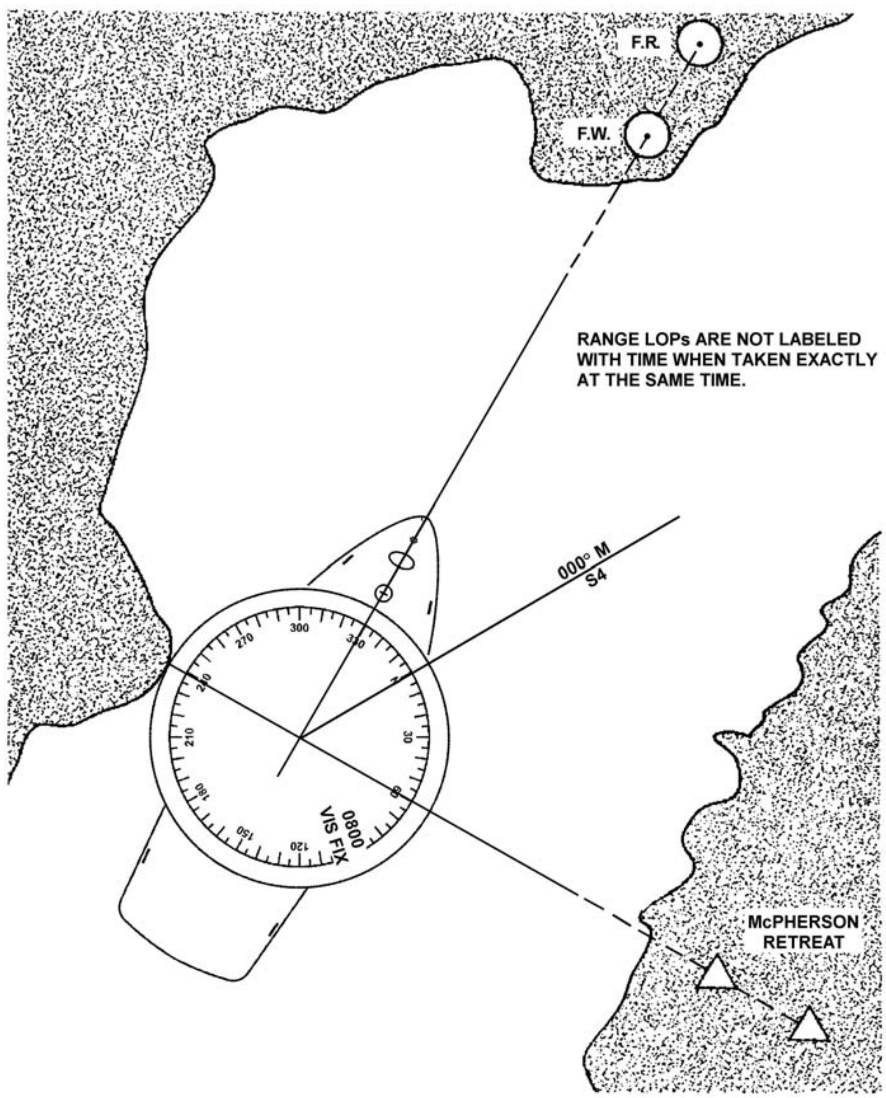

Figure 14-33
Fix by Two Ranges

D.37.d. Running Fix (R RIX)

Often it is impossible to obtain two bearing observations within a close enough interval of tie 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.

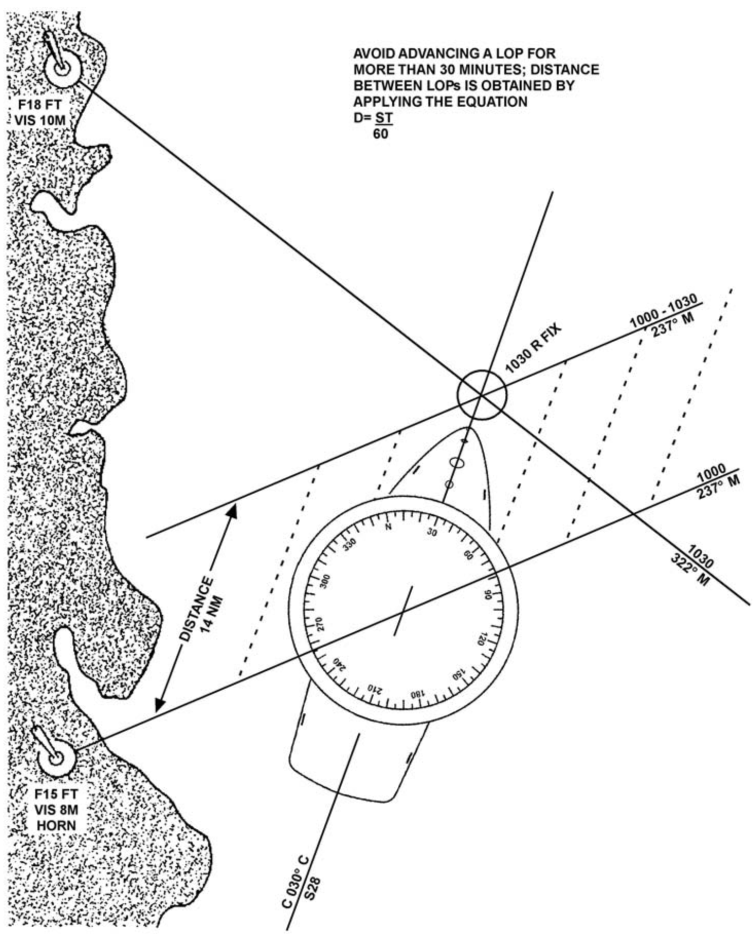

Figure 14-34
Running Fix

D.37.e. Danger Bearing

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 objects 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 form the danger area to the leading object is the danger bearing. **Figure 14-35** indicates that 311º M is a danger bearing
2	Label the danger bearing with the abbreviation 'DB" followed by the direction (DB 311º M). Frequent visual bearings should be taken. If the bearings are greater than the danger bearing, the boat is in safe water.

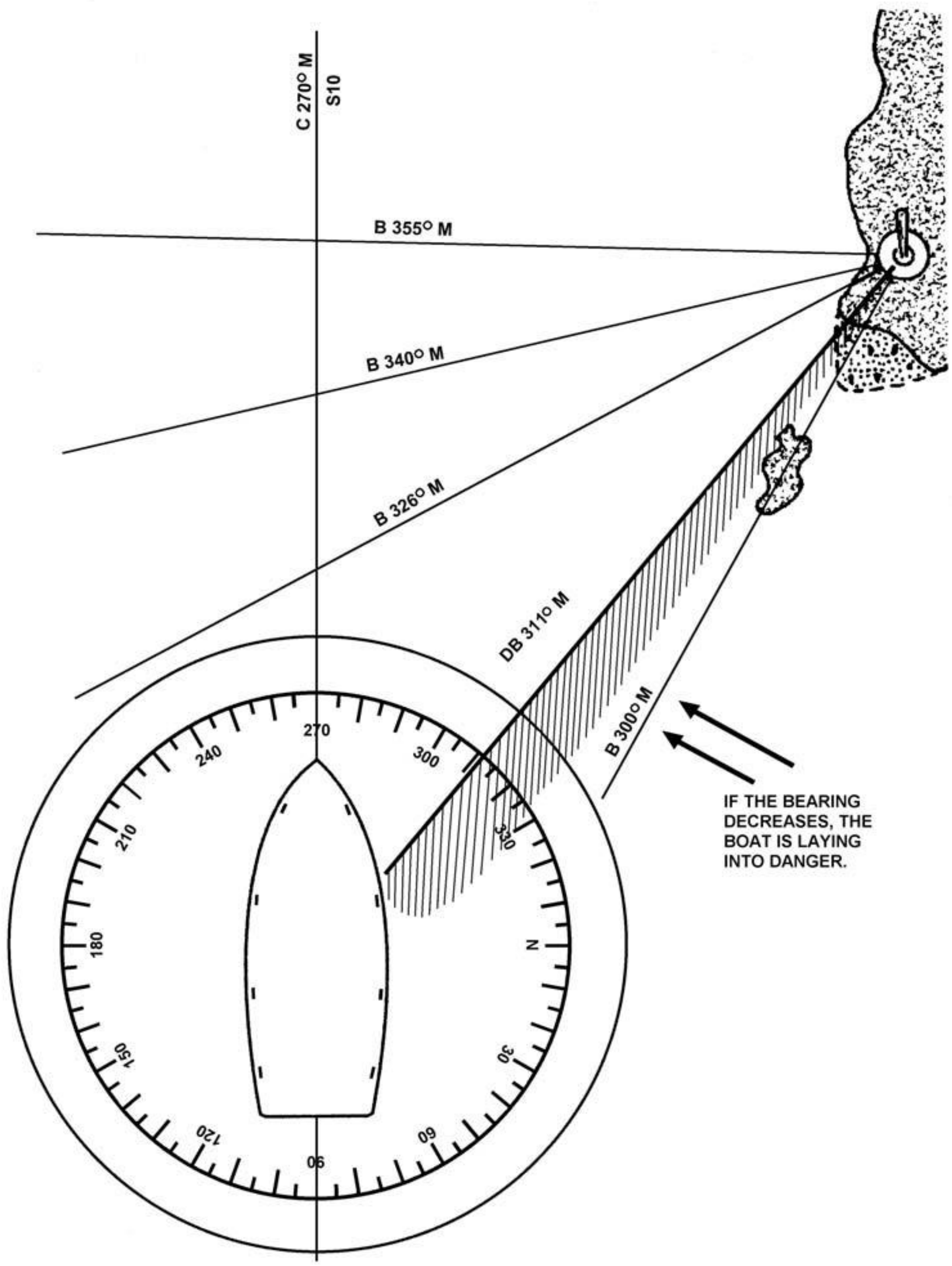

Figure 14-35
Danger Bearings

When a bearing is observed to be less than the danger bearing, such as 300º 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 on **Figure 14-35**.

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

The VO 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.

Radar

D.38. 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 VO's experience with radar operation. It also depends on the VO's knowledge of the local operating area and is not a substitute for an alert visual lookout.

D.39. Basic Principle
A radar radiates radio waves form its antenna (Raydome) 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).

D.40. Advantages
Advantages of radar include:

- Can be used at night and in low visibility conditions.
- Obtains a fix by distance rangers 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.41. Disadvantages
The disadvantages of radar include:

- Mechanical and electrical failure.
- Minimum and maximum range limitations.
- They eat up a lot of energy from a battery.

D.41.a. Minimum Range
The minimum range is primarily established by the radio wave pulse length and recover 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.41.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. See **Figure 14-36**

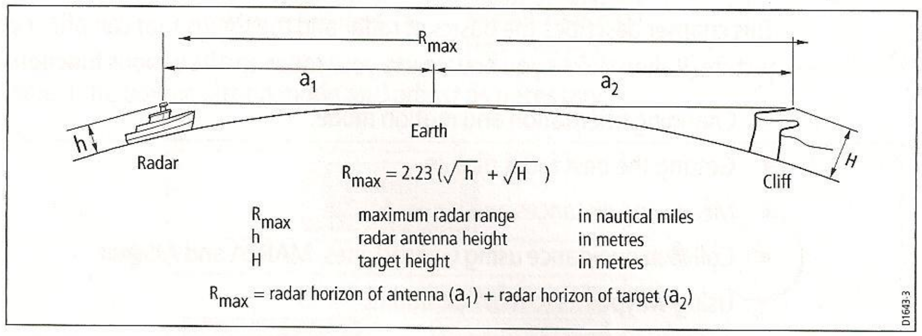

Figure 14-36
Radar Range

D.41.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.42. Reading the Radar Indicator
Interpreting the information presented on the indicator takes training and practice. 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.43. Operating Controls
Different radar sets have different locations of their controls, but they are a 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.44. Reading and Interpolating Radar Images
With the radar scanner connected and the radar in transmit mode, the radar picture provides a map-like representation of the area in which the radar is operating. Typically your boat's position is at the center of the display, and its dead ahead bearing is indicated by a vertical heading line, known as the Ship's Heading Marker (SHM).

On-screen targets may be large, small, bright or faint, dependent on the size of the object, its orientation and surface. Strongest target returns are displayed in yellow with weaker returns in two shades of blue. Be aware that the size of a target on screen is dependent on many factors and may not necessarily be proportional to its physical size. Nearby objects may appear to be the same size as a distant larger object. With experience, the approximate size of different objects can be determined by the relative size and brightness of the echoes.

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

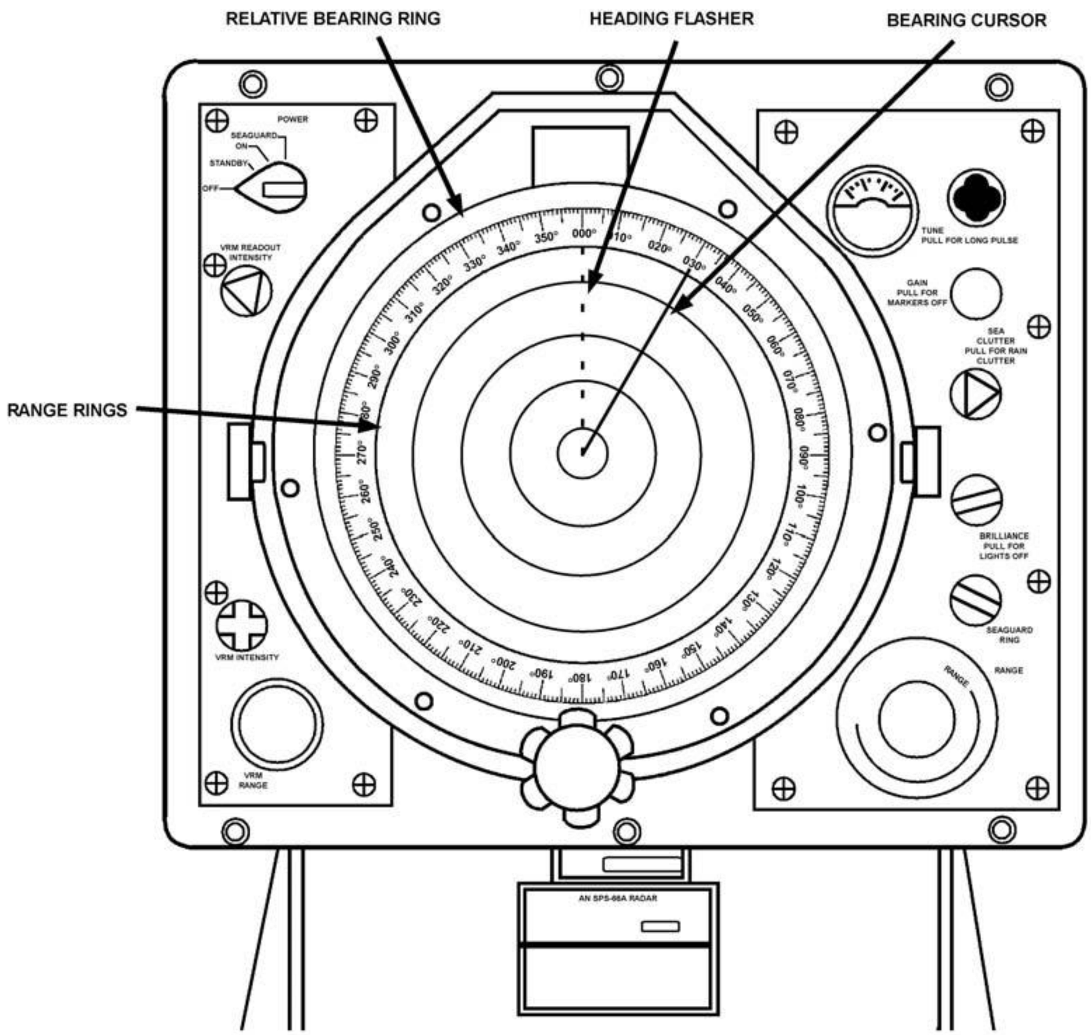

Figure 14-39

Radar Range Rings, Relative Bearing Ring, Heading Flasher, and Bearing Cursor

D.44.a. Radar Bearings

Radar Bearings are measured in relative direction the same as visual bearings with 000º relative bearing dead ahead. (See **Figure 14-39**) In viewing any radar indicator, the silhouette vessel image (as viewed from above) in the center indicates the boat's position. The line from the vessel image 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 and crosses the target. The radar bearing is read form 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.44.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.

Use the range rings to gauge the approximate distance between points. Range rings are concentric circles displayed on the screen and centered from your boat at pre-set distances. The number and spacing of the rings can change as you range in and out. See **Figure 14.40**

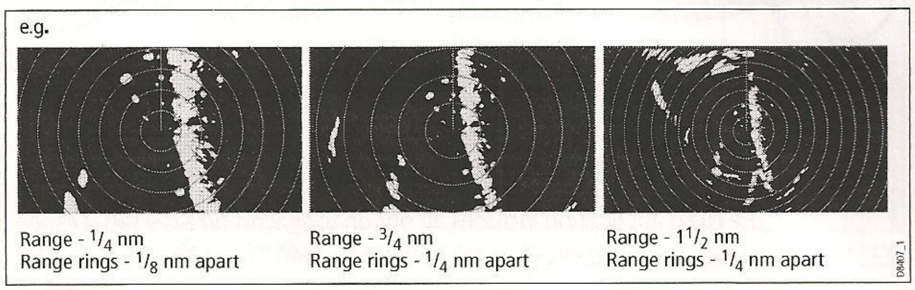

Figure 14-40
Range Rings

D.45. 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.46. 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.46.a. 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.46.b. Distance Measurement Example

At 0215, the boat is on a course of 300º (303º M). The radar range scale is on 16 miles. Two radar contacts (land or charted landmark) are observed. The first has a bearing of 330º relative at 12NM. This target is on the third range circle. The second target is bearing 035º relative at 8 NM. This target is on the second rage circle. Obtain a distance measurement fix by performing the following procedures: (See **Figure 14-41**)

Note: Radar ranges are usually measured from prominent land features such as cliffs or rocks. However, landmarks such as smoke stacks 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 the 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' (0125 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.

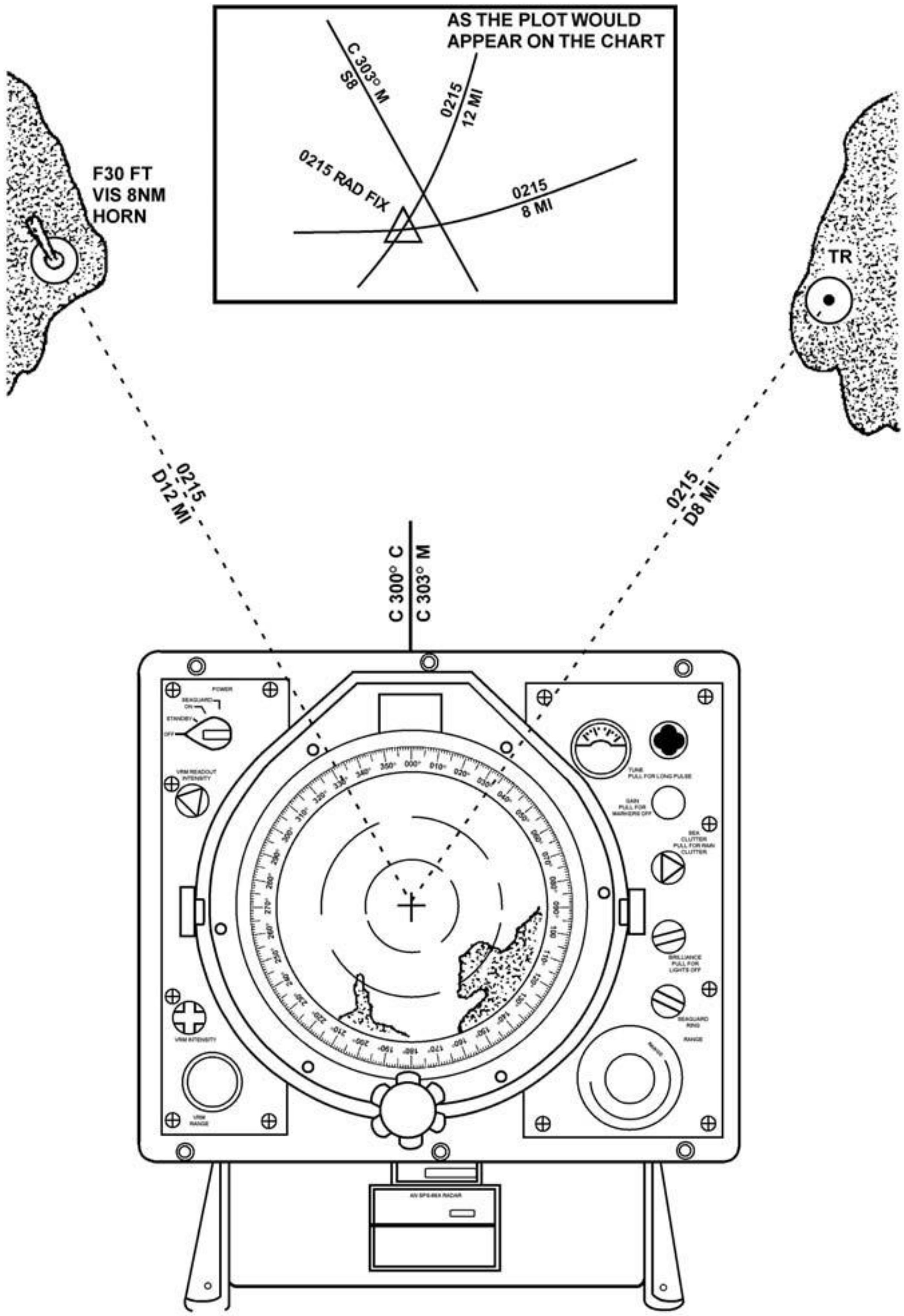

Figure 14-41
Obtaining a Radar Fix Using Two Distance Measurements

D.46.c. Sample DR Plot

A DR plot typically includes many types of LOPs and fixes. **Figure 14-42** 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.

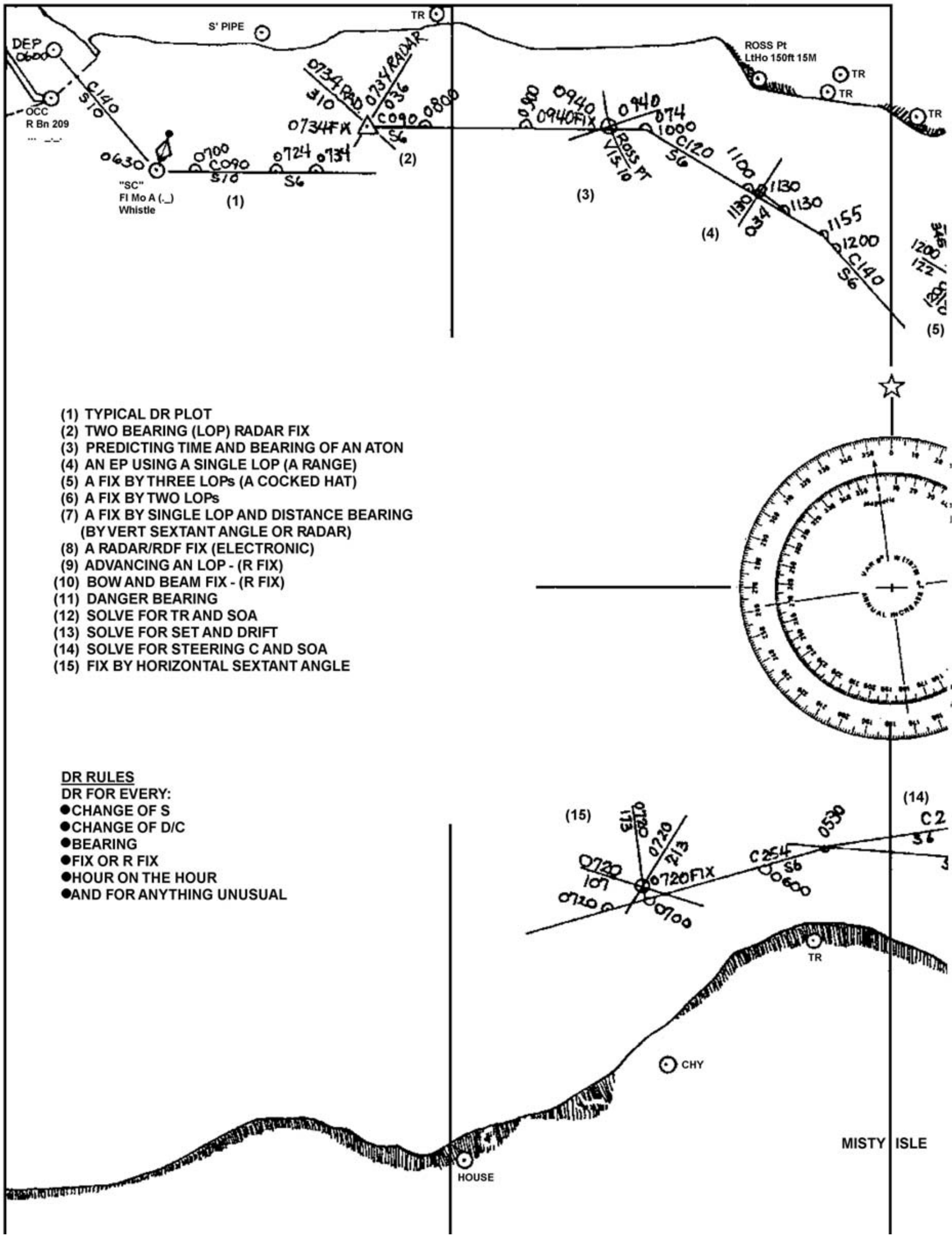

Figure 14-42
Sample DR Plot

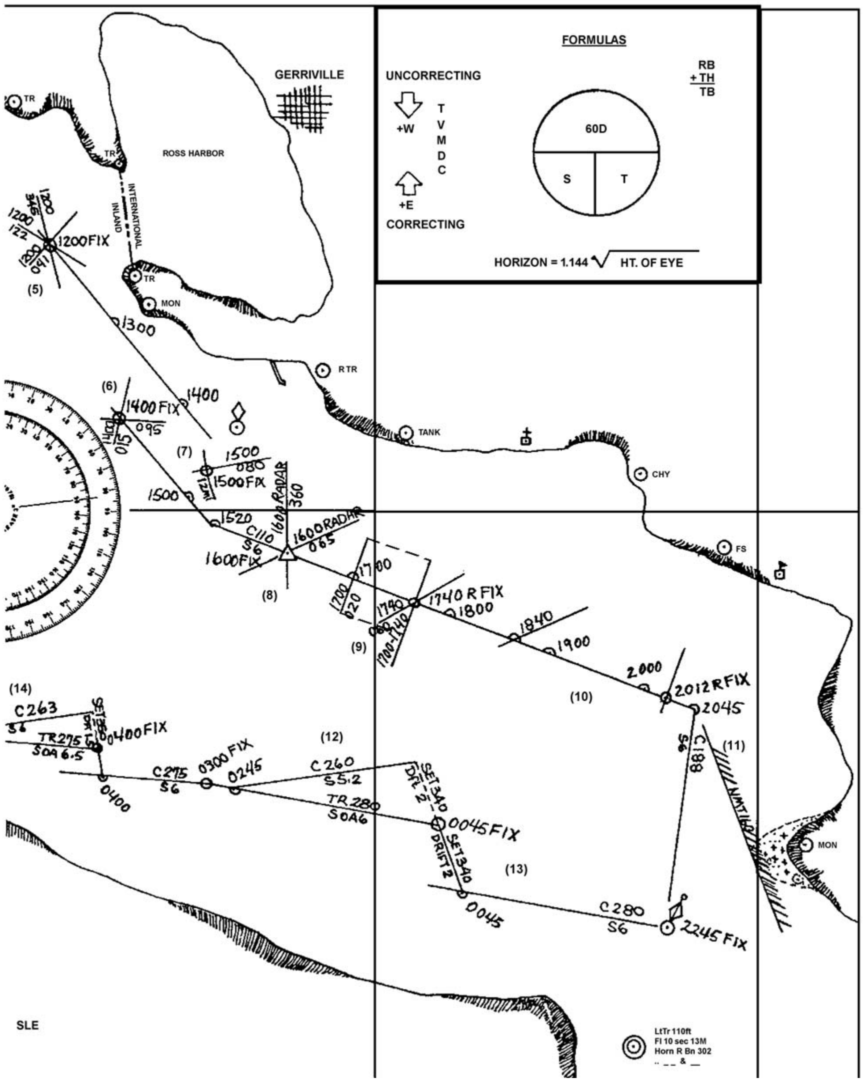

Figure 14-42 (continued)
Sample DR Plot

Global Positioning System (GPS)

D.47. Description

As previously discussed in *Chapter 13, Section D*, the GPS is a radio-navigation 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.48. 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. This is the system the Division uses on their vessels.

D.49. Precise Positioning Service
PPS provides fixes accurate to within 10 meters. This service is limited to approved U.S. Federal Government, allied military, and civil users.

D.50. 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.

DGPS

D.51. Description
As previously discussed in *Chapter 13, Section D,* the Coast Guard developed the DPGS 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 maritime radiobeacons to send DGPS corrections to users. DGPS provides accurate and reliable navigational information to maritime uses in HEA, along U.S. coastal waters, the Great Lakes, navigable portions of the western rivers, Puerto Rico, Hawaii, and Alaska. NDGPS system has been expanded to include coverage throughout the continental U.S.

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