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FACULTY OF NAVIGATION AND MARITIME TRANSPORT

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Scientific advisor
Assoc. Prof. COSTEL STANCA

Undergraduate
OKPORU PRINCE JOSEPH

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“ANALYSIS OF LINES OF POSITION USED IN COASTAL NAVIGATION”

Scientific advisor
Assoc. Prof. COSTEL STANCA

Undergraduate
OKPORU PRINCE JOSEPH

Constanta
2017

STATEMENT

I, OKPORU PRINCE JOSEPH hereafter undersigned, firmly state that the thesis entitled “ANALYSIS OF LINES OF POSITION USED IN COASTAL NAVIGATION” is an original work, drawn up by myself and it has never been defended in any other higher education institution in the country or abroad.

Constanta,

June 2017

OKPORU PRINCE JOSEPH

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ABSTRACT

Coastal navigation requires continuous and accurate determination of a vessel's position to ensure safety, efficiency, and adherence to the planned voyage. This thesis presents a systematic analysis of the Lines of Position (LOPs) used in coastal navigation, examining their principles, classifications, methods of application, and inherent limitations. The study addresses both bearing-based and non-bearing-based techniques, highlighting their continued relevance in navigational practice, particularly in situations where electronic systems are degraded or unavailable. Core concepts including bearings, ranges, cross bearings, running fixes, horizontal angles, transit lines, distance arcs, soundings, and lines of equal depth are discussed with emphasis on procedural accuracy and reliability. The research follows a structured methodological approach, beginning with a theoretical foundation of LOPs and progressing to detailed chart-work applications. Navigational instruments such as the compass, sextant, parallel rulers, dividers, station pointer, and transparent paper are evaluated in relation to their effectiveness in position fixing. Special attention is given to object selection, angle optimization, time management, and the correction of compass and observational errors, all of which significantly influence fix accuracy. General and systematic errors commonly encountered in coastal navigation are analyzed to enhance situational awareness and decision-making. A practical case study constitutes the core of the thesis, demonstrating the application of multiple LOP methods along a defined coastal route using real chart data and vessel particulars. The results confirm that traditional position-fixing techniques remain essential navigational skills. This thesis provides a comprehensive academic and practical reference work.

Keywords: Coastal Navigation, Lines of Position, Position Fixing, Nautical Chart Work, Navigational Errors.

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INTRODUCTION

General frame.

Analysis of Lines of Position used in Coastal Navigation as a thesis is a very welcoming challenge and the main reason of chosen this theme for development is to improve my knowledge and that of the readers as to how a navigator can use the accurate information or knowledge guiding the Lines of Position used in Coastal Navigation. It is for this reason that a thorough research and a methodological approach has been applied to providing the needed information which will help navigators to understand and analyse the various types of Lines of Position used in Coastal Navigation. The structure of the thesis will be discussed in three main chapters where we will start with an explanation of Lines of Position and their importance with the specific types that uses bearing line, such as bearing and a distance, cross bearings, running fix with others which will be discussed in chapter one in details, and there after we will introduce the methods that rarely apply with the use of bearing, such as transit line, a line of soundings, distance arc, horizontal angles etc. and few general errors encountered in fixing the ship that will be discussed in Chapter two followed by a third Chapter of which we will use a practical approach to analyse the Lines of Position used in Coastal Navigation.

Importance and opportunity of the theme.

Analysis of Lines of Position used in Coastal Navigation is a vital and indispensable theory in the field of navigation, as the name implies it provides position of the ship with methodological applications of either bearing lines from a navigational object or with the use of sextant and other navigational instruments to provide lines and angles drawn on the chart to provide a fix, which is known as the position of the ship. In Coastal Navigation knowing the current and accurate position of the ship is a necessity for the navigator to know where exactly they are in the globe, the distance and time the ship has sailed from one point to the other. Lines of Position enable us to know if we are sailing in line with the plan route of the voyage, which is a major priority of the navigator that can only be checked with the analysis of lines of position.

This theme; Analysis of Lines of Position is a great opportunity for navigators and people aspiring to sail in the future to acquaint their selves with the necessary knowledge to apply correctly the Lines of Position used in Coastal Navigation and to know the step by step approach to conveniently and without unnecessary delay to fix the ship while on a voyage. It provides all the needed information as to how, when and where it is appropriate for a navigator to apply the various types and methods used in Coastal Navigation.

Objectives of the thesis study

1. To outline and analyse the different types and methods of fixing the ship position in Coastal Navigation.
2. To highlight and explain in detail the Lines of Position used in Coastal navigation.
3. To highlight the step by step approach in the different types of Lines of Position used in Coastal Navigation.
4. To analyse the importance of choosing Lines of Position in respect to the Coastal area of Navigation.
5. To explain where, when and why a particular Line of Position should be chosen to determine the ship position.

6. A practical approach to plotting and analysing the Lines of Position in Coastal Navigation.

The methodology used in this thesis is a unique and easy way to learning and analysing the Lines of Positions used in Coastal Navigation. The scientific sequence of each chapters is interconnected and is well discussed with the outlining of chapter topics/heading and subheadings of that specific chapter, using a clear and self-descriptive demonstration of figures to enable the reader to understand easily what is being discussed. After a detailed explanation of each of the lines of position used in coastal navigation and a graphical demonstration, a practical and well explained approach is applied at the end chapter which is titled as a “Case Study of Analysis of Lines of position used in Coastal Navigation,” providing for the reader more and clear information as to how to fix the ship with Lines of Position considering all factors influencing the accurate determination of the ship.

Terms used, Symbols and definitions.

Cable	Cbl	One-tenth of a nautical mile.
Chart datum		The vertical datum to which depths and drying heights on a chart are referred.
Chart Variation	CharVar	Difference of change in magnetic error in years interval.
Compass Bearing	CB	Angular distance from compass north (000°) to the object.
Compass Course	CC	The direction in which the ship is intended to be steered, defined by the angle between Compass north and the fore and aft line of the ship, expressed in angular units from compass north (000°).
Compass Error	CE	The sum of Magnetic variation and deviation.
Compass North	CN	Northerly direction of the needle or zero-index of a magnetic compass.
Course of Advance	COA	Direction from the ship's last fix to the next estimated position, expressed in angular units from true north.
Course line		Graphical representation of a ship's intended course to make good.
Cross track distance	XTD	Position distance perpendicular to the intended ground track.
Dead reckoning Position	DR	Calculated position of a vessel obtained by adding to the last fix the ship's true course and own speed.
Degree	°	$1^\circ = \pi/180^\circ \text{rad}$
Depth of water		Distance between water surface and bottom.
Deviation	DEV	Angle between the magnetic meridian and the axis of a compass card, expressed in degrees east or west to indicate the direction in which the northern end of the compass card offset from magnetic north when it is disturbed by local attraction, from magnetic north to compass north eastwards named E (sign plus), westwards named W (sign minus).
Distance	Dist.	Measurement of length from point A to B.
Estimated Position	EP	Most probable position of a vessel obtained by adding to the last fix the ship's course and speed of advance, considering all estimated influences, including current.
Fix	fix, $\otimes$	Ship's position determined without reference to any other former position.
Gyro Course	GC, GyC	The direction in which the ship is intended to be steered,

		defined by the angle between Gyro north and the fore and aft line of the ship, expressed in angular units from gyro north (000°).
Gyro Bearing	GB, GyB	Angular distance from gyro north (000°) to the object, the direction of the electronic bearing line on a plan position indicator (PPI).
Gyro Error	GE, GyE	Correction of all errors (Including speed error) of a gyro compass. Angle between true north and gyro north, from true north eastwards with sign plus, error low, westwards with sign minus, error high.
Gyro North	GyN	Northerly direction indicated by the gyro-compass.
knots	Kn	1Kn = 1NM/h=0.514 m/s
Latitude	ρ	Angular distance from the equator (00°) measured northwards or southwards through 90° and labelled N or S to indicate the direction of measurement.
Leg		Intended ground track between waypoints.
Longitude	λ	Angle at the pole between the prime meridian (000°) and the meridian of a point on the earth, measured eastwards or westwards from the prime meridian through (180°) and labelled E or W to indicate the direction of measurement.
Lines of Position	LOPs	A plotted line on which a ship is located.
Magnetic Bearing	MB	Angular distance from magnetic north (000°) to the object.
Magnetic Course	MC, M CRS	The direction in which the ship is intended to be steered, defined by the angle between the magnetic meridian through its position and the fore and aft line of the ship, expressed in angular units from magnetic north (000°).
Magnetic North	MN	Northerly direction of the horizontal component of the earth's magnetic field
Magnetic Variation	MV	Angle between the geographic and the magnetic meridians at any place of the earth, also called magnetic declination, from true north to magnetic north eastwards named E (Sign Plus), westwards named W(sign minus).
Minute	Min, ‘	1’=1°/60
Nautical Mile	NM	1NM = 1852m
Route	RTE	Intended ground track of a voyage
Speed	S, SPD	Own ship's speed in dead ahead direction produced by machine or sail.
True Bearing	TB	Angular distance from true north (000°) to the object, the direction of the electronic bearing line on a plan position indicator (PPI).
True Course	TC	The direction in which the ship is intended to be steered, defined by the angle between the meridian through its position and the fore and aft line of the ship, expressed in angular units from true north (000°).
True North	TN	Northerly direction of the meridian.
Waypoint	WP	Point on a route
World Geodetic System	WGS	A global geodetic reference system developed by the USA for satellite position fixing and recommended by IHO for hydrographic and cartographic use.

CHAPTER ONE

LINES OF POSITION

1.1. Description of Lines of Position.

Lines of position are plotted lines on which a vessel is located, determined by observation or measurement. Also, called POSITION LINES. In order that the navigator may be sure that he is following his predetermined course, it is necessary for him to ascertain his position from time to time. This he does by observing landmarks, celestial bodies, radio signals and series of soundings and from his observation he obtains what is known as lines of position or position lines.

A position line is any line drawn on the chart, on which the ship's position lies on. It may be a straight or a curved line. There are different methods to obtain a position line which will be highlighted below and be discussed one after the other and analysis of their possible errors and accuracy in determining a ship's position. The simplest form of lines of position is the line of a bearing obtained from a navigational aid which position is known. For example, supposing a lighthouse (K in figure 1.1 is seen to bear 070° at 1130. A line drawn through K in the direction of the reciprocal bearing 290° is the line of position.

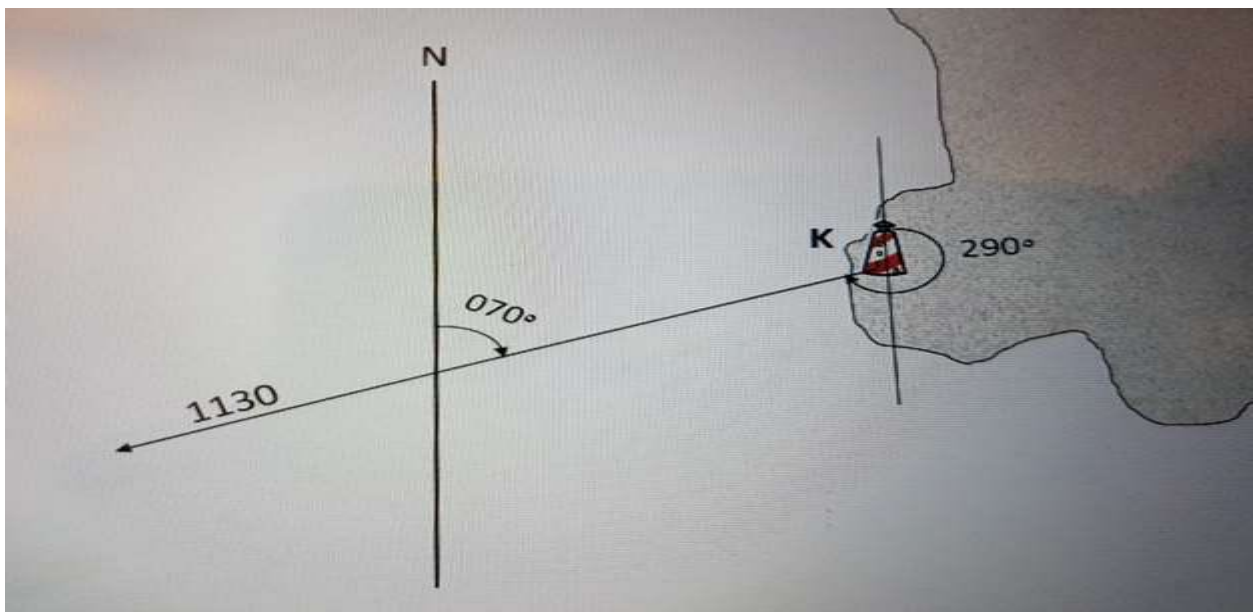


Figure 1.1 Line of position using one bearing. Source: drawn with PowerPoint by self.

Lines of position are not just ordinary lines or lines of any kind drawn on the chart, for there are specific principles to apply or procedures to follow when making these lines of position and for that we will discuss below the things to consider when choosing an object and the principle involved in determining a ship's position and the equipment or tools used in measuring and drawing the lines of positions.

Choosing objects.

Navigational aids or objects chosen for position fixing should be at least 30° apart in bearing. When three objects are observed, they should be 60° apart, two objects, 90° . The best angle between two chosen objects is 60° and accepted angles are between 30° and 150° . When choosing objects, they should be charted, identifiable and the range of visibility in order to avoid

possible errors. However, it is more advisable to take bearings of objects ahead the ship rather than astern. See figure 1.2 for graphical demonstration.

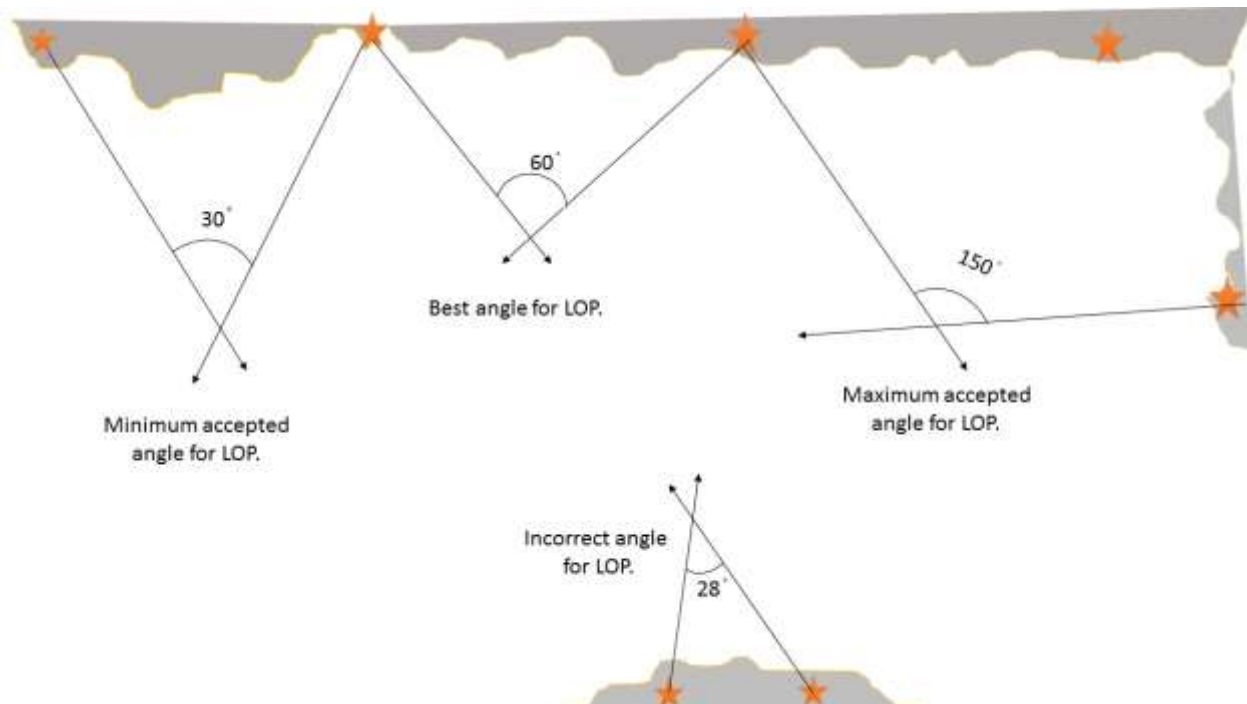


Figure 1.2. Accepted angles for LOPs. Source: drawn with PowerPoint by self.

Principle of determination the ship's position

1. To determine the ship's position one need at least a minimum of TWO LOPs.
2. To have a more accurate position, we need THREE LOPs.
3. More LOPs are used in other types of navigation, such as satellite navigation. But for visual observations, we cannot measure simultaneously LOPs up to five (5) objects.
4. In fact, the observations are not made all at the same time, but within a successive short time interval, one after the other.
5. When only ONE LOP can be observed due to lack of enough visible aids to navigation, second LOP will be obtained when another AtoN will become visible, or by observing the same AtoN after a period of time.
6. In both cases the time between observations must be enough in other to obtain a proper intersection of the TWO LOPs to determine an accurate ship position.
7. To obtain this intersection the LOP obtained in the first observation will be transferred for the moment of the second one.
8. The course and speed of the ship must be unchanged during the time the two observations are being made.

Equipment/tools used to make lines of position

Marine Alidade: The Marine alidade is used to obtain bearings. It is a device fixed on gyro repeaters or magnetic compass to sight a distant object and use the line of sight as a bearing to fix the ship's position. (see figure 1.3 for image).

Sextant: It is a device used to measure the angle of objects between the horizon and celestial sphere. It provides information base on the angle and distance of the object allowing the navigator to make calculations with the given data. "Sighting the height of a landmark can give a measure of distance off and, held horizontally, a sextant can measure angles between objects for a position on a chart."^[1] Sextant is mostly used when fixing the ship using horizontal angle/vertical angle or capable arc. (see figure 1.3 for image).

Navigational Triangle: Is a transparent Triangular plastic object with calibrations indicating a circle of 360 degree and cardinal marks used mainly for wind directions when plotting on the chart. It is very swift to move it around the chart and for most part, it is used to draw lines of position using bearing figures and connecting lines of different points in the chart. (see figure 1.3 for image).

Parallel Rulers: Parallel rulers are a drafting instrument used to draw parallel lines on charts. The tool consists of two straight edges joined by two arms which allow the user to move closer or further away while always remaining parallel to each other.^[2]

Compass: It is a technical drawing instrument used to make circles and arcs. For lines of position that apply a capable arc and bearing with a range, this proves more than useful serving its purpose. As **dividers**, they are used to measure distances between two points or objects on the map.

Pencil: 7H is suggested for pin-pointing positions when using either a parallel and dividers or a tracing. For normal chart work, mariners may prefer a softer pencil such as a 2B. As a student, I have been accustomed to using a specific type call mechanical pencil of 0.7mm. It is thin and makes line visible, easy to erase without a trace if found with a mistake. Pencil is something we cannot do without as far as a chart work is concern.

Eraser: It should be soft and use only for rubbing out pencil marks or tracks on charts or Notices to mariners (NMs) recorded in the paper chart.

Transparent Paper: As the name implies, it is a paper used to draw lines of position and transferred from one place to another as its transparency helps making objects or chart features visible.

Station pointer: A surveyor's instrument for locating on a chart the position of a place from which the angles subtended by three distant objects, whose positions are known, have been observed.^[3]

Having discussed how to choose an object, equipment/tools used in lines of position and the procedures or principles involved in determining the ship position. We will be discussing on the different types of lines of position, how to obtain a line of position using these different types and the order of steps to follow in order to fix the ship's position.

¹ Seddon, J. Carl (June 1968). "Line of Position from a Horizontal Angle". *Journal of Navigation*. 21 (03): 367–369. doi:10.1017/S0373463300024838. ISSN 1469-7785

² <http://encyclopedia.thefreedictionary.com/Parallel+rulers>.

³ https://en.wiktionary.org/wiki/station_pointer

1.2. Types of Lines of Position

There are many different types of Lines of Position used to determine the position of the ship, among all we will be discussing the types that uses bearing line to the determine the fix. All other methods that are used without bearing will be discussed in chapter two, Methods used in determining the Lines of Position. Below are the types of Lines of Position using bearing line.

1. Bearing

- 1.1. Fixing the ship with bearing and range.
- 1.2. Fixing the ship by two cross bearing.
- 1.3. Fixing the ship by three cross bearing.
- 1.4. A bearing and horizontal angle from which a range may be calculated.

2. Running fix

- 2.1. Fixing by two bearings of a single AtoN.
- 2.2. Fixing by bearings from two AtoN.
- 2.3. Doubling the bow angle.

1. Bearing

A bearing is defined as the direction of an object with reference to your ship or to another object. In terrestrial navigation, bearings are indicated according to the different bearing types used in making calculations for determining the ship position. True bearings are measured clock wisely from the true north while relative bearings are measured either clock wisely or anti-clock wisely from the fore and aft line of the ship to the object. Measurements are in angular distances as they are expressed in degrees and in three digit always. The acronyms used are TB for True Bearing and RB for Relative Bearing. Also, there is what we called Compass bearing, Magnetic bearing and Gyro bearing having their own specific acronyms as CB, MB and GyB respectively. In most cases, the Navigator uses these bearings when he is taking his course values from the Magnetic Compass and the Gyro Compass.

Since the ship course values are taken from these devices which are subject to errors, it is advisable for the navigator to make the necessary corrections before using the bearing values to plot the lines of position. In the case study, we will analyse all the possible errors that can affect our lines of position and we will provide a solution to eliminate such errors in other to get an accurate fix. Now we will discuss on how to plot lines of position using the different methods under bearing.

1.1. Fixing the ship with bearing and range.

This type of fixing the ship is used when the navigational area lacks objects and is quite easy to obtain the ships position with the combination of a visual aid and range. Below are steps to fixing the ship with bearing and range.

- I. Observe a navigational aid and highlight it in your chart. Make sure it is visible.
- II. Take its true bearing using a marine alidade or any other device taking bearing on board the ship (Magnetic compass, Gyro compass, radar etc.).
- III. Take the range of the object from your ship. Write both the bearing and the distance down.
- IV. Draw the bearing line from the NAVAID towards the ship.
- V. Use the divider to measure the range on the latitude measurements.
- VI. Place the divider on the base of the object and indicate the range on the bearing.

- VII. Where the range ends mark the position of the ship. From this point a new course line is drawn.

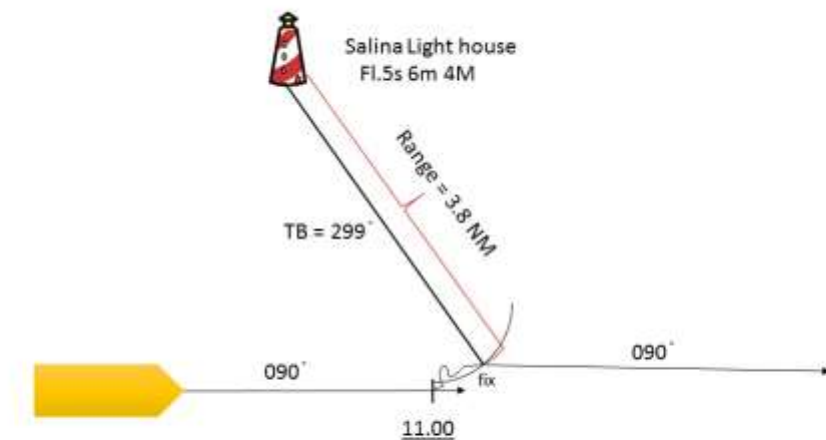


Figure 1.3 Bearing and Range. Source: drawn with PowerPoint by self.

1.2. Fixing the ship by two cross bearing.

Unlike the bearing and range where there are insufficient NAVAIDS to fix the ship position, in this type of fixing, it depends on the navigator to choose among different objects to be used in making the lines of position. During my terrestrial navigation classes, students often use this type of fixing because you can hardly find any error using two cross bearings. Even if there are errors it can only result to the wrong placing and unintentional movement of the navigational triangle when drawing the bearing lines. Also, another mistake people normally do when applying cross bearing to fix the ship is the use of lesser angles between two chosen objects. As we discussed earlier on “Choosing Objects”, the accepted angles for determining LOPs should be in between 30^0 and 150^0 . Anything less than 30^0 is not accepted and anything more than 150^0 is wrong. So, before choosing the two objects, also consider the angle before you make use of them. Below are steps to fixing the ship by two cross bearing.

- I. Identify two aids to navigation on your chart which will be visible at the same time and will offer a good angle for cross bearing lines.
- II. Identify correctly the two aids to navigation selected on the chart to avoid repetition and delays.
- III. Measure the bearings of the two selected objects very quickly.

Order for bearing measurement:

- FIRST OBJECT – the one closer to the fore and aft line (A)
 - SECOND OBJECTV- the one closer to the beam of the vessel(B)
- (See figure 1.4a)

- IV. During the night time, the first object should be the one with the shortest light characteristic.
- V. Note the time for which the two observations are made.

- VI. Correct the value of bearings using appropriate error: $TB = CB + CE$ or $TB = GyB + GyE$.
- VII. Draw the TRUE BEARING lines for each of the two objects on the chart.
- VIII. The intersection of the two LOPs is called the FIX also known as the ship position.
- IX. Draw the course line from the FIX.

After getting the fix or position of the ship, the latitude and longitude of the fix should be taken and a measurement of distance from previous position to the fix known as error (defined as bearing and distance from DR to FIX).



Figure 1.4a. order for bearing measurement Source: drawn with PowerPoint by self.

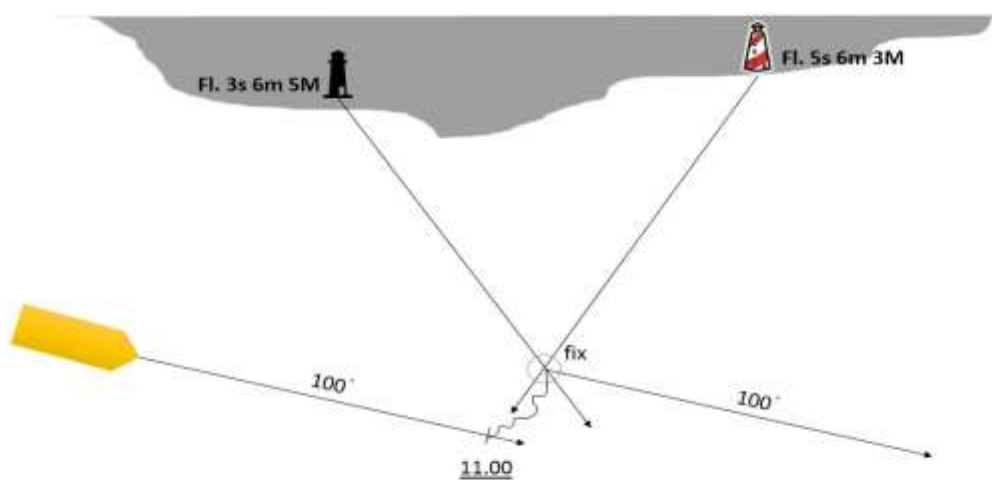


Figure 1.4b Fixing the ship by two cross bearing. Source: drawn with PowerPoint by self.

1.3. Fixing the ship by three cross bearing.

Like the two-cross bearing, this is just an addition of one object making it three LOPs to determine the ship position. In most cases, students find it difficult to know the exact position of the ship after obtaining the three Lines of position. It always forms a triangle shape called cocked hat. Most students roughly assume the middle to be the fix, but there is a technique used in identifying almost an accurate position inside the cocked hat. This type of fix takes more time than the previous one. So, speed and accuracy is required to determine the objects in respect to

their angles apart and to put the lines of position on the chart. Below are steps to fixing the ship by three cross bearing.

- I. Identify three aids to navigation on your chart which will be visible at the same time and will offer a good angle for the cross-bearing lines.
- II. Identify correctly the three aids to navigation selected on the chart to avoid repetition and delays.
- III. Measure the bearings of the three selected objects very quickly.
 - Order for bearing measurement:
 - FIRST OBJECT – the one closer to the fore and aft line (A).
 - SECOND OBJECT – the one closer to the beam of the vessel (B).
 - THIRD OBJECT – the one from the either starboard bow or the port bow depending on the side the object is sighted.
- IV. During the night time, the first object should be the one with the shortest light characteristic.
- V. Note the time for which the three observations are made.
- VI. Correct the value of bearing using appropriate error. $TB = CB + CE$ or $TB = GyB + GyE$.
- VII. Draw the TRUE BEARING lines for each of the three objects on the chart.
- VIII. The intersection of the three LOPs is the fix.
- IX. Read the latitude and longitude of the fix and measure the fixing error (defined as bearing and distance from DR to FIX).
- X. Draw the course line from the FIX.

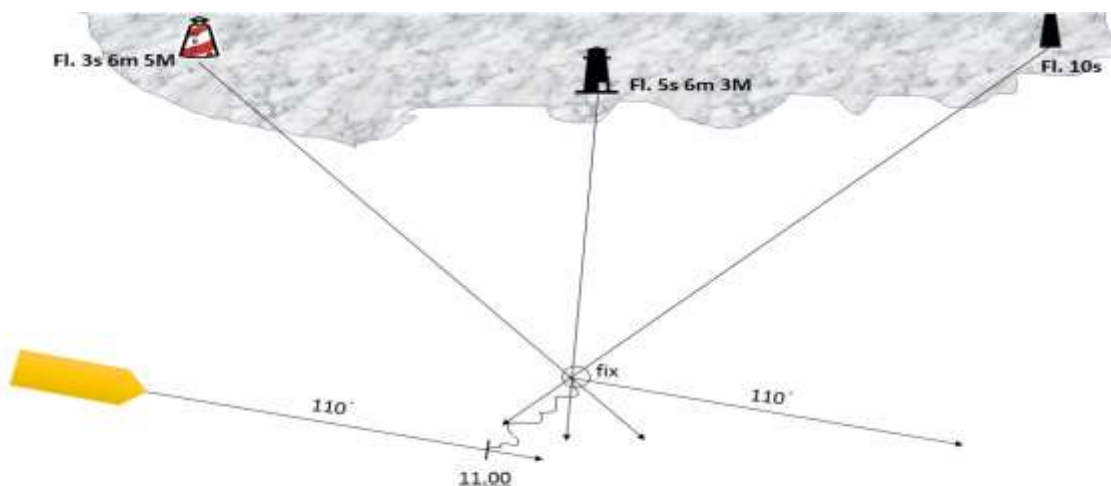


Figure 1.5. Fixing the ship by three cross bearing. Source: drawn with PowerPoint by self.

In most cases, after drawing the three lines of position you will find out that the three bearing lines does not cross at the same point as it happens in the above figure and with two cross bearing. Looking at the triangle in the figure below, one can conclude that the ship position is assumed to be at any point of the triangle. The bigger the triangle the bigger the error, the smaller the triangle the smaller the error. No matter how big and small.

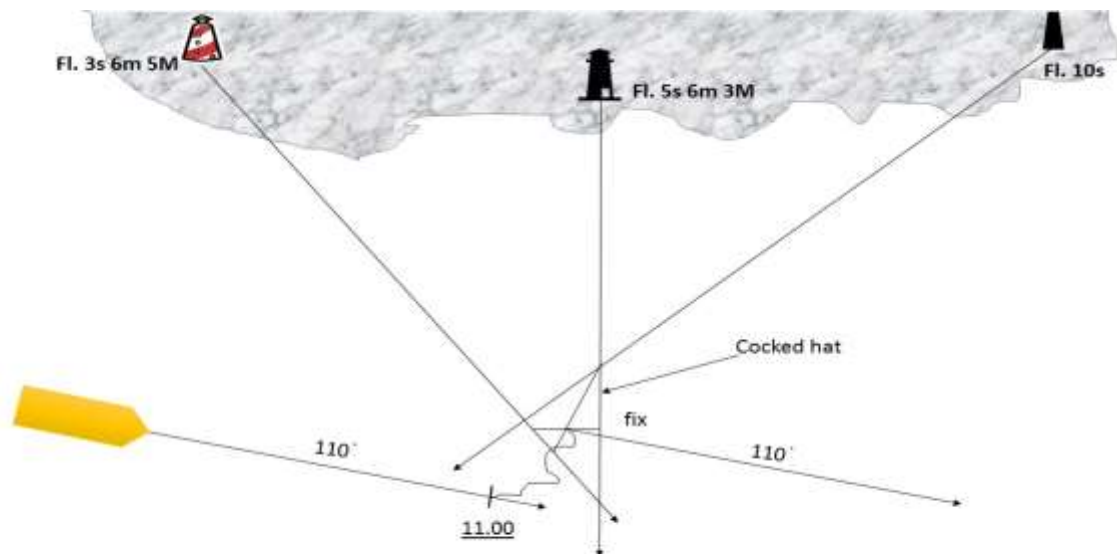


Figure 1.6 Three cross bearing forming a triangle. Source: drawn with PowerPoint by self.

it is, to determine an almost accurate position the gravity center of the triangle is used as the fix or exact ship position. The gravity center is determined by a perpendicular line drawn among the longest lines in the triangle. The intersection of these two perpendicular lines are used as the center of gravity for the fix. Note; the gravity center is used when the sides of the triangle are less than 1 NM. See figure 1.6 above for demonstration. In a situation, whereby the lines of the triangle are greater than 1 NM, we must study the error in the triangle by applying other methods to get a better or more accurate fix.

Other applicable methods to eliminating triangle errors.

- If the sides of the triangle are longer than 1 NM length, study again the potential errors and if you identify an important error – eliminate it or repeat the observation.
- Applying the difference of bearings by obtaining two horizontal angles from the difference of FIRST TWO and LAST TWO bearing: $\alpha = TB_A - TB_B$, $\beta = TB_B - TB_C$. The FIX will be obtained at the intersection of the two capable arcs specific to the two horizontal angles. (See figure 1.7 for demonstration.)
- Applying similar triangle by increasing or decreasing the angles of bearing with a constant value between 2° and 5° . Draw the new bearings obtaining a similar triangle with the triangle of errors. Connect the edges that have the same names. The FIX will be obtained at the intersection of the two lines connecting two edges with the same name. (See figure 1.8 for demonstration.)

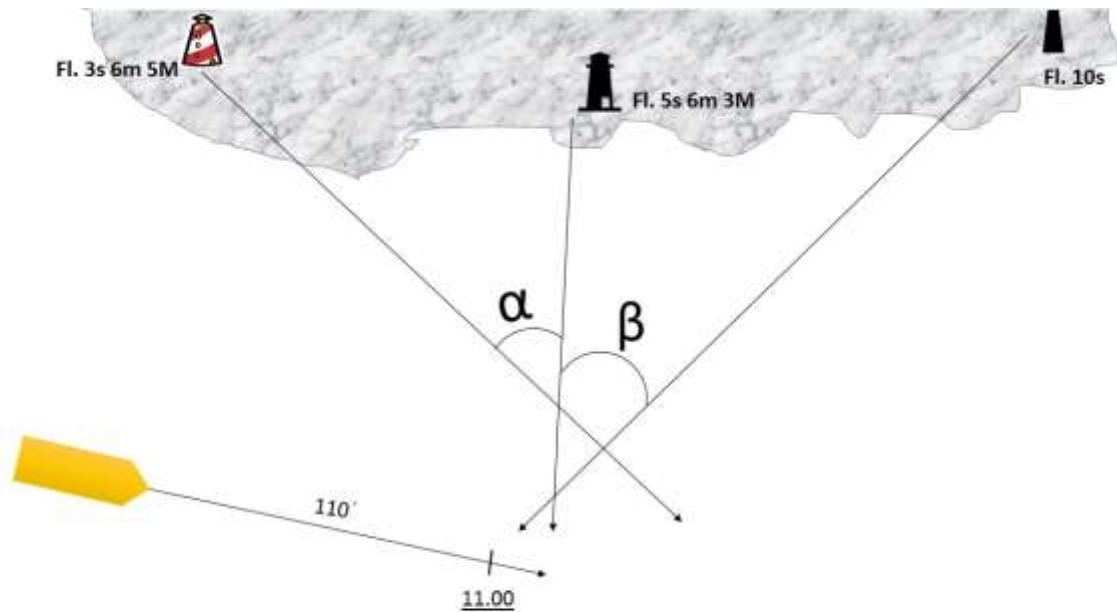


Figure 1.7 Horizontal angles from the difference of first and second bearing.
Source: drawn with PowerPoint by self.

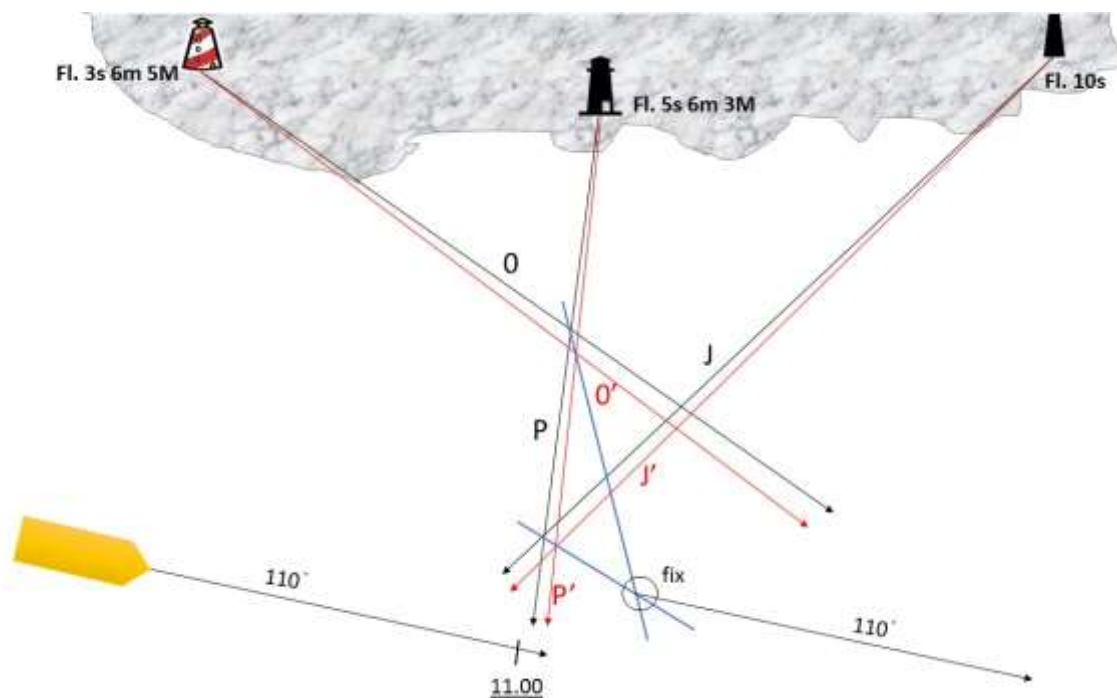


Figure 1.8 Increasing or decreasing the angles of bearing with a constant value between 2° and 5° . Source: drawn with PowerPoint by self.

1.4. A bearing and horizontal angle from which a range may be calculated

This type of fix is used when the ship sights a small Island in an area where there are no other navigational aids. The compass bearings of the two edges will provide an angle especially, in the absence of radar and rangefinder. In such case, observe the bearing of one edge and take a horizontal sextant angle between the edges. The range of the ship is calculated by measuring the width of the island on the chart. According to the figure below the sextant angle between the

extremes of the island is 0.9 miles wide, 9° in between the two bearings and at the same time 078° . To find the distance of the ship from the island, let R miles equal the distance. Then, since $\text{arc} = \text{radius} \times \text{the angle in radians}$:

$$\frac{R}{0.9} \times \frac{360}{2\pi \times 9}$$

$$R = 5.73 \text{ miles}$$



Figure 1.9 A bearing and horizontal angle from which a range may be calculated

Source: drawn with PowerPoint by self.

2. Running fix

Running fix is applied to fix the ship's position in a situation where by there is only one navigational aid visible and used for two NAVAIDS where possible. To determine a running fix with one object, the navigator must take an initial bearing after sighting the object and proceed for a reasonable amount of time which will provide an optimal angle of 90° when a second bearing will be taking from the same object. After taking a second bearing, the initial bearing is transferred in respect to the distance and course line drawn parallel from the Object base. The intersection of the transferred line and the second bearing lines provide a fix called as Running fix which is normally abbreviated as RFIX on the chart. During this period of observation and elapsed time, the speed and course of the ship must remain unchanged. To make it more simple and understandable, we will discuss in detail procedures the two commonly known methods in addition to particular cases using two bearings.

2.1. Fixing by two bearings of a single AtoN.

This is applied when there is only one object visible in the navigation area. Below are steps to fixing the ship by two bearings of a single object.

- I. Identify the AtoN in the chart and make an estimate for which the two moments of observations will provide a good angle of intersection for the two lines of position.
By good angle I mean 30° to 150° .
- II. Identify correctly the AtoN to be used on site.
- III. Measure the bearing and take the time at which the bearing is taking.
- IV. Correct the bearing to obtain true bearing.
- V. Draw the bearing on the chart.
- VI. Proceed without changing the course and speed until the bearing has developed a better angle, more than 30° .
- VII. Measure a second bearing to the same object and take the time at which the bearing is taken.
- VIII. Correct the bearing to obtain the true bearing.
- IX. Draw the second bearing on the chart.
- X. Transfer the first line of position to the second moment:
 - Draw a parallel line with the value of the ship's true course from the base of the object

- Mark on this parallel line the distance sailed by the ship between the two observations.
- From this mark draw a parallel line of the initial bearing.

XI. The RUNNING FIX is at the crossing point of the second bearing line.

After getting the fix or position of the ship, the latitude and longitude of the fix should be taken and a measurement of distance from previous position to the Running Fix known as error (defined as bearing and distance from DR to RUNNIN FIX). A new course line is drawn from the RUNNING FIX.

2.2. Fixing by bearings from two AtoN

Running fix is obtained by two bearings of different AtoN at a given time interval with a transfer of the first bearing line to intersect with the second LOP having measured and drawn a parallel line to ship true course with its distance. Like the one discussed above, the only difference is the use of a second navigational aid. Below are steps to fixing the ship's position with running fix by two AtoN.

- Identify the AtoN in the chart and make an estimate for which the two moments of observations will provide a good angle of intersection for the two lines of position. By good angle it means 30^0 to 150^0
- Identify correctly the AtoN to be used on site.
- Measure the bearing and take the time at which the bearing was taken.
- Correct the bearing to obtain the True Bearing.
- Draw the bearing on the chart.

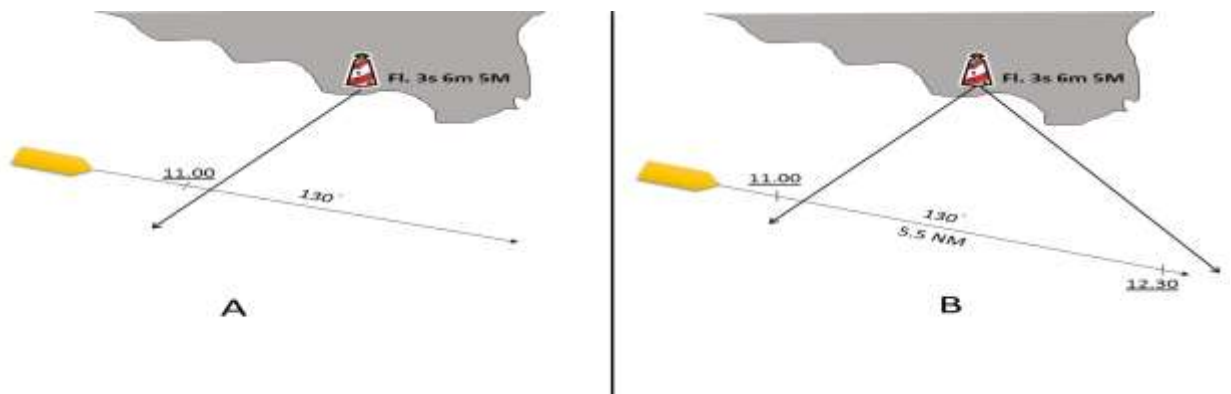


Figure 1.10a. Running fix using one AtoN. Source: drawn with PowerPoint by self.

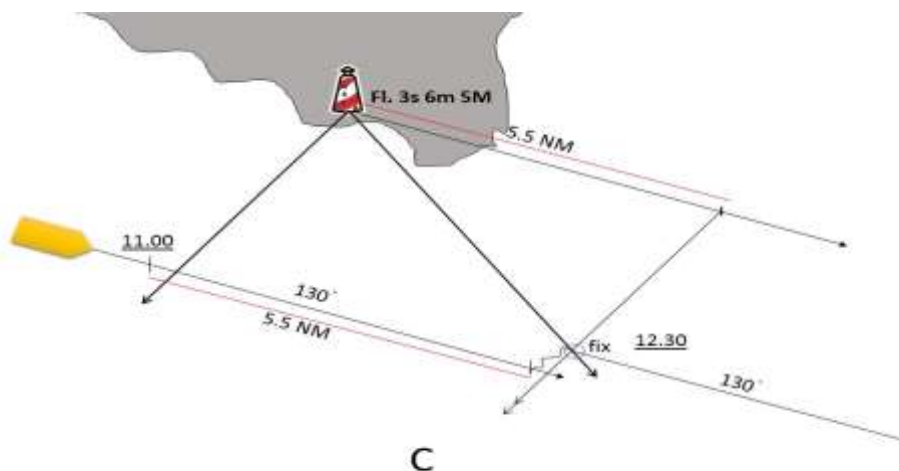


Figure 1.10b. Complete Running fix using one AtoN. Source: drawn with PowerPoint by self.

- VI. Proceed without changing the course and speed until the bearing has developed a better angle, more than 30° .
- VII. Make a second observation and take the bearing of the AtoN.
- VIII. Correct it's bearing and draw it on the Chart.
- IX. Draw a parallel line to the own ship True Course, starting from the base of the first AtoN.
- X. Measure the distance travelled between the first and second observation of the AtoN on the parallel line.
- XI. Transfer the True bearing of the first AtoN to the end of the parallel line and indicate it with double arrow.s
- XII. Where the transfer line intersect with the second bearing line provides a Running fix.

After getting the Running fix or position of the ship, the latitude and longitude of the R.fix should be taken and a measurement of distance from previous position to the Running Fix known as error (defined as bearing and distance from DR to RUNNIN FIX). From that position, a new True Course is drawn. See figure 1.11 below for demonstration.

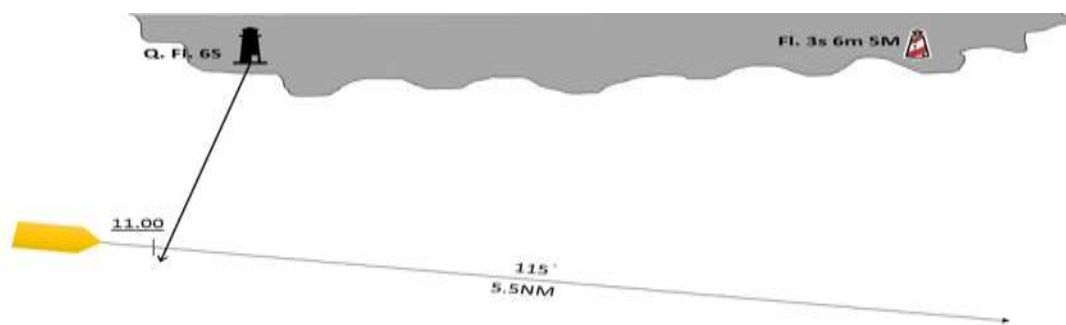


Figure 1.11a. Observation to first AtoN. Source: drawn with PowerPoint by self.

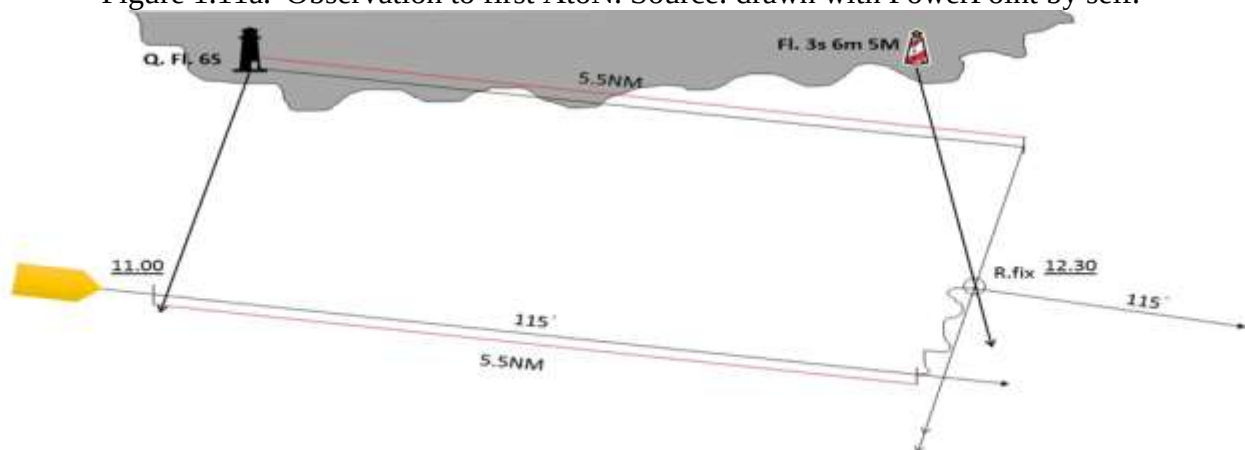


Figure 1.11b. Complete Running fix using two AtoN. Source: drawn with PowerPoint by self.

2.3. Running fix using doubling the bow angle.

Running fix by doubling the angle is a quick and faster means to determine the position of the ship with less error. It is also applied when there are insufficient aids to navigation in the coastal area. It is a method where we derive an isosceles triangle with successive observation of the same Navaid closed in with the distance covered by the ship course. It is like that of bearing and range. The only difference is, in place of two bearings intersecting to give us a running fix, we use bearing and range from the second observation of the same object. Anywhere the range

ends in the bearing line is considered as our running fix. Within this interval of observation, the course and speed of the ship remain unchanged. Below are orderly steps to determining a Running fix doubling the angle at the bow.

- I. Identify the AtoN in the coastal area or chart in such a way that the second semi-circular relative bearing will be double of the first one. A better angle of intersection for the two lines of position should be between 30° and 150° .
- II. Identify correctly the object selected to be used.
- III. Measure the first bearing and note down the time at which it was taken.
- IV. Correct the bearing to obtain the True Bearing of the object.
- V. Draw the bearing on the chart.
- VI. Proceed with Course and speed unchanged until when the semi-circular relative bearing will double than the first bearing.
- VII. Take a second bearing from the same object indicating the time at which it was taken.
- VIII. Draw the second bearing line on the chart.
- IX. A triangle is formed after drawing the second bearing known as Isosceles triangle. Triangle ABC which is $AC=BC$, with AC representing the distance to the object while BC represent the distance of the True Course.
- X. Draw the distance arc from the base of the object with a radius equals distance sailed by ship between the two observations.
- XI. The intersection of the distance arc and the second bearing line is considered as Running fix.

After getting the Running fix or position of the ship, the latitude and longitude of the R.fix should be taken and a measurement of distance from previous position to the Running Fix known as error (defined as bearing and distance from DR to RUNNIN FIX). From that position, a new True Course is drawn. See figure 1.12 below for demonstration.

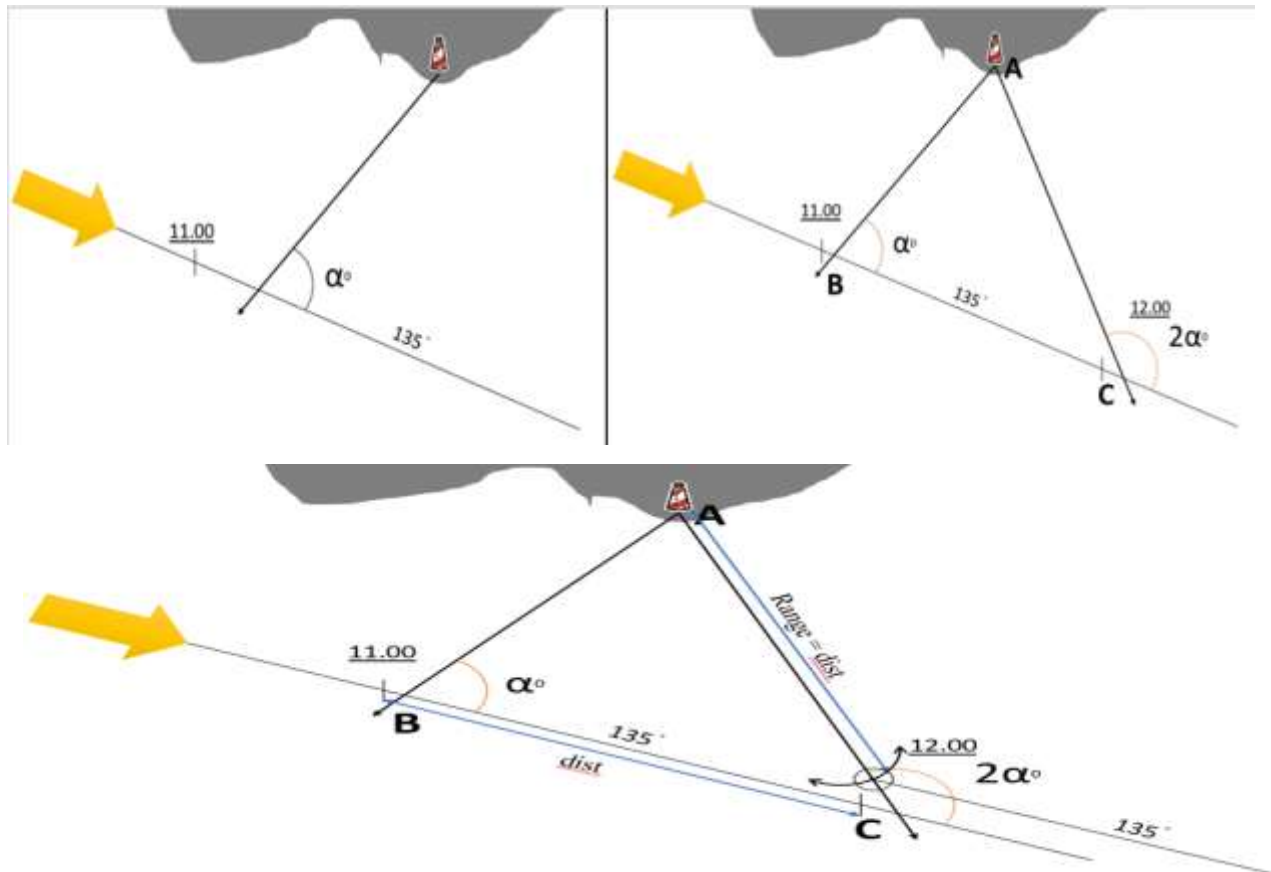


Figure 1.12. Process of Running fix by doubling the bow angle. Source: drawn with PowerPoint by self.

Conclusion

From the above detailed explanation of Lines of Position, we are meant to understand that with the aids of lines and objects observed and drawn on the chart, a ship's accurate position is determined and among which there are different types that has been described in detail above, such as fixing the ship with bearing and range, by two cross bearing, three cross bearing, a bearing and a horizontal angle which a range may be calculated, a Running fix by two bearings of a single AtoN, Running fix by bearings from two AtoN and by doubling the bow angle. All this types of determining the LOPs has to do with their different specific and orderly steps, but the most common and relevant procedures that are repeatedly applied in each LOPs is the correct observation and highlighting of a navigation aid within a visible range with the consideration of a better angle for intersection and the correction of the bearing with the time at which the bearing was taken. After the drawing of the bearing lines, the intersection of the LOPs is considered as our fix, which is the position of the ship. However, a new True Course is drawn from this point after taking the latitude and the longitude with a measure of the Dead reckoning point to the fix known as error.

CHAPTER TWO

METHODS USED IN LINES OF POSITION

In this chapter, we are going to discuss the methods used in determining the Lines of Position which are without bearing or rarely with the use of a bearing line. Although, there are many other devices to determine the position of the ship without using bearing line, such as, sounding, GPS system, Astronomical observations, etc.

2.1. Other Methods used in Lines of Position.

1. **Transit line.**
2. **Distance Arc Method.**
3. **A line of soundings.**
4. **Horizontal Angles.**
5. **Lines of equal depth.**

1. Transit line.

Transit line method is applied when a navigator sights two objects that is in a straight-line order. He has to join the two objects in a straight line connecting from one to the other and to the ship. The ship is in any point of this straight line. The distance from the closest object should be less than three times the distance between the objects in transit. The transit is then sufficiently “sensitive” for the movement of one object relative to the other to be immediately apparent. It can of course be used at greater distances. It is also most useful for checking the error of the compass. There are two specific symbols used to indicate a transit in a chart. The symbol $\emptyset$ is used for a transit while the symbol $\neq$ is used by the Hydrographer to designate transits on Admiralty charts, and shown in the Chart Booklet 5011, Symbols and abbreviation used on Admiralty Charts. See Figure 2.1 for demonstration.

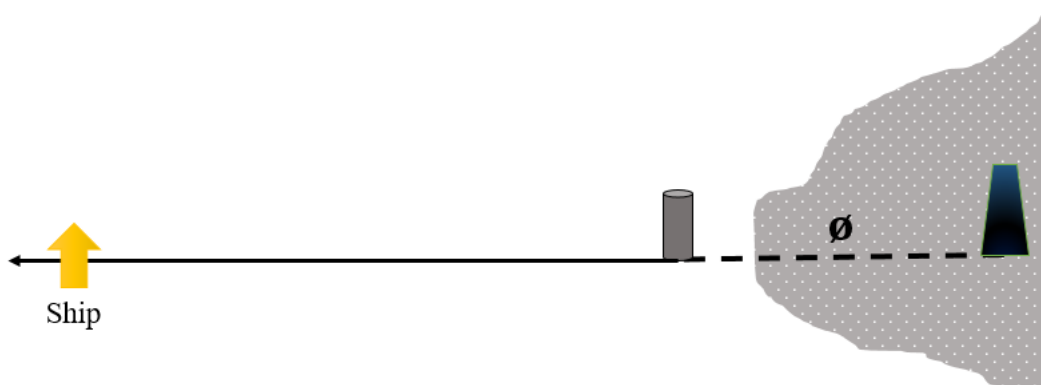


Figure 2.1. Position line of a transit. Source: Drawn with PowerPoint by self.

2. Distance Arc Method.

Distance arc method is quite easy and fast to determine the position of the ship. What you need to do is to make observations to two navigational aids around the coastal area. Instead of taking their bearings, we take their different range. Having done that, we make an arc with the ranges of the two respective objects. Where the two arcs intersect mark the position of the ship. See figure 2.2 for demonstration.

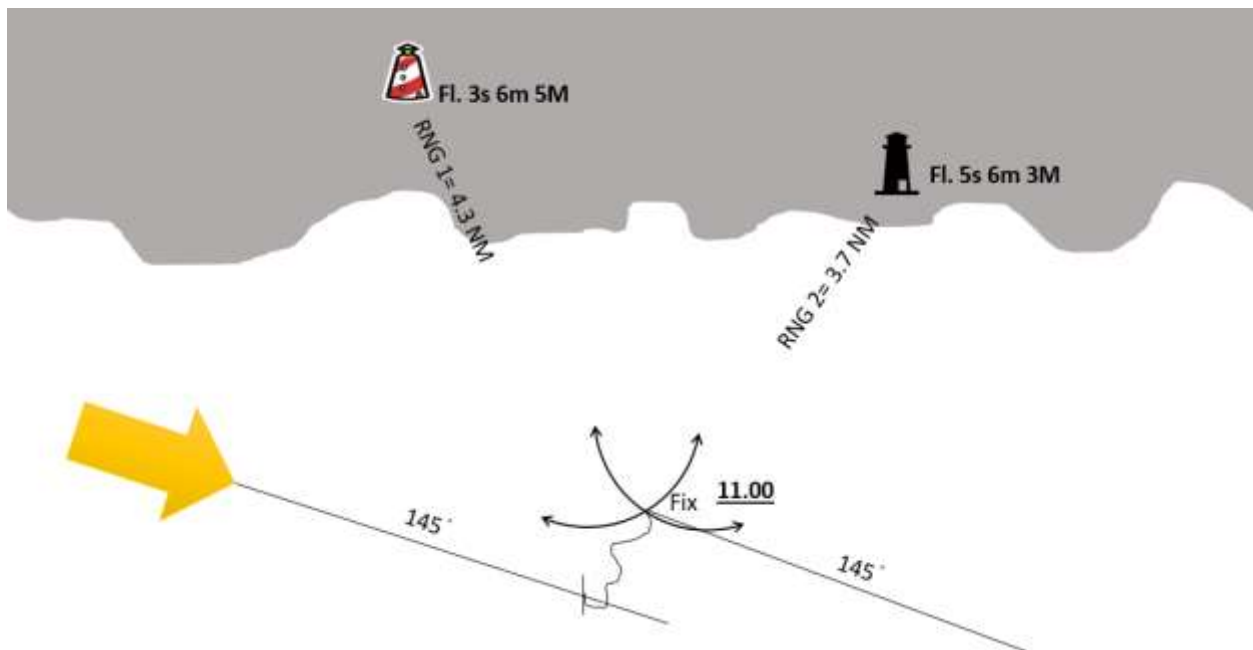


Figure 2.2. Fixing the ship with distance arc method. Source: Drawn with PowerPoint by self.

3. A line of Soundings.

A line of sounding is used when there are no objects suitable for observations, in this situation we obtain the ship position by take soundings at regular intervals noting the depth. All depths must be corrected for the height of tide, also for draught if measured below the keel. On a piece of tracing paper draw a meridian of longitude and a parallel of longitude, then lay off the ship's estimated ground track at the scale of the chart in use. Place the tracing paper on the chart in the vicinity of the ship's estimated position and use the tracing paper to move about the chart until the soundings in the tracing paper coincide with that of the chart. The frequency at which soundings should be taken depends on the speed of the ship and the spacing and nature of the soundings on the chart. See figure 2.3 below for demonstration.

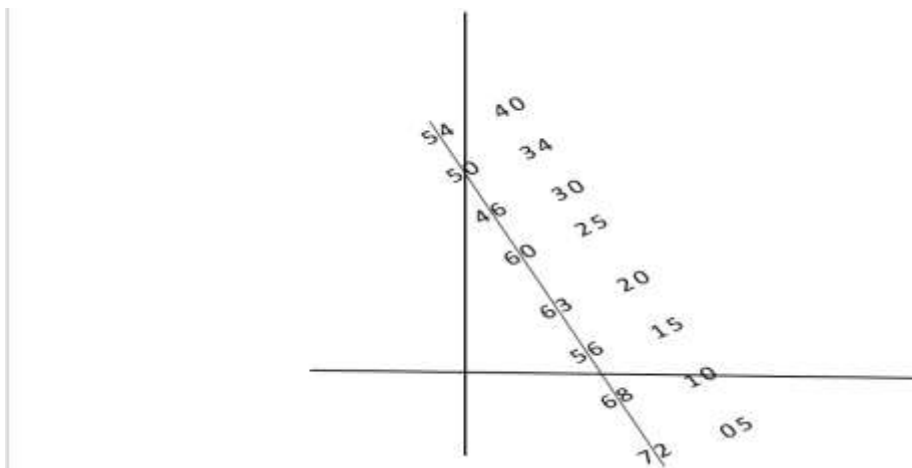


Figure 2.3. A line of Soundings. Source: Drawn with PowerPoint by self.

4. Horizontal Angles.

Horizontal angle uses angles between navigational objects to determine the Lines of Position and with the use of sextant, station pointer and transparent paper. All these are instruments with their specific method of application which will be discussed one after the other. In Horizontal Angles, you need at least three Navigational objects to obtain a Lines of Position and the positions are highly accurate. With the help of the sextant we will be able to measure the

angles between objects from any location of the ship. The only disadvantage is it takes a longer time to determine the Fix. To obtain a proper Lines of Position, the navigator need to pay careful attention to the objects being selected, in terms of visibility and better angle actualization. Before we talk about the different methods to fix the ship with the different instrument using horizontal angles, few steps that will guide us to obtain a better fix is highlighted below.

- I. Identify three objects to be used in the chart or in the coastal area considering how suitable they are to provide a better angle of intersection for the two Lines of Position.
- II. Identify correctly on site the three objects selected to be used.
- III. Measure the two horizontal angles quickly, one after the other (α, β) noting their time down.
- IV. Use one of the methods (Capable arcs, Segments, Transparent paper, Station pointer) to find the position of the ship.
- V. Read the latitude and longitude.
- VI. Measure the fixing error (bearing and distance from DR to Fix).
- VII. Draw a new course line form this point.

With this we can now explain how to use the different methods starting from Capable arc methods.

Capable Arc Method.

After making the necessary observations, a line is drawn connecting all the three objects (ABC) with a perpendicular line drawn from the middle of the two lines (AB and BC) in between objects intersecting the line forming the angles (AO). Radius from the line forming the angle (AO) is drawn for the first and third objects, where the two arcs intersect forms the Fix of the ship. See figure 2.4 below for demonstration.

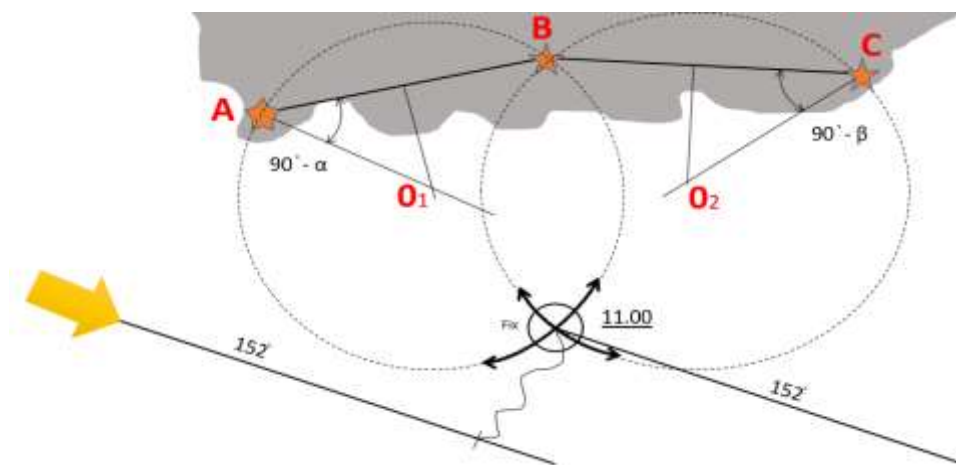


Figure 2.4 Capable Arc Method. Source: Drawn with PowerPoint by self.

Segments Method

First of all, draw a line connecting the three objects (A-B, B-C) and secondly, draw from the central object (B) lines having an angle ($90^\circ - \alpha$) with AB and ($90^\circ - \beta$) with BC and thirdly, draw from A and C two lines perpendicular on AB and BC. At the intersection of lines starting from B with the horizontal line connecting point X and Y provides the Fix of the ship. From this point a new course line is drawn. See figure 2.5 below for demonstration.

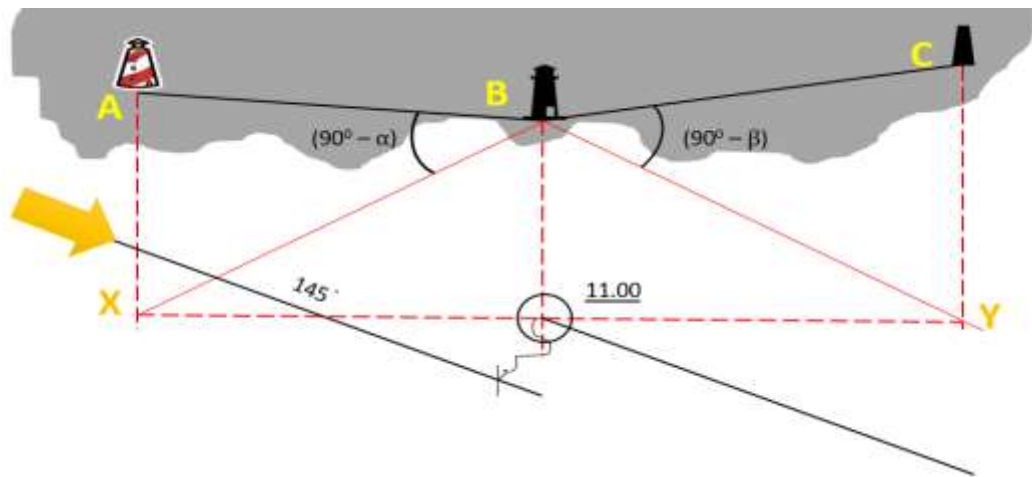


Figure 2.5. Fix with segments method. Source: Drawn with PowerPoint by self.

Transparent paper method.

This method uses a transparent paper as the name implies. On the transparent paper is drawn a horizontal line with a perpendicular line on the middle, after then, is drawn another two lines with angles equals α° and β° . After drawing the three lines on the transparent paper, it is then moved to the three objects on the chart having represented a vertical line for the middle object and the other two lines with α° and β° . The intersection of the three lines from the three objects is known as the fix. From this point, a new course line is drawn. See figure 2.6 below for demonstration.

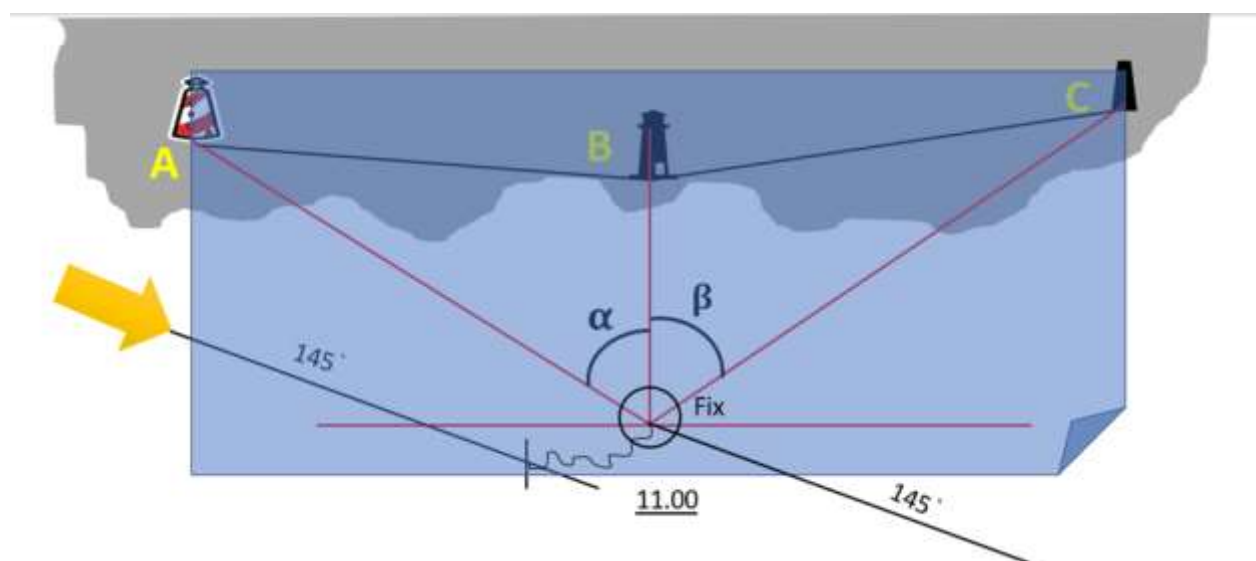


Figure 2.6a. Fixing the ship with transparent paper method. Source: Drawn with PowerPoint by self.

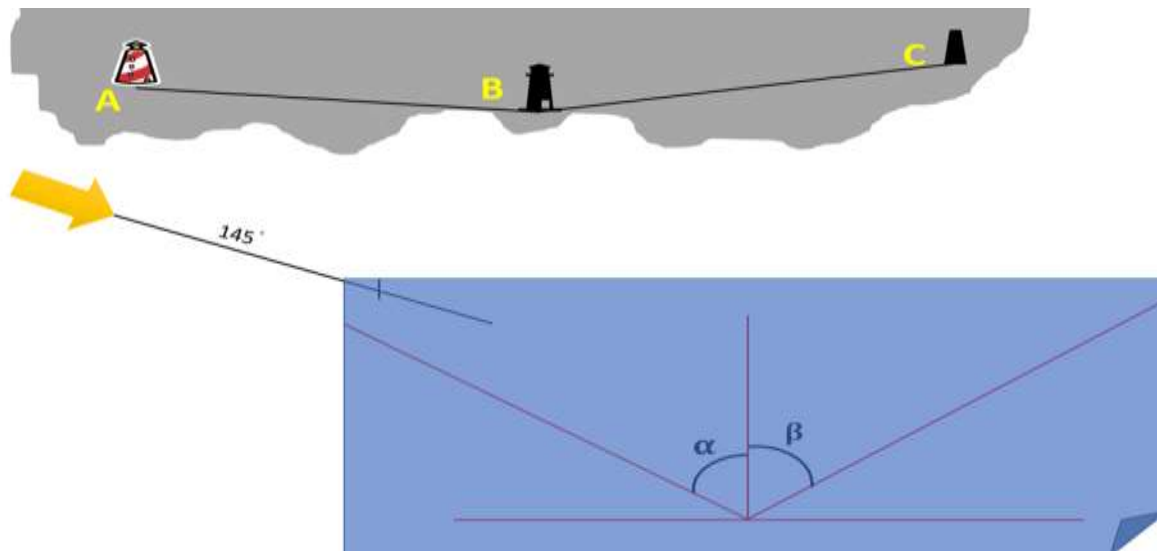


Figure 2.6b. Fixing the ship with transparent paper method. Source: Drawn with PowerPoint by self.

Station Pointer.

The station pointer is quite easy and faster to use when determining the position of the ship. In this method, you just have to move the mobile arms to have α^0 , β^0 with the central arm. The arms on the station pointer must align with the three selected objects with respect to the two angles formed. A fix is formed in the center of the station pointer circle. See figure 2.7 below for demonstration.



Figure 2.7. Fixing the ship using station pointer. Source: https://www.google.ro/search?q=station+pointer&source=lnms&tbn=isch&sa=X&ved=0ahUK Ewji8teLkMPUAhWkYpoKHfVUCkkQ_AUICigB&biw=853&bih=394&dpr=2.25#imgsrc=mgeL0p_482d8SM.

Lines of Equal Depth.

Lines of equal depth are also known as bathymetric lines that form a contour shape according to the irregular changes or topography of the sea bottom. To determine the ship position using lines of equal depth the mariner must take a sounding and compare it to the bathymetric lines in the chart in order to know where the ship is at that particular area. Depths must be taken at a constant basis to know if the ship is on the same bathymetric line. See figure 2.8 below for demonstration.

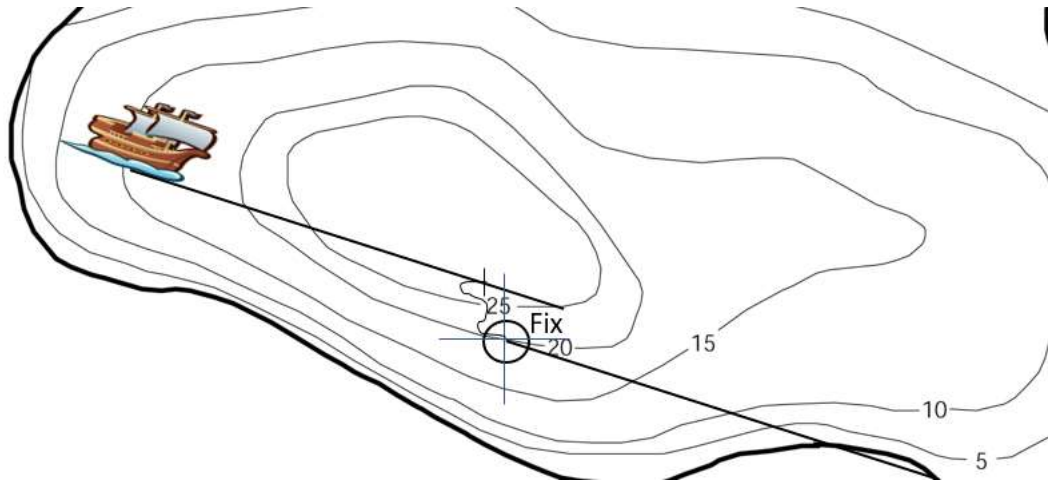


Figure 2.8. fixing the ship with bathymetric lines. Source: Drawn with PowerPoint by self.

2.2. General Errors in the Methods used.

Navigation is an increasingly exactness of science. Electronic positioning systems provide for the navigator a great certainty than ever that his location or position is correct within a few meters. In some cases, the navigator may make some certain assumptions which would be unacceptable in purely scientific work.

For Instance, when the navigator uses his latitude calibration as a mile scale to compute a great circle course and distance, in doing such, he neglects the flattening of the earth at the poles. Another instance look at, where a navigator plots visual bearing on a Mercator chart using a rhumb line to represent a great circle and substituting a rhumb line for a small circle when plotting a celestial line of position. When the navigator interpolates in sight reduction tables, he assumes a linear change between tabulated values, having all these assumptions, there is no way an error will not be introduced.

Navigation has a lot of approximations that result to a natural tendency for some of them to eliminate others. However, If the various minor errors in a particular fix and all have the same sign, in such case the error might be significant. As such, the navigator should make sure he recognizes the limitations of his positioning systems and understand the sources of position error.

Definitions.

Error is the variation of results between a specific value and the standard or correct value. This definition does not include a mistake, but it is related to the absence of perfection. For instance, an altitude determined by a navigational sextant is corrected for a standard amount refraction. If the refraction at the time of observation differs from the standard required, the value taken from the table is an error being identified with the variety of the standard and actual values. Such an error will be compounded with others in the observed altitude. Similarly, a water depth taken by an echo sounder can be erroneous just for the fact that, there is a difference

between the actual speed of sound waves in the water and the speed used for the calibration of the instrument.

The main concern of a navigator studying the sources of errors is primarily the deviation from standard values. Though, a generalized correction can be applied for standard values for errors. It is the deviation from standard, as well as mistakes that produce results which are inaccurate in navigation.

Mistake is a wrong action or statement proceeding from faulty judgement, application of inadequate knowledge or inattention to something. For example, an incorrect reading of bearings or any other navigation instrument, the wrong application of values from nautical tables, entering the wrong data in a database or plotting a reciprocal bearing.

Standard is an established figure, value or quantity by custom, agreement, or an authority as a basis for comparison. Often times, standards are chosen as a model which approximates a mean or average condition. Distinction between standard values and actual values should not be forgotten at any time. Thus, a standard atmosphere has been established in which the temperature, pressure and density are specified precisely for each altitude. Though, the actual conditions are generally different from those defined by the standard atmosphere. A similar case will be the values for dip given in the nautical almanacs whose values are considered standard by those who use them, but the actual dip may vary due to the non-standard atmospheric conditions.

Accuracy is the degree of conformity of a measure to a standard or true value while precision is a measure of refinement of a value. Hence, an altitude determined by a marine sextant might be stated to the nearest 0.1' and yet be accurate only to the nearest 1.0' if the horizon is indistinct.

In navigation systems, there are three types of accuracy, with the first being an absolute accuracy, sometimes referred to as predictable or geodetic accuracy. This is the accuracy of a position with respect to the true geographical coordinates according to the datum being used on that geographical area. Repeatable accuracy is the accuracy with which a navigation system can return to a previously identified position and the last but not the least, Relative accuracy which is a measure of the ability of two different receivers of the same type to define a position concurrently.

Systematic and Random Errors.

Systematic errors are those errors that can be predicted using some rules.

Random errors on the other hand, are unpredictable. Random errors are governed by the laws of probability.

If a mariner take some measurements that are subject to random error and draw a graph of the results, the error values would be normally distributed around a mean, or average value.

Most Probable Position

Most mariners have misled by the simplified definitions and explanations to draw up a conclusion that the line of position is almost unerring and that a good fix has a very little error.

A concept which is more realistic is that of the Most Probable Position(MPP). By applying this concept, a mariner will be able to recognize the probability of errors in all navigation information and determines position by assessing and evaluating all information available.

Assuming a ship were to start from an accurate position and proceed on dead reckoning. If course and speed over the bottom is of equal accuracy, it will definitely increase equally in all

directions the uncertainty of dead reckoning. As the ship proceed a circle of uncertainty would grow around the dead reckoning position. If the mariner has full knowledge of the distribution and nature of the errors of the course, speed and the necessary knowledge of statistical analysis, where he could make a computation for the radius of a circle of uncertainty, using 55 percent, 85 percent, or other probabilities. This method is known as fix expansion when done graphically.

Fix Expansion takes into consideration possible errors in the dead reckoning calculation caused by factors which tend to affect the ship actual course and speed over the ground. The Mariner considers all such factors and develops and expanding “error circle” around the dead reckoning plot. One of the basic assumptions of fix expansion is that the different individual effects of current, leeway and steering errors combine to cause a cumulative error which increases over time. Errors considered in the calculation of fix expansion include all errors that can lead to dead reckoning inaccuracy. Among all, the most important factors are current and wind, compass or gyro error and steering error. The mariner determines the effect of all the various errors on his course and speed over ground and applies that error to the fix expansion calculation. As explained above, error is a function of time; it grows as the ship proceeds along the track without obtaining a fix. For this reason, a mariner must incorporate his calculated errors into an error circle whose radius increases with time. For instance, assuming the mariner calculate that all the different sources of error can create a cumulative position error of no more than 1.5nm. Then his fix expansion error circle would grow at that rate; it would be 1.5nm after the first hour, 3nm after the second and so on. According to the different navigational instrument used on board the vessel, each has a specific value for accuracy. For example, a satellite navigation system has an accuracy of 0.5 nm. For this the navigator is meant set an initial error circle of 0.5 nm around that fix.

First, enclose the fix position in a circle, the radius of the circle must be equal to the accuracy of the system used to obtain the fix. Secondly, lay out the ordered course and speed from the fix position. Apply the fix expansion circle to the dead reckonings hourly, at each DR's increase the radius of the circle by the error factor each time. From the example given above, the dead reckoning will be enclosed with a radius of 1.5 nm after one hour and it increases consecutively in each one hours' time which will be 3.0 nm, 4.5 nm etc. After encircling the four-hour DR positions with the error circles, the navigator then draws two lines starting from the first position which has to be tangent to all the error circles in the direction of the true course of the ship. The navigator then closely examines the area between the two tangent lines to check if there is any hazard to navigation. This technique is demonstrated in figure 2.9 below.

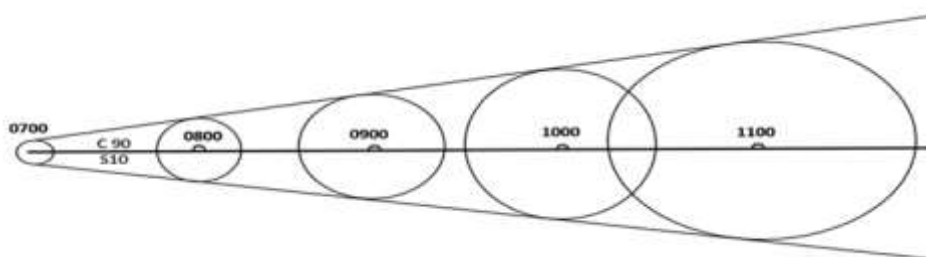


Figure 2.9. Fix expansions. All positions of the ship lie between the lines tangent to the expanding circles. Examine this area for dangers; Source: Nathaniel Bowditch, (2002).

“Navigational errors,” The American practical Navigator, pp 240-350

In ordinary navigation, statistical computation is not practicable. In most cases the navigator estimates at any time the likely error of his dead reckoning or estimated position. With practice, considerable skill in making this estimate is possible. Taking into account the fact that the area of uncertainty might better be represented by an ellipse than a circle, with the major axis

along the course line if the estimated error of the speed were greater than the course and the minor axis along the course line if the estimated error of the course were greater. The navigator will recognize that the size of the area of uncertainty would not grow in direct proportion to the distance or elapsed time, because influence of factors such as wind and current, could not be expected to remain of constant magnitude and direction. Also, he would know that the starting point of the dead reckoning might not be free from error completely.

The navigator can combine LOP with either a dead reckoning or estimated position to determine a Most Probable Position. The MPP is primarily used as a judgement by the navigator to determine the accuracy of the dead reckoning and estimated positions. See figure 2.10 below.

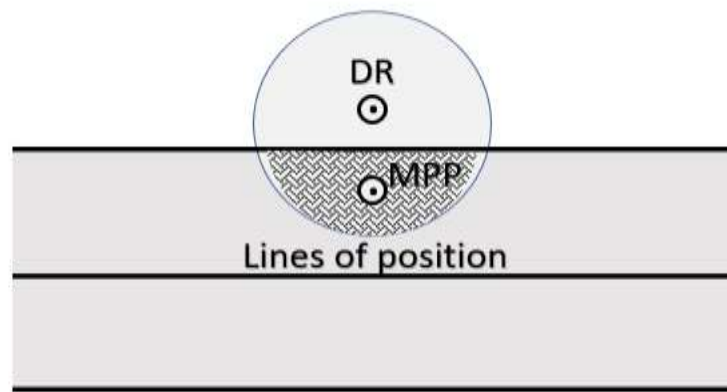


Figure 2.10 A most probable position based upon a dead reckoning position and lines of position having equal probable errors; Source: Nathaniel Bowditch, (2002). "Navigational errors," The American practical Navigator, pp 240-350

If a fix is obtained from two lines of position, the area of uncertainty is a circle if the lines are perpendicular and have equal error. If one is considered more accurate than the other, the area is an ellipse. As shown in figure 2.11. It is also an ellipse if the likely error of each is unequal, the major axis of the ellipse if the likely error of each is equal and the lines cross at an oblique angle. If the errors are unequal, the major axis of the ellipse is more nearly in line with the line of position having the smaller likely error.

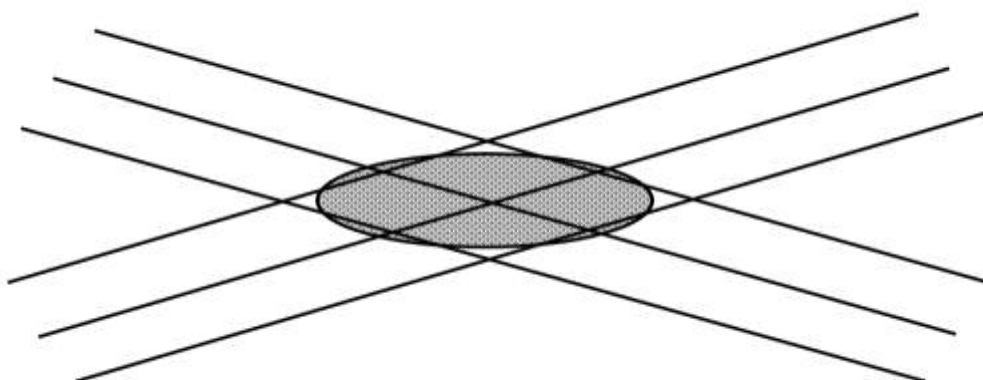


Figure 2.11. Ellipse of uncertainty with lines of positions equal probable errors crossing at an oblique angle. Source: Nathaniel Bowditch, (2002). "Navigational errors," The American practical Navigator, pp 240-350

If a fix is obtained from three or more lines of position with a total bearing spread greater 180° , and the error of each line is normally distributed and equal to that of the others, the most probable position is the point within the figure equidistant from the sides. If the lines are of equal error, the distance of the most probable position from each line of position varies as a function of the accuracy of each LOP.

Systematic errors are treated differently. Generally, the navigator tries to find out the errors and eliminate them or compensate for them. In the case of a position determined by three or more lines of position resulting from readings with constant error, the error might be eliminated by finding and applying that correction which will bring all lines through a common point.

Lines of position which are known to be of uncertain accuracy might better be considered as “bands of position”, with a width of twice the possible amount of error. Intersecting bands of position define areas of position. It is most probable that the vessel is near the center of the area, but the navigator must realize that he could be anywhere within the area and must navigate accordingly.

COMMON ERRORS AND SOURCES

A great deal of factors contributes to potential errors during the course of fixing the ship position and among all, some are unnoticeable while some are widely known making them common in the day to day activities of operating the ship. As the operation of a ship is such a sensitive and diverse application of tasks with procedures, if one fail to observe such procedures duly, then negligence of safety becomes a threat to the ship and its operation. For this reason, every navigator should be aware of such errors and sources so as to find a counteracting solution. Highlighted below is a list of common errors and sources contributing to wrong position determination of which we are going to consider while we analyse the different methods of lines of position used in coastal navigation.

Common Errors.

1. Mis-identification of aids to navigation.
2. Failure to use navigation aids effectively.
3. Failure to apply deviation.
4. Failure to apply variation
5. Failure to adjust magnetic and gyro compass and to keep a table of corrections.
6. Failure to check gyro and magnetic compass regularly.
7. Failure to keep dead reckoning plot
8. Failure to correct chart.
9. Failure to obtain soundings.
10. Failure to indicate course and speed values with direction indication.
11. Failure to compare bearing values taken from navigation devices.
12. Failure to plot new information.
13. Failure to properly evaluate data or information.
14. Poor judgement.
15. Failure to use information in charts and navigation publications.
16. Failure to have back-up navigational methods or devices in case of emergency.
17. Failure to recognize degradation of electronically obtained LOP's or latitude/longitude positions.

SOURCES OF ERRORS.

1. Navigation devices, equipment and tools errors resulting to deviation and variation of magnetic compass, gyro error, sextant error, etc.
2. Observer's errors resulting to less visual acuity or lack of experience.
3. Use of chart and nautical publications that are not up to date there by making use of displaced AtoN and other datum in the navigational area.
4. Weather conditions that leads to the rolling and pitching of the ship as well as causing poor measurement on board.
5. Selection of methods according to the different circumstances encountered during the voyage (selection of objects, time, objects availability, traffic congestion, navigation hazards, etc.)

Every time a position line is obtained from any source (celestial observation, visual bearing, radar range, radio navigation aid etc.). It must be possible to judge its likely accuracy and thus the accuracy of the ship's position obtained from the intersection of two or more such position lines. The accuracy of the position must be taken into consideration which is more probable among the two fixing methods and influencing factors such as tide, current and wind. It is advisable to make a careful analysis of the difference positions encountered after fixing the ship position using DR and EP. From the figure below, ships initial position was determined using celestial observations obtaining a fix at position A at 1100. The DR Position B and the EP position C are both plotted for a fix at 1200. At 1200, a single visual position line was obtained from the light house F. What position should be chosen for 1200 with respect to the DR position and the EP?

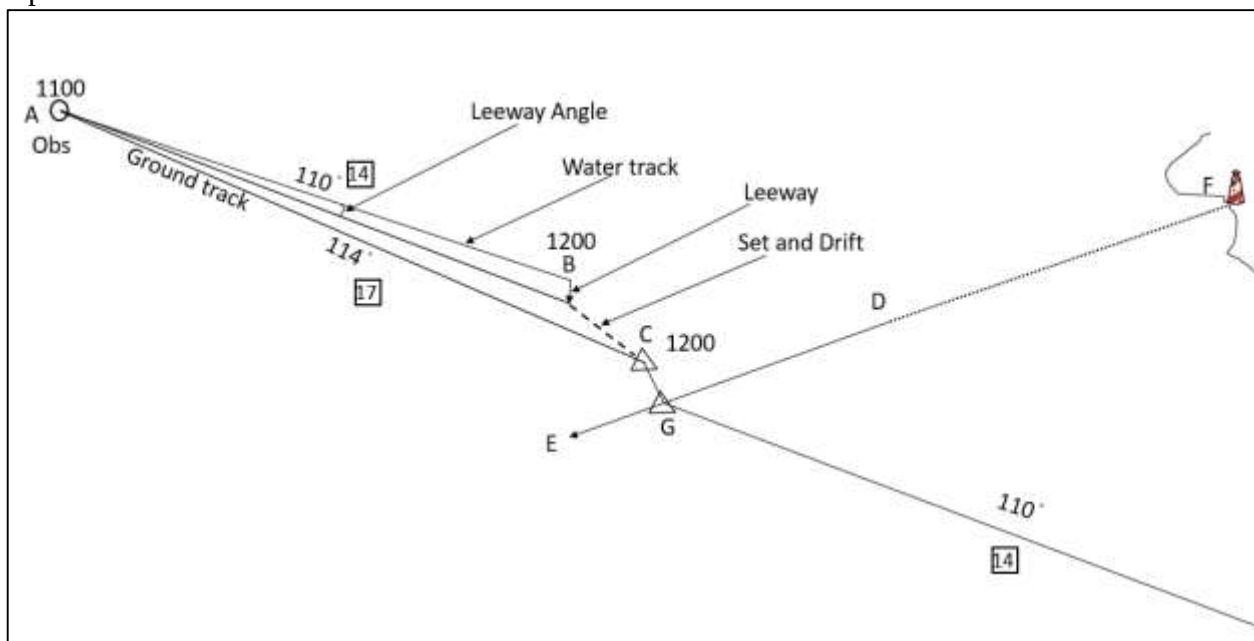


figure 2.12. Deriving the ship's position. Source: Nathaniel Bowditch, (2002).
 "Navigational errors," The American practical Navigator, pp 341-344

From the above diagram, it might be assumed that the observed position' A at 1100 was apparently reliable, the plotting of the of the DR (AB) was apparently correct, the estimates of Leeway, Set and Drift (BC) were less certain but that position line DE at 1200 was apparently reliable. At first glance, it may therefore seem reasonable to take point G as the 1200 EP (where CG is perpendicular to DE, with G being the nearest point to C on the line DE).

Conclusion

The Methods of Lines of Position explained in this chapter, such as transit line, distance arc, line of soundings, horizontal angles and lines of equal depth are methods that are very convenient and efficient to determine the fix of the ship, but it is time consuming than those with bearing lines, such as lines of soundings where the depth of the water has to be taken at regular basis in time intervals. There are also methods that make use of angles, such as horizontal angles, where we have the capable arc method, the segment method, the transparent paper method and the station pointer method of which some are fast and simple while the rest take time to come up with a fix position. The major requirement is to make the correct observation to the navigational aid and to choose objects with better angles. As explained in subheading 2.1; General errors in the methods used, there are many ways a navigator can make an unnecessary error when plotting the LOPs on the chart. As accuracy is a priority in the fixing of LOPS, one must be very careful in all the procedures involved in arriving at a better fix.

CHAPTER THREE

CASE STUDY OF LINES OF POSITION USED IN COASTAL NAVIGATION

3.1. Method of Approach

In this chapter, we are going to discuss about some of the lines of position used in coastal navigation with real charts by selecting a specific route where we will sail to determine our ship position and different fixing methods with observations to ensure that the lines of position are rightly used. For that, we are choosing a ship with details that will be used for computations which will be described briefly below. The planned route is from the North East of CAPO FERRO in position Latitude $41^{\circ}14'.1$ N and Longitude $009^{\circ}35'.6$ E to the South East of CAPO CODA CAVALLLO in position Latitude $40^{\circ}49'.7$ N and Longitude $009^{\circ}47'.3$ E. Along this route we will be using the different lines of position to fix the ship with detail explanation.

3.2. Chart details for Case Study.

Name of chart: Italy – Sardegna CAPO FERRO TO CAPO CODA CAVALLLO.

Chart number: 1211

Depth in meters: Scale 1:50000

Depths are in meters and are reduced to chart Datum, which is approximately the level of lowest Astronomical Tide. The tidal range is less than 0.5 meters.

Heights are in meters above Mean Sea Level.

Positions are referred to WGS84 Datum (CAUTION – see CHART ACCURACY note.)

Navigational marks: IALA Maritime Buoyage System – Region A (Red to Port)

Projection: Transverse Mercator.

Sources: Italian Government charts of 1990 – 2009. Details of the source surveys are not available. Later information has also been included.

Notices to Mariners: provide important information concerning safety of navigation, such as weather information known as hydrographic information, changes in radio channels, shift of navigational aids, etc. In this chart, the last year of update is 2014. It is very possible that most of the chart information must have changed by now which needs an update from notices to mariners. To have good fixes or the accurate position of the ship, you need a chart



Figure 3.1 Notes of notices to mariner. Source: Photo from Chart 1211.

that is up to date, even if it is not, as a navigator it is your responsibility to find the latest information in notices to mariners to update it. Looking at the figure above you will see that there is a note on the chart advising mariners to exercise caution due to significant depth changes in the stated position and the indication for the last update which is 2014 written in red.

3.3. Ship Details for Case Study.**Vessel Type:** Tanker**Name:** ANGELICA SCHULTE**Nationality:** Liberia.**IMO/Lloyd's No:** 9296822.**Radio accounting:** CY 03.**MMSI:** 636 090 864.**Table 3.1. Hull dimensions and Load lines**

HULL DIMENSIONS		LOAD (Freeboard deck line)	LINE from	
Length LOA. Ext.	243,00m	Tropical		5688 mm (T)
Length LPP	233,00m	Summer		5995 mm (S)
Breadth moulded	42,00m	Winter		6302 mm (V)
Depth moulded	20,70m	Winter Atlantic	North	Not required
Summer draught	14,75m	Load line:		
Corresponding deadweight	106,443mt	Fresh water allowance		334 mm above (S)
Max air draft above BL.	49,258m	The upper edge of the deck line from which these freeboards are measured is		

Table 3.2. Tonnage values.

Tonnage	Gross	Net
International	56,163	32.720
Suez	57,624.26	53,519,48
Light Ship weight	16.403 mt	16,403 mt
L.S Freeboard	18,497	18,497

Table 3.3. Speed Characteristics

RPM and SPEED			
Engine order	RPM	Speed in loaded condition	Speed in ballast condition
Full navigation	97.6	15.7 Knots	16.7 Knots
Full ahead	68	11.0 Knots	12.3 Knots
Half ahead	58	9.4 Knots	10.8 Knots
Slow ahead	41	6.6 Knots	8.0 Knots

Dead slow ahead	32	5.2 Knots	6.5 Knots	
Time and Distance to stop				
	Normal loaded condition		Normal ballast condition	
	Time	Distance	Time	Distance
Full navigation	15m 02s	1.88 nm	8m 08s	1.1 nm

Main Engine: One “SULZER” 7RTA58T two-stroke, turbo-charged marine diesel engine / Max Cont. Rating: 14,000 kW at 103 rpm / Cont. Service Rating: 11,900 kW at 97.6 rpm / Max. F.O. daily consumption: 48.3 Mt / Max bunker intake: 2,972 m³ Fuel Oil -330 m³ Diesel Oil / Propeller submerged at: 7.54 m.

The most important characteristic of the ship that will influence our voyage is the draft and the speed characteristics of the vessel in terms of turning when changing the course head of our ship and as for the draft of the vessel we are sailing on a summer draft of 14.75m in a geographical area with minimum depth of 52m which is free from grounding and speed with 9.4 knots (half ahead) on a loaded condition that will enable us to make observations in allowed time and can also be reduced to 6.6knots (Slow ahead) when needed for collision avoidance purpose.

The details given above are real information that will help us to make our computations as regard bearing correction and magnetic compass correction, and to compute the distance and time intervals between route legs. Among other details are the **Deviation** which is **0 °.8**, the **Loch Factor** which is **1.00** and the **Gyro Error** which is **1 °.4**. With these we will be able to make our corrections and computation for the different route legs. As a tanker ship which is running at an average speed of 6.4 knots, it will be quite easy for the mariner to make his observations to navigational aids and a less expectation of magnetic errors that will affect the bearings, since it does not carry cargoes made of iron or other metals that can compromise the functionality of the magnetic compass on board.

3.4. Personal Practical Contribution.

SAILING FROM CAPO FERRO TO CAPO CODA CAVALLO.

As we sail from CAPO FERRO to CAPO CODA CAVALLO we will be using different lines of position in fixing the ship and why those methods seem the best to be used at those different positions. What specifically are we considering when applying these different methods and indication of potential errors. In all methods, there will be a figure to show what has already been discussed in other for we to understand better. The ship is steering at Gyro Course, so we will be computing the true course to know the differences and the correction for true bearings, since the bearings will be taking as gyro bearing at first.

Firstly, find the position of the ship, and to do that, we need a line of position which will give us a fix indicating the current position of the ship.

Obtaining Lines of Position using bearing and Range.

Why are we using bearing and range? Looking around the navigational area we can observe that there are insufficient Nav aids, we only have two light houses that is seen on the same bearing line, one lying behind the other. In this case, what we need to do is to use one of the light houses, probably, the one closer and visible to the ship. Highlight it, take the name (North Cardinal light house at **SECCA DEI MONACI Q.6m3M**) down. Take a bearing from the light house already highlighted in the figure below with red colour. In our own case the bearing is Gyro bearing, $GB=249.6^{\circ}$. Make corrections to the True Bearing and draw it on the chart. After drawing the line, measure the range of the bearing starting from the base of the light house. In our own case the range is 2.4 NM. Where the range ends that is where the fix is formed, which is the position of the ship and the time noted close to the fix which is 06.00. As for the correction, the True Bearing formula is $TB=GB + GE, = 249.6^{\circ} + 1.4^{\circ} = 251^{\circ}$. Now we can see that there is a variation between the GB and the TB or assuming the GE is -1.4° , an omission of bearing correction $[249.6^{\circ} + (-1.40)^{\circ} = 248.2^{\circ}]$ will make a difference of 2.8° contributing as bearing error. So, always make the correction before drawing the lines of position on the chart to avoid potential errors.



Figure 3.2 Obtain the ship position using bearing and range. Source: Photo from Chart 1211.

From the fix, the ship alter a gyro course of 162.6° . Having known that we are sailing on a gyro course we must compute our True Course and Compass Course and use the TC for the drawing of the route leg. The computation will make us to know the effect of the magnetic variation and the deviation. The True Course formula is $TC = GyC + GE = 162.6^{\circ} + 1.4^{\circ} = 164^{\circ}$.

Magnetic Variation.

Magnetic variation is the difference of angular measurement between the True North and the Magnetic North. It is either inclined to the westward or eastward side of the True North. It either increases or decreases according to the effect produced by the rotation of the earth or other gravitational forces around the earth. In almost all chart the magnetic variation is indicated as follows $3^{\circ}.00$ W 2016 ($6'$ E) or $1^{\circ}.04$ E 2013 ($6'$ W) inside a compass drawn inside the chart. The first cardinal mark after the degrees represents the side of inclination with a positive sign (+) for East and negative sign (-) for West and values with minute sign and cardinal mark in bracket represent the annual rate of change. The same sign rules are applied to it too. In every chart, depending on the geographical areas in the chart, there are different magnetic variations in different areas which must be corrected in order to know our Compass Course and to know the correct True bearing of our observations. In our own case the magnetic variation is $2^{\circ}.00$ E 2014 ($6'$ E) throughout the whole chart. So, after calculating it we will use it to correct the Compass Course and all the True Bearings in our consecutive fixes. (See figure below.)

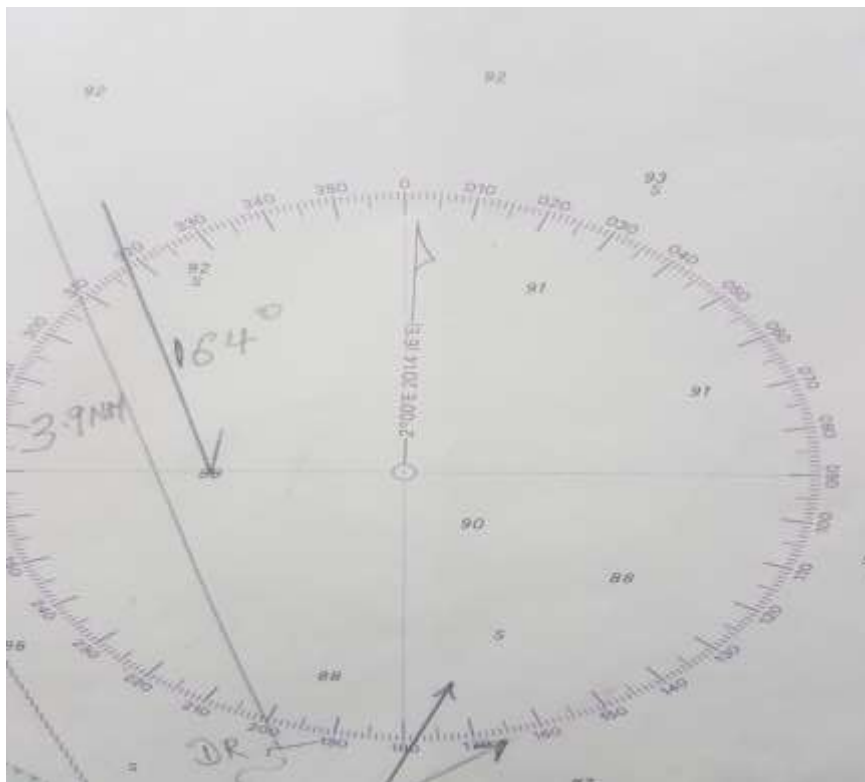


Figure 3.3 Magnetic Rose with variation for the year 2014. Source: Photo from Chart 1211.

The formula for Magnetic Variation is $\text{MagVar} = \text{MagVar}_{2014} - \text{ChartVar} = \text{MagVar}_{2017} = +2^{\circ}.00' + [3 \times (+6) = 0^{\circ}.18'] = +2^{\circ}.18' = +2^{\circ}.3$.

The chart variation is multiplied by the year difference with the annual rate of change which will be in minutes and be converted to degrees and minutes. From our calculation, it shows that the chart variation for the year 2017 is $+2^{\circ}.3$. To know our Compass Course, we need to calculate the Compass Error before can start looking for the Compass Course. Formula for Compass Error is $\text{CE} = \text{MagVar} + \text{Dev} = +2^{\circ}.3 + 00.8 = +3^{\circ}.1$.

Now we can calculate the Compass Course which is the addition of True Course and Compass Error. $\text{CC} = 164^{\circ} + 3^{\circ}.1 = 167^{\circ}.1$. You can see that the difference between the True Course and the Compass Course is because of the Compass Error. The best thing is to always make the corrections to avoid variations that will lead to steering the ship in the wrong Course.

After steering on a True Course of 164° for 3.9NM, a second lines of positions were used to fix the ship's position.

Obtaining Lines of Position using three cross bearing.

Why three cross bearing? Looking around the coastal area, unlike the above situation we have more than two navigational aids to fix the ship. Applying three cross bearing will be able to tell well where the position of the ship is. As usual, the first thing is to make the observation with the time at which they were being observed and the second thing is to take the True Bearing and correct the bearings and draw them out on the chart. When making the observation, make sure all the three bearings are visible. In our own case, we have chosen three bearings which are;

1. CAPO FERRO Fl.R.3s14m8M, TB = 268°
2. A Leading Line, TB = $252^{\circ}.4$
3. Q (3) 10s 6m4M, TB = 201°



Figure 3.4 Three cross bearing with potential errors. Source: Photo from Chart 1211.

The three LOPs taken are expected to intersect in one point to give us the position of the ship, but after drawing them on the chart, we found out that a triangle is being formed which is called a **cocked hat**. As we discuss in chapter one under the types of Lines of Position; **Fixing the ship by three cross bearing**. We discussed that whenever the three bearings form a cocked hat, we should apply the centre of gravity principle to determine the ship's position, but before that we must find out the length of the triangle sides to see if they are less than 1 NM. From our plotting the sides of the length is more than 1 NM of which we cannot apply the centre of gravity rule. That means, something is wrong somewhere that we need to correct immediately. Looking at the angles formed by the bearings, it is so obvious that the angle between light house **CAPO FERRO Fl.R.3s14m8M** and the **Leading Line**. A measurement of the angle reveals that it is less than 30° which is unacceptable to use as a LOP. This is one of the reasons why we need to

take into account the angles between Navaids before using them, to avoid delays and potential errors. (See figure 3.4 above for the angle and the size of the cocked hat).

Since the mistake has been found, we must retake our true bearings again, this time considering the angles between the chosen objects.

1. CAPO FERRO Fl.R.3s14m8M, TB = 268°
2. ISOLE DI LI NIBANI Q.21m4M, TB = 232°
3. Q (3) 10s 6m4M, TB = 201°



Figure 3.5. Obtaining ship Position using three cross bearing. Source: Photo from Chart 1211.

From the figure above you can see that there is a good angle between the bearings and the formation of the triangles are far less compared to the previous plotting. Looking at the sides of the triangle all sides are less than 1 NM, So, we can apply the center of gravity rule to know the center. The center of the triangle is the fix which is the position of the ship. From the figure above you can see both the time for the determination of the fix and also where the next True Course of the ship is drawn from. The main reason why we were able to use another bearing in place of the Leading Line is because of the lesser angle and we have a lot of navigational aids in the coastal area. What is advisable is to know how many navigational aids are in the coastal area and the selection of object should be done considering how far apart the aids to navigation are to avoid the triangle error and delays in fixing the ship. From this position, the ship is steering a True Course of 151° and sailing 4 NM. After sailing for 4 NM another Lines of Position was used to determine the ship's position.

Obtaining Lines of Position with Running fix.

Why running fix? Before we could answer this question, we need to remind ourselves about what was discussed about Running fix in chapter one. In chapter one, it was explained under running fix that it can be applied to fix the ship when we lack aids to navigation. In our own case, not that we lack aids to navigation, but because the aids to navigation are not visible from the bay we are passing by, assuming there are enough visible aids, we can apply any other methods to fix the ship. Also, we could have used one aid only for the running fix, but in this case using two aids to navigation is preferred. At 07:16 a navigational aid was observed and a bearing was taken, which is **TB = 256°** from a Navaid at **ISOLE MORTORIOTTO FL (2) 6s10m4M**. Then the ship sailed for a distance of **4.8 NM** and make another observation. During these time of the voyage the ship's True Course and the Speed remain the same, because any change in the True Course will result to unwanted errors in fixing the ship. So, Course and Speed remain unchanged from first to second observation. The second bearing was taken from a **Radio Mast** with a **TB = 243°**. After drawing the second bearing on the chart, the True Course line is transferred or drawn from the base of the first object. The parallel line should be measured with the distance sailed in between the first observation and the second observation. In our case, the ship sail for 4.8 NM. So, we are measuring the range of the parallel line with 4.8 NM. At the end of the parallel line we either transfer the bearing of the first object or we draw the True bearing of the first object. Most times student find it difficult to transfer it, while moving the navigational triangle their hands shake and it alter the bearing, but either way it takes practice to perfect it.

After transferring the first object to the end of the parallel line, it will intersect with the second bearing line. The transferred line is marked with double arrows. The intersection is called Running fix (It is highlighted with a yellow arrow in the diagram). From this point the ship steers either on the same course or it alters it Gyro course. (See figure 3.6 below for the plotting as described.). From this point the ship alter her Gyro course to **128°.6** and sails for **7.8NM**. At 09:14 the ship made new observations to determine a fix using different Lines of Position.



Figure 3.6 Lines of position with Running fix using two Objects. Source: Photo from chart 1211

Obtaining Lines of Position using distance arc method.

This type of fixing the ship is more like the bearing and range, but an exemption of bearing while we use only the navigational aids and the range of each objects and it is quite easy to fix the ship with such method, because you don't have to take bearings and corrections. At 09:14 two navigational aids; **PTA TIMONE (63) LFL (2) 10s72m15M** and **FL (2) Y.10s** was observed one after the other, having a range of **4.6NM** and **3.6NM** respectively. We use the instrument called compass to make an arc for both objects with their specific range. After making an arc with their range, the intersection of the two arcs is known as our fix. See figure 3.7 below.

The navigational objects used for the Distance arcs are highlighted with red circle and a yellow arrow indicating where the fix point is. From the fix is drawn another true course line. In this diagram if you can look very well at the two navigation aids, it is so obvious that the angle between them is more than 30 degrees and that makes it more perfect in determining the fix. We can also use another method of Lines of Position, probably two cross bearing would have been a perfect method to determine our fix, but the main purpose is to use different methods with different LOPs. The advantage of using Distance arc method is the time used compared to the two-cross bearing where you must take the bearings, correct them and draw them on the chart which might also result to drawing errors. With all these, distance arc is more convenient and faster to determine the ship position. But that notwithstanding, it has its own disadvantages too, in a situation where by the compass used in making the arcs are loose, then we will not be able to get an accurate position of the ship. So, a mariner must make sure the instrument used in making the arcs are not loose, to avoid potential errors. Proceeding on a True Course of 157° , the ship sail for **3.2 NM** to determine another fix using Lines of Position. At this point, the ship uses two cross bearing to determine its position.

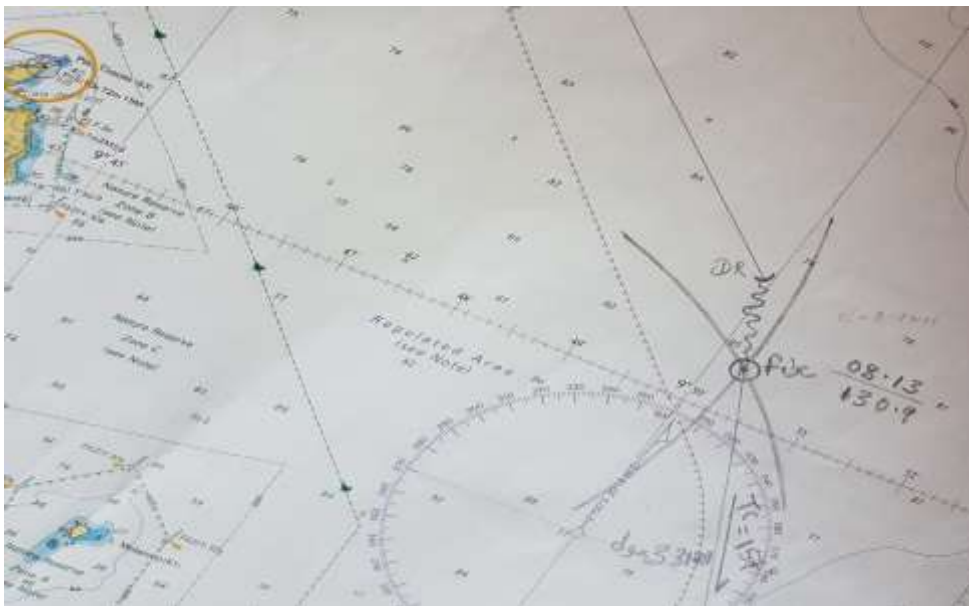


Figure 3.7. Fixing ship position with two Capable arcs. Source: Photo from chart 1211

Obtaining Lines of Position using two-cross bearing.

As explained in chapter one under types of LOPs, the first step is to make our observations to the navigational aids around the vicinity and how visible they are. Looking at the



coastal area we can found out that we have a lot of Navaids, so we decide to take a first bearing from **FL (2).10s** with a **TB = 284°** and take another bearing from **FL.Y.5s** with a **TB = 260°.5**. After every necessary correction, we draw the bearing lines on the chart. The intersection of the two bearing lines provide a fix for us, which is the position of the ship. Quite simple as explained. See figure 3.8 for demonstration.

Figure 3.8. Obtaining ship position using two cross bearing. Source: Photo from chart 1211.

Looking at the figure above there are up to four navigational aids in the vicinity, and our fix seems very perfect. But if you look closely you will found out that something is wrong with the LOPs used. The number of Navaids should not be a determining factor to using two or three of them. What we didn't consider in this fix was the angle between the chosen objects. The angle is less than 30° which is unacceptable in determining fixes. We might have a fix as perfect as it is indicated with the yellow arrow in the figure above. But the lesser the angles between objects the bigger our positional errors. To avoid this, a mariner must always consider the angles between two chosen Navigational aids before using them, or drawing them on the chart. The main reason why two cross bearing was used here is because, we have many objects in the vicinity. But the priority should be the angle between the objects. To be more accurate, a **bearing and range** should be used to determine the position of the ship. We can choose any of the Navaids around for the bearing and range. As discussed in chapter one under types of LOPs; figure 1.4a illustrate the order of measuring bearing, that objects from abeam and on the forward sides of the fore and aft line of the ship should be used to determine the ship. In our own case looking at the Navigational aids in the vicinity, the light house **FL.Y.5s** is in a perfect order from our ship. It is located abeam of our ship. Having chosen the right object, we take it bearing which is **TB = 260°** and draw it on the chart after necessary correction. Then, the second step is to measure the range of the bearing on the bearing line which is **3.3 NM**. At the end of the measurement of the range, we mark it as fix indicating the position of the ship. Look at the figure 3.9 below for demonstration.

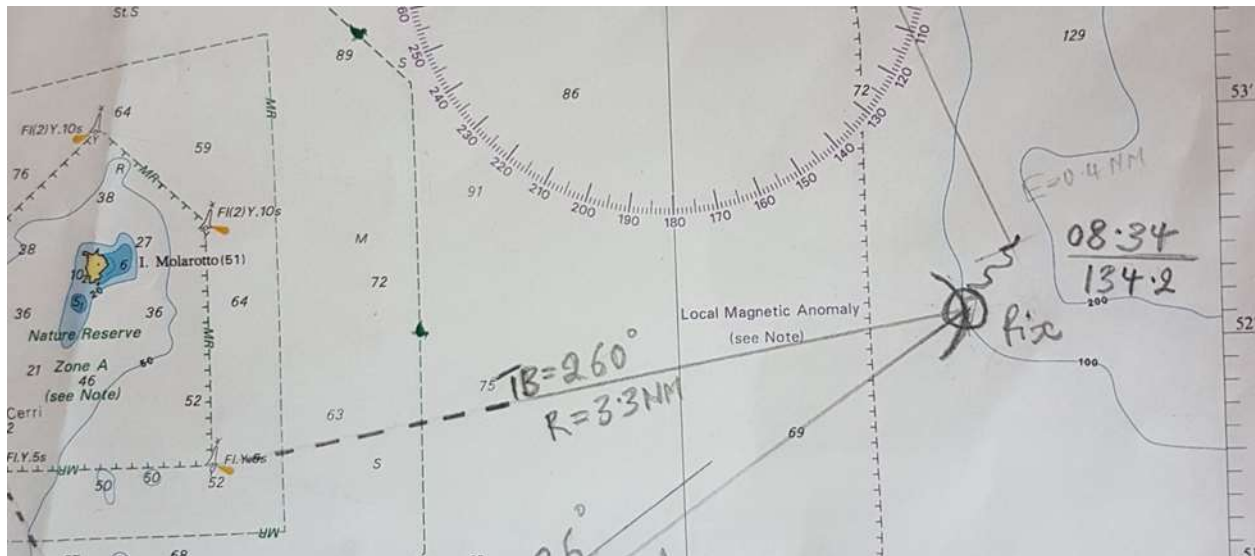


Figure 3.9. Obtaining ship position using Bearing and Range. Source: Photo from chart 1211

From the chart, we are instructed to see a note specifying a Local Magnetic Anomaly. These are some of the factors contributing to wrong bearing lines, and as a mariner it is very important to make correction to the Magnetic Compass, so that, both our bearings and the True Course of the ship will not be susceptible to errors. See image of note below.

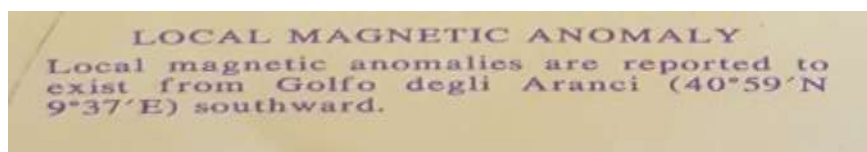


Figure 3.10. Notes concerning Local Magnetic anomaly. Source: Photo from chart 1211

Obtaining Lines of Position using Two cross bearing at arrival destination.

After steering a True Course of 236° for 3.9NM, the ship arrived at **CAPO CODA CAVALLO** and two cross bearing was used to determine her position. A first bearing was taken from the light house **FL.Y.5s** with a **TB = 334°** and a second bearing was taken from a southern cardinal mark at **SCOGGIO TESTA DI MORO Q (6) + LFL.15s6m3M** with a **TB = 262°** . All bearings being corrected, a fix was determined at the intersection of the two Lines of Position drawn on the chart. See figure 3.11 for demonstration.

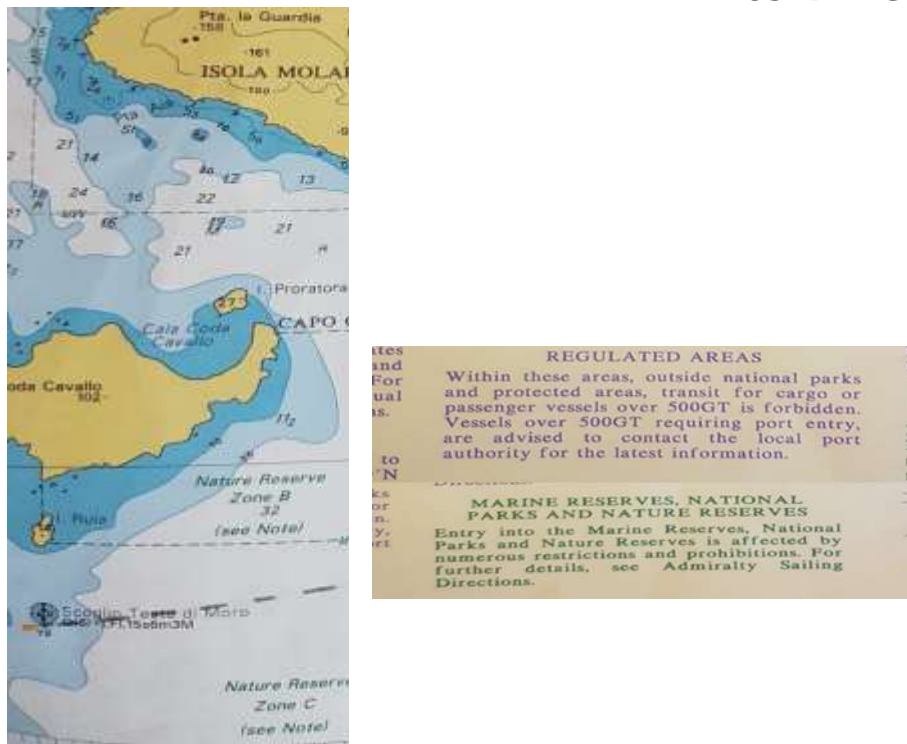


Figure 3.11. Obtaining ship position using two cross bearing to fix ship position: Photo form chart 1211

Looking at the fix area, there are many notices to mariner with specific instruction and information. For this we must take a look at each of them to know whether our fix is in the right zone or not. See figure 3.12 for demonstration.

- Regulated Area (see note); Within these areas, outside national parks and protected areas, transit for cargo or passenger vessels over 500GT is forbidden. Vessels requiring port entry, are advised to contact the local port authority for the latest information.
- Nature Reserve Zone C (see note); Entry into the Marine Reserves, National Parks and Nature Reserves is affected by numerous restrictions and prohibitions. For further details, see Admiralty Sailing Directions.

In respect to the first and second bullet point, our ship is a tanker vessel with gross tonnage of 998 which requires more information from local port entry before even making our last fix. Looking at the vicinity there are a lot of restriction zones, though our fix is in the Regulated Area and quite close to the Nature Reserves Zone. Before determining the fix, the mariner must consider the notices to mariner and contact Local Port authority to stop at a zone permitted by them. If not, the fix is in the wrong position. See figure 3.11 and 3.12 for demonstration.

Figure 3.12. Notes of Notices to mariners: Photo form chart 1211.

Computation for route legs.

Chart1211, Sailing is done by gyrocompass; $\Delta g = 1^\circ.4$

Loch correction factor = 1.00

Dev = $0^\circ.8$

Vessel Speed = 9.4 Knts = 1.57 Cb/Min

Table 3.4. Data for Computation

Nr.	$\frac{H}{Log}$	Known data	Needed datas
1.	$\frac{06.00}{110}$	Ship position $\phi_1 = 41^\circ 14'.1$ N, $\lambda_1 = 009^\circ 35'.6$ E. Ship position was deteminated by Bearing and distance: • TB = 251° to SECCA DEI MONACI Q.6m3M • RNG = 2.4 NM From this position the ship alters course to GyC= $162^\circ.6$.	TC;
2.	$\frac{06.25}{Log_2}$	Ship position was deteminated by Three Cross Bearing: • GB ₁ = $266^\circ.6$ To CAPO FERRO Fl.R.3s14m8M. • GB ₂ = $230^\circ.6$ To ISOLE DI LI NIBANI Q.21m4M. • GB ₃ = $199^\circ.6$ To Q (3) 10s 6m4M From this position the ship alters course to GyC= $149^\circ.6$.	ϕ_2 ; λ_2 ; dist ₁ ; Log ₂ ; TB ₁ ; TB ₂ ; TB ₃ ; TC; CE; CC. E ₁ .
3.	$\frac{06.51}{Log_3}$	Ship position was determined by GPS. ϕ_3 : $41^\circ 06'.2$ N. λ_3 : $009^\circ 39'.9$ E From this position the ship alter courses to GyC= $141^\circ.6$.	Dist ₂ ; Log ₃ ; TC; CC.
4.	$\frac{H_4}{123}$	Ship position was deteminated with a Running Fix using two Nav Aids. • TB ₁ = 256° to ISOLE MORTORIOTTO FL (2) 6s10m4M at 07.16. • TB ₂ = 243° to a Radio Mast at CAPO FIGARI (second True Bearing taken after sailing for 4.8 NM) From this position the ship alter courses to GyC= $128^\circ.6$.	ϕ_4 ; λ_3 ; dist ₃ ; H ₄ ; TC; CC; E ₂ .
5.	$\frac{H_5}{130.8}$	Ship position was deteminated with two Nav Aids and distance: • Nav Aid1 PTA TIMONE (63) LFL (2) 10s72m15M , RNG = 4.6 NM • Nav Aid2 To FL (2) Y.10s , RNG = 3.6 NM From this position the ship is alter course to GyC= $155^\circ.6$	ϕ_5 ; λ_5 ; dist ₄ ; TC; CC; E ₃ .
6.	$\frac{08.34}{Log_6}$	Ship position was deteminated by Bearing and range: • TB = 260° . To FL.Y.5s. • RNG = 3.3 NM From this position the ship alter course to GyC= $234^\circ.6$	ϕ_6 ; λ_6 ; $\Delta\phi_4$; dist ₅ ; Log ₆ ; TC; CC; E ₄ .
7	$\frac{08.59}{Log_7}$	Main engine has stopped. Ship postion was determined by Two Cross Bearing. • GB ₁ = $332^\circ.6$ To FL.Y.5s. • GB ₂ = $260^\circ.6$ To SCOGGIO TESTA DI MORO Q (6) + LFL.15s6m3M.	ϕ_7 ; λ_7 ; dist ₆ ; Log ₇ ; E ₅ .

Abbreviations/Symbols used in the computation.

- S = Speed, $6.4 \div 6 = 1.07$ Cb/Min
- H = Hour.
- T = Time.
- Dist = Distance.
- Cb = Cable
- Min = Minute

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- MagVar = Magnetic Variation
- CharVar = Chart Variation
- ϕ_2 = Latitude
- λ = Longitude
- LogDist = Log Distance
- Dev = Deviation
- TC= True Course

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- CC= Compass Course.
- CE = Compass Error
- GC= Gyro Course
- GB= Gyro Bearing
- TB= True Bearing.

Table 3.5. Solution for needed Information

NO.1			
<u>1.FIND TC</u> GC= $162^{\circ}.6$ + GE = $+1^{\circ}.4$ TC= 164°			
NO.2			
<u>1.FIND TIME</u> $H_2 = 06.25$ - $H_1 = 06.00$ T= 25 Min	<u>2.FIND Dist1</u> S = 1.57 Cb/Min × T= 25 Min Dist1= 39 Cb = 3.9 NM	<u>3.FIND LogDist</u> Dist1= 3.9 NM ÷ F = 1 LogDist = 3.9	<u>4.FIND Log2</u> Log1= 110 + LogDist= 3.9 Log2=113.9
<u>5.FIND TB₁</u> GB ₁ = $266^{\circ}.6$ + GE = $+1^{\circ}.4$ TB ₁ = 268°	<u>6.FIND TB₂</u> GB ₂ = $230^{\circ}.6$ + GE = $+1^{\circ}.4$ TB ₂ = 232°	<u>7.FIND TB₃</u> GB ₃ = $199^{\circ}.6$ + GE = $+1^{\circ}.4$ TB ₃ = 201°	
<u>8.FIND MagVar 2017</u> MagVar14= $+2^{\circ}.00$ + CharVar $[3 \times (+6)] = +18' = +0^{\circ}.18'$ MagVar17= $+2^{\circ}.18' = +2^{\circ}.3$	<u>9.FIND CE</u> MagVar= $+2^{\circ}.3$ + Dev = $+0^{\circ}.8$ CE= $+3^{\circ}.1$	<u>10.FIND TC</u> GC= $149^{\circ}.6$ + GE = $+1^{\circ}.4$ TC= 151°	
<u>11.FIND CC</u> TC= 151° + CE = $+3^{\circ}.1$ CC= 151°	<u>12.FIND Latitude 2</u> ϕ_2 : $41^{\circ}09'.7$ N <u>13.FIND Longitude 2</u> λ_2 : $009^{\circ}37'.3$ E	<u>14.FIND Error 1</u> E ₁ = $0^{\circ}.6$	
NO. 3			

<u>1.FIND TIME</u> H ₃ = 06.51 - H ₂ = 06.25 T= 26 Min	<u>2.FIND Dist2</u> S = 1.57 Cb/Min × T= 26 Min Dist1= 41 Cb = 4.1 NM	<u>3.FIND LogDist</u> Dist2= 4.1 NM ÷ F = 1 LogDist = 4.1	<u>4.FIND Log3</u> Log2= 113.9 + LogDist= 4.1 Log3=118
<u>5.FIND TC</u> GC= 141 ⁰ .6 + GE = +1 ⁰ .4 TC=143 ⁰	<u>6.FIND CC</u> TC= 143 ⁰ + CE = +3 ⁰ .1 CC=146 ⁰ .1	<u>7.FIND Latitude 3</u> φ ₃ : 41°06' .2 N <u>8.FIND Longitude 3</u> Λ ₃ : 009°39' .9 E	
NO.4			
<u>1.FIND LogDist</u> Log4= 123.1 - Log3= 118 LogDist= 5.1	<u>2.FIND Dist3</u> LogDist = 5.1 ÷ F= 1 Dist1= 5.1	<u>3.FIND TIME</u> Dist3= 51Cb ÷ S = 1.57 Cb/Min T = 32 Min	<u>4.FIND H₄</u> H ₃ = 06.51 + T =00. 32 H ₄ = 07.23
<u>5.FIND TB₁</u> GB ₁ = 254 ⁰ .6 + GE = +1 ⁰ .4 TB ₁ = 256 ⁰	<u>6.FIND TB₂</u> GB ₂ = 241 ⁰ .6 + GE = +1 ⁰ .4 TB ₂ = 243 ⁰	<u>7.FIND CC</u> TC= 130 ⁰ + CE = +3 ⁰ .1 CC=133 ⁰ .1	<u>8.FIND TC</u> GC= 128 ⁰ .6 + GE = +1 ⁰ .4 TC=130 ⁰
<u>9.FIND Latitude 4</u> φ ₄ : 41°01' .2 N <u>10.FIND Longitude 4</u> Λ ₄ : 009°42' .1 E	<u>11.FIND Error 2</u> E ₂ = 0 ⁰ .4		
NO.5			
<u>1.FIND LogDist</u> Log5= 130.9 - Log4= 123.1 LogDist= 7.8	<u>2.FIND Dist4</u> LogDist = 7.8 ÷ F= 1 Dist4= 7.8	<u>3.FIND TIME</u> Dist4= 78 Cb ÷ S = 1.57 Cb/Min T = 50 Min	<u>4.FIND H₅</u> H ₄ = 07.23 + T =00.50 H ₅ = 08.13
<u>5.FIND CC</u> TC= 157 ⁰ + CE = +3 ⁰ .1 CC=160 ⁰ .1	<u>6.FIND TC</u> GC= 155 ⁰ .6 + GE = +1 ⁰ .4 TC=157 ⁰	<u>7.FIND Latitude 5</u> φ ₅ : 40°55' .4 N <u>8.FIND Longitude 5</u> Λ ₅ : 009°50' .4 E	<u>9.FIND Error 3</u> E ₃ = 0 ⁰ .7
NO.6			

<u>1.FIND TIME</u> $H_6 = 08.34$ $- H_5 = 08.13$ $T = 21 \text{ Min}$	<u>2.FIND Dist5</u> $S = 1.57 \text{ Cb/Min}$ $\times T = 21 \text{ Min}$ $\text{Dist5} = 33 \text{ Cb} = 3.3 \text{ NM}$	<u>3.FIND LogDist</u> $\text{Dist5} = 3.3 \text{ NM}$ $\div F = 1$ $\text{LogDist} = 3.3$	<u>4.FIND Log6</u> $\text{Log5} = 130.9$ $+ \text{LogDist} = 3.3$ $\text{Log6} = 134.2$
<u>5.FIND TB₁</u> $\text{GB}_1 = 258^{0.6}$ $+ \text{GE} = +1^{0.4}$ $\text{TB}_1 = 260^0$	<u>6.FIND CC</u> $\text{TC} = 236^0$ $+ \text{CE} = +3^{0.1}$ $\text{CC} = 239^{0.1}$	<u>7.FIND TC</u> $\text{GC} = 234^{0.6}$ $+ \text{GE} = +1^{0.4}$ $\text{TC} = 236^0$	<u>8.FIND Latitude 6</u> $\phi_6: 40^\circ 52' .1 \text{ N}$ <u>9.FIND Longitude 6</u> $\Lambda_6: 009^\circ 51' .6 \text{ E}$
<u>10.FIND Error 4</u> $E_4 = 0^{0.4}$			
NO.7			
<u>1.FIND TIME</u> $H_7 = 08.59$ $- H_6 = 08.34$ $T = 25 \text{ Min}$	<u>2.FIND Dist5</u> $S = 1.57 \text{ Cb/Min}$ $\times T = 25 \text{ Min}$ $\text{Dist5} = 39 \text{ Cb} = 3.9 \text{ NM}$	<u>3.FIND LogDist</u> $\text{Dist5} = 3.9 \text{ NM}$ $\div F = 1$ $\text{LogDist} = 3.9$	<u>4.FIND Log6</u> $\text{Log5} = 134.2$ $+ \text{LogDist} = 3.9$ $\text{Log6} = 138.1$
<u>5.FIND TB₁</u> $\text{GB}_1 = 258^{0.6}$ $+ \text{GE} = +1^{0.4}$ $\text{TB}_1 = 334^0$	<u>6.FIND TB₂</u> $\text{GB}_2 = 258^{0.6}$ $+ \text{GE} = +1^{0.4}$ $\text{TB}_2 = 260^0$	<u>7.FIND Latitude 7</u> $\phi_6: 40^\circ 49' .7 \text{ N}$ <u>8.FIND Longitude 7</u> $\Lambda_6: 009^\circ 47' .3 \text{ E}$	<u>9.FIND Error 5</u> $E_5 = 0^{0.4}$

Conclusion

The application of the Lines of Position on the plan route from CAPO FERRO to CAPO CODA CAVALLLO highlight the fact that when determining the LOPs, we should take into account the visibility of the objects, the angles between the objects chosen for a better intersection, the correction of the magnetic compass in order to correct the True Bearing of the selected objects, the time at which objects are taken, and also to maintain the Course and speed of the vessel wherever necessary, especially, in the case of running fix using two navigation aids at time intervals. There are other things we need to consider when plotting the LOPs which are the Notices to Mariners that give us information about restricted areas in order for us to avoid making a fix in a wrong coastal area. The time, distance and speed with latitude and longitude of the fixes should be taken for reference purpose and the errors between a Dead Reckoning and a fix.

Remarks/Comments

The principles and procedures applied in this case study would not have been effective without the required knowledge, materials and the guidance from my professor. Concerning the materials, the chart in particular was very helpful, it made it easy for me to find enough navigational objects to apply most of the Lines of Positions discussed in Chapter One and the area of navigation was full of many notes of notices to mariners that raised my awareness on where to determine the position of the ship with the LOPs considering the fact that am carrying a

dangerous cargo. The ship characteristics are another perfect contribution that I can't overemphasize, it made it easy for me to make the computation for the different route legs.

In conclusion, this case study was an opportunity for me to grow my knowledge in fixing the ship with the different Lines of Position and how to do chart work accurately with the different observations, discussions and analysis that took place with my professor during the project work.

CONCLUSION

Analysis of Lines of Position Used in Coastal Navigation as a thesis defined clearly in terms of detailed elaboration and demonstration in the various chapters above has left us with a great knowledge of how a navigator can fix the ship position using the types of LOPs, such as bearing and a range, by two cross bearing, three cross bearing, a bearing and a horizontal angle which a range may be calculated, a Running fix by two bearings of a single AtoN, Running fix by bearings from two AtoN and doubling the bow angle with other methods like the used of transit line, distance arcs, a line with sounding, horizontal angles and bathymetric lines which are sufficient with information on how to make the plotting starting from the moment an object is observed with an analysis of its visibility, distance, angle, time at which it was taken to the correction of bearing, drawing of the bearing lines on the chart to the point of intersection of LOPs which forms a fix for the ship position.

There are many choices to choose among the different Lines of Position to fix the ship, but it is advisable for a navigator to choose any of the above methods with a mindset of which coastal area the ship is sailing at, and how sufficient the navigational objects with respect to their visibility range, the effect of wind, wave and other weather influence and how fast and convenient the chosen method will enable you to determine the fix.

In our own case study, we are sailing with a tanker ship with the speed of 9.4 knots in a coastal area prone to other vessels that we need to observe carefully when plotting our fix positions as well as turning to avoid collision situations that will endanger the environment or could cause any pollution to the marine environment. When sailing we should keep a good safe margin from the coast and other ships in other to keep our cargo in good condition. Because most cargos are very reactive and might be influenced with sudden and unexpected activities in proximity. For this, we should be taking into account of the environmental factors when sailing in the coastal area.

Applying these various types and methods of Lines of Position in Coastal Navigation will enable the ship and her crew to determine her accurate position with less error in the course of shipping in the maritime environment as we hope to improve and advance with more research to making Lines of Position easy and efficient to use.

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