Seamanship International Ltd.

NAVIGATION

ADVANCED MATES/MASTERS

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Captain Nadeem Anwar

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Author's Preface

Navigational inaccuracies have mostly been the source of most of the catastrophic maritime disasters. The industry is heavily legislated and more regulations are likely to be developed in the near future. It is important to understand that it is the basic skills of the seafarers, especially the navigators that are the main stay of maritime safety.

There are ever increasing concerns about the competence and skills of seafarers, in particular the navigation watch-keepers. Training and development of seafarers is time consuming, costly and demanding. There is also the need to keep the knowledge current by staying abreast of the new developments and practices.

This book is aimed at the navigator of today and the future. The increasing workload on the watch-keeper demands simple methods of working and, clear and concise instructions, so that the navigator can spend more time concentrating on the watch-keeping. The methods of working used in the book are not just easy to follow for learning, but are for onboard applications as well. It contains sufficient number of worked examples, plots, templates for working and exercise to allow the navigator to gain the basic and advanced navigation skills. The book not just mentions the methods, it actually explains the methods.

The future of maritime safety is to a large extent reliant upon advanced navigational skills. The book is aimed at Masters and senior navigation officers and would prove equally beneficial for the junior navigation officers helping them gain knowledge and develop skills not just for shipboard applications, but also for future career progression.

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1 Regulatory Requirements

Shipping is one of the most globalised industries and, as it needs to work to common international standards, legislation is very important. This legislation affects all aspects of shipping, from construction to safe operations, with navigation no exception.

In consultation with member states and using expert help from the relevant sub-committees, the International Maritime Organisation (IMO) produces draft proposals. Once a certain number of the member states, who between them have a certain percentage of world tonnage, agree to a proposal, the Convention is formed.

While the actual regulations that a ship should follow will be the national law of the country (flag state) where the ship is registered, the Conventions provide minimum standards for international trading. The ship must also meet any port and coastal state standards, which will sometimes be different to, but often of a higher standard than, the IMO Conventions.

Navigation and issues related to it are covered under international instruments such as the SOLAS, STCW and Collision Regulations. In addition, the flag states advise their own ships through regulations, codes and notices. These are the main areas covered:

- Safety of Navigation (covered under SOLAS Chapter V, National Laws and the Bridge Procedures Guide by ICS)
- Carriage of Navigational Equipment and Publications (covered under SOLAS and National Laws)
- Training and Certification (covered under STCW'78 / 95)
- Management (covered under ISM Code in SOLAS'74)
- Collision Regulations (COLREGS'72)

The significance of each of these codes and regulations are briefly discussed in this chapter. In addition, some non-statutory requirements of a similar nature are covered for completeness.

1.1 ISM Code

Analysis of any accident or incident will generally show an element of human error or management failures, as will so-called 'equipment failure' or 'Act of God' incidents. Equipment or machinery may not have been adequately maintained, too much reliance may have been placed on a single system or decisions may not have been taken in time. Management can be an issue where an error of judgment or a mistake by one individual should have been spotted in time and corrective action taken. To overcome these human error and management issues, general principles and objectives to promote the evolution of sound management and operating practices within the industry as a whole were introduced into shipping through the ISM Code under SOLAS.

The full title of the ISM Code is: 'The International Management Code for the Safe Operation of Ships and for Pollution Prevention'. Its objective was to ensure safety, to prevent human injury or loss of life and to avoid damage to property and the environment, in particular the marine environment. Navigation safety is a significant achievement of these objectives.

1.1.1 SMS

This Code reinforces the responsibility of the owner or company to ensure proper management and operation of the ship. The owner or company is required to develop, implement and maintain a Safety Management System (SMS) for use by the company and the ship in order to meet the objective. An SMS must have the following relevant functional requirements:

1.1.1.1 Navigation Policy

With particular reference to the safety and environment protection policy, the SMS should include a clear statement on the navigation policy of the company. This may be brief, highlighting the general aims of the company that are to be achieved through safe navigation.

1.1.1.2 Procedures

This is a full set of instructions and procedures for the performance of safe ship operations and environmental protection, while satisfying applicable international and flag state requirements. Generally, this will be a large part of SMS. The Code requires procedures to be available for all aspects of operations, implying that all known aspects of navigation are to be covered. The procedures provide clear instructions, in line with company policy, to prepare for navigation, execution and monitoring, including how to keep relevant records and the review of performance. The procedures will define safety limits to be applied and maintained in particular circumstances. It also covers the maintenance and upkeep of equipment and associated material.

1.1.1.3 Authority and Communications

An organisational structure that defines the levels of authority and lines of communication between and amongst company and shipboard personnel. In addition to general watchkeeping duties, the Master may delegate responsibility for certain aspects of navigation to the officer(s).

1.1.1.4 Reporting Procedures

Procedures for reporting non-conformities within the provisions of the ISM Code, as well as accident reporting, will be covered in full within the operations procedures.

1.1.1.5 Emergency Preparedness

Procedures for readiness and response to emergency situations. The company supplies the ship with standard contingency plans, and the company's own procedures for response and communication to the Master are also established within this section.

1.1.1.6 Audits and Reviews

Procedures for detailing internal audits and reviews. This sets out how performance can be measured, how deficiencies in procedures should be determined, what resources are required and the mechanisms for using audit to improve performance.

1.1.2 The Master's Responsibility

1.1.2.1 Implementing Policy

The Master must ensure that all officers and crew with navigational duties are fully aware of company policy on navigation and understand the established procedures. The Master should also determine the competence of individuals before allocating responsibilities. Finally, the Master must ensure that all individuals are fit for duties and are adequately rested.

1.1.2.2 Motivating Crew

Training is considered to be the best motivator. Personnel with navigation duties should be fully trained on the equipment they will use for navigation.

1.1.2.3 Issuing Orders

The Master should write a full set of standing orders for the watch officers, supplemented by night orders (and bridge orders where required). The use of standard marine vocabulary should be the adopted practice for all bridge communications.

1.1.2.4 Special Requirements

All international and flag state requirements must be followed to the satisfaction of the Master. This requires that the operational status of mandatory equipment such as Automatic Identification Systems (AIS), VDR, relevant records (Radio), regular reporting (danger messages and reporting systems) and receipt of information (MSI) all meet the necessary standards.

1.1.2.5 Review And Reporting

The Master should review the navigation of the ship before the voyage begins, while it is in progress and when it is complete. The process starts with ensuring appropriate resources are available and that all personnel are competent and properly trained. Passage plans must be completed in a timely manner and should contain enough detail to ensure the safe navigation of the ship on its current passage, taking the environment into account. During the performance stages of the voyage, the stipulated watchkeeping resource (in the passage plan) should be maintained and a check kept on the ship's safe and efficient progress. On completion, or where any problems have been experienced, review all the information and records to determine the possible improvements that can be made on future voyages. Where necessary, these include:

- Additional resources required
- Additional training
- Proposed amendments of procedures required
- Lessons to be learnt and communication of such to others

The Master has overriding authority in cases involving safety and pollution prevention. The Master may override procedures to complete the operations safely but cannot amend them permanently. Amendments can only be done by the owner, i.e. the company.

The Master may follow advice from external authorities such as routeing instructions but may also choose to override these to ensure the safety of vessel and the prevention of damage to the environment.

1.1.3 Simplified Compliance

Knowledge of current international and flag state requirements and methods of complying with them are important for compliance with the ISM Code. Whether it involves navigation, collision avoidance, navigation equipment or radio and communications, a few basics apply in all cases. These can be summarised as follows:

- Equipment must be approved as per requirements
- Equipment must be sufficient in numbers as per requirements
- Personnel must be familiar with and trained on the use of all equipment
- Personnel must have full knowledge of the procedures to be followed
- Proper records, whether they are automatic or human interface, must be maintained
- Records must be maintained for the specified periods
- Checklists must be regularly reviewed
- Valid documents must be available at all times
- Crews must have the ability to communicate clearly

- Risk assessment principles and techniques should be completed for all identified risks
- Regular assessment and monitoring should be carried out
- The SMS should not be at variance with the law, though the company may choose to make their own requirements more stringent for added safety.

Authors Note:

Critics of the Code will argue that "If all procedures are in place, what is the need for training"? But procedures are for guidance only and are generic. Not all situations are the same. Those responsible for navigation must have detailed knowledge and understanding of the tasks and their duties in order to deal with all types of circumstances and scenarios. This also applies to instructions from external bodies. A Master, fully competent on the navigational issues, can make a sound judgement whether or not to follow the advice or guidance or to prepare his own plans to meet requirements and to ensure safety of ship, crew and the environment.

Another debate is about the perceived conflict between the requirements under the ISM Code to produce a wide range of documents and reports as a part of its SMS and the consequential production of potentially self incriminating evidence that could be used against those who produced that evidence. This text is no place to state the right or wrong answer to the conflicting position. The only comment by the author is that the compliance with the Code – and hence the SMS – is a legal requirement and where it demands records to be maintained, such records cannot be avoided. In addition, the Code is designed to ensure safety and prevent accidents or incidents. Where these are still happening, then something is going wrong somewhere and the authorities should use some tools to teach appropriate lessons. The issue of use of records for commercial cases is beyond the scope of this text.

1.2 SOLAS Chapter V

Chapter V identifies certain navigation safety services that should be provided by contracting Governments and outlines the operational provisions that apply to all ships on all voyages.

Subjects covered include:

- A general obligation for Masters to assist those in distress
- Maintenance of meteorological services for ships
- Ice patrol service
- Routeing of ships
- Maintenance of search and rescue services.

Chapter V requires Contracting Governments to ensure that all ships are sufficiently and efficiently manned from a safety point of view. The chapter makes mandatory the carriage of Voyage Data Recorders (VDR) and automatic ship identification systems (AIS) for certain classes of ship.

1.2.1 Reports by the Master

The Master of every ship that meets with any of the following conditions must make a report in English, by all available means, to the nearest coast radio station (CRS) or signal station. Send these messages on DSC, R/T and Inmarsat.

- Tropical storms
- Winds of force 10 and above, for which there has been no warning
- Air temperatures below freezing, associated with gale-force winds causing severe icing (ice accretion)
- Dangerous ice
- A dangerous derelict.

Precede each message with SECURITE (or PAN PAN as appropriate).

The contents of the reports have been included in the appropriate chapters where the messages are relevant.

1.3 Bridge Procedures Guide

International chamber of Shipping

This publication is produced by the ICS and is designed to make mariners aware of good operating practice and efficient bridge organisation. It ensures that similar actions are taken on the bridges of all ships.

1.3.1 Contents

1.3.1.1 Part A

Covers guidance to Masters and navigating officers on these topics:

- Bridge resource and bridge team management
- Passage planning in ocean waters and, in restricted waters, pilotage, ship's routeing, ship reporting systems and vessel traffic services
- Duties of the OOW with regard to watch-keeping, navigation, communication, pollution prevention and emergency situations
- Operation and maintenance of bridge equipment.

It also has Annexes that contain the formats used for pilotage, lists of distress frequencies and guidance on steering-gear test routines.

1.3.1.2 Part B

Provides bridge checklists for routine bridge procedures for the following:

- Familiarisation with bridge equipment
- Preparation for sea
- Preparation for arrival in port
- Pilotage
- Passage plan appraisal
- Navigation in coastal waters
- Navigation in ocean waters
- Anchoring and anchor watch
- Navigation in restricted visibility
- Navigation in heavy weather or in tropical storm areas
- Navigation in ice
- Changing over watch
- Calling the Master

1.3.1.3 Part C

Provides checklists for use during emergencies such as:

- Main engine or steering failure
- Collision
- Stranding or grounding
- Man overboard
- Fire
- Flooding
- Search and rescue
- Abandonment of the ship.

1.4 Buoyage

IALA (The International Association of Marine Aids to Navigation Lighthouse Authorities) has set the design and standard of buoys that are to be used for navigational purposes.

It divides the world into two regions, A and B, for the purpose of Lateral Marks. B includes all of the Americas, Japan, Philippines and South Korea. The cardinal marks are uniform throughout the world.

1.4.1 Direction of Buoyage and Distance

Direction of buoyage can be found from either the navigational charts or the sailing directions. Locally, it is the direction taken by the mariner from seaward when approaching a harbour, river, estuary or other waterway. Generally, it is determined by buoyage authorities and is mainly clockwise around continental landmasses.

There is no specified minimum distance at which a buoy should be passed. Observation of the chart, proximity to hazards, draught of the ship and the amount of sea room can help to decide the safe distance that should be maintained. In congested waters, this distance is not expected to be large.

When following the lateral marks, the vessels should remain as near to the mark on the starboard hand side of the ship as is appropriate.

- When proceeding with the direction of buoyage, use the starboard hand marks.
- When going against the direction of buoyage, use the port hand marks.

1.4.2 Special Marks

Special marks are used for marking:

- Cables or pipelines
- Recreational areas
- Ocean data acquisition systems
- Firing or military exercise zones
- Termination points of Traffic Separation Scheme, where required
- Spoil ground
- Channel within a channel

Author's Note: To remember this, take the first letter of each to spell CROFTS Ch.

1.4.3 New Dangers

New dangers are marked by one or more cardinal or lateral marks as required by the IALA system. If fitted, lights are quick or very quick.

Where the danger is especially grave, at least one of the marks will be duplicated by an identical mark as soon as is practicable, until the danger has been fully notified. A RACON using morse code D, with a signal length of one nautical mile on a radar display, may be used on the duplicate mark.

IALA has developed a new emergency 'wreck marking buoy'. It will be in the form of a pillar or spar buoy, with yellow and blue vertical stripes, and a yellow and blue alternating flashing light that has a nominal range of 4nm.

1.5 ISPS

The provisions of the International Ship and Port Facility Security Code (ISPS) may have a bearing on navigation. At the planning stage, areas with heightened security threats should be avoided or passed at increased distances and transits completed allowing for these added precautions.

The ship's officers should be aware of potential evasive manoeuvres, as indicated in the security plan of the ship. Similarly, depending upon the security level of a port, the ship should be able to stay clear of port or be ready to leave port at very short notice if the conditions dictate. Contingency plans for all eventualities should be available in a tabular format that can be transferred to the navigational charts as and when required.

1.6 STCW

The International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) was adopted by the International Conference on Training and Certification of Seafarers on July 7th, 1978. The 1978 STCW Convention (known as STCW '78) came into being on April 28th, 1984. Since then, three amendments to it were made and adopted in 1991, 1994 and 1995.

The 1991 amendments relate to the Global Maritime Distress and Safety System (GMDSS) and were adopted on December 1st, 1992. The 1994 amendments relate to special training requirements for personnel on tankers and were adopted on January 1st,1996.

In the 1995 amendments, a complete revision of the annex to the 1978 STCW Convention took place. This included the following:

- Clarification of the standards of competence required
- The qualification requirements for trainers and assessors
- Provision of effective mechanisms for enforcement
- Provision of mechanisms for greater flexibility in the assignment of functions on board ship, which broadens the career opportunities of seafarers.

The Convention set out the minimum global standards of knowledge, understanding, experience and professional competence required by the States that are members of it. The STCW 1995 came fully into force on 1 February 2002 and is generally referred to as STCW '95.

The STCW '95 Code stipulates the minimum training and certification requirements for Masters, Chief Mates, OOWs and ratings. These are governed by STCW '95 Regulations and take the ship's gross tonnage and near/non-near coastal voyages as criteria. It will always be a factor in deciding the safe manning-levels of ships.

1.7 Pollution

The concern for the navigator is to advise the relevant departments about the distances from the nearest land, depth of water (for chemical tankers) and the presence of the ship within special areas. Obtain specific authority from the bridge before allowing any MARPOL-controlled discharges from the ship.

1.8 Guidance From a Flag State

IMO Conventions may either be adopted by a flag state to form its own law. Alternatively, the flag state may produce legislation that fulfils the requirements of the relevant IMO Convention and also enhances them. In addition, the flag state may provide guidance in the form of codes of practice or guidance notices related to specific areas. This will happen:

- When new legislation is introduced
- When an enquiry into an accident has identified poor practice
- Where there are issues involving safety and pollution prevention
- When the industry has to be notified of a change.

The flag state administration may also issue notices. The UK's MCA issues notices in three series:

1.8.1 Merchant Shipping Notices (MSN):

These are related to UK legislation and contain information to comply with it. They contain technical details related to statutory instruments and regulations and are numbered in sequence, with a prefix MSN, and are related to publications such as COSWP, LSA regulations, SOLAS.

1.8.2 Marine Guidance Notes (MGN):

These provide guidance and advice to improve the safety of shipping. They are concerned with issues related to safety of life at sea and pollution prevention. They are sequentially numbered with a prefix MGN. Examples are Navigation in Dover Strait, Navigation in fog, STCW and MARPOL.

1.8.3 Marine Information Notices (MIN):

These are intended for a limited readership and are only valid for a limited period of time. They provide information regarding training establishments, equipment manufacturers and results of research.

1.8.4 Carriage Requirements for Publications

Flag states also make mandatory requirements for the carriage of bridge publications. As an example, these are required under UK law:

- A full set of navigational charts, fully corrected and in the latest edition, including the chart catalogue. These could be approved electronic charts
- Notices to mariners
- Annual summary of notices to mariners
- International Code of Signals
- Mariners handbook
- Sailing directions
- List of radio signals
- List of lights
- Tide tables
- Tidal stream atlases
- MSN (Merchant Shipping Notices), MIN (Marine Information Notices), MGN (Marine Guidance Notices)
- Nautical Almanac
- Operating and maintenance instructions for the ship's navigational equipment.

1.9 Voyage Data Recorder

For operational and legal reasons, ships are required to maintain extensive records. These records allow performance to be analysed and compliance with legislation proved.

There are two main problems with traditional methods of record keeping:

- Manipulation and falsification of records by unscrupulous individuals
- Loss of entire evidence and records in the event of ship loss or a major fire

Considering the aviation industry's experiences with the Black-Box, the IMO has made it mandatory for ships to be fitted with a 'Voyage Data Recorder' (VDR). The main purpose of the VDR is to make the data available after an incident so that the investigators can gain a better understanding of the events that led to it, particularly where the ship is lost without trace, where records have been lost or where the crew have perished during the accident.

The requirement is part of SOLAS under Chapter V. The following ships must be fitted with a VDR:

- Passenger ships built on or after July 1st, 2002
- Ro-Ro passenger ships built before July 1st, 2002, but not later than the first survey on or after July 1st, 2002
- Passenger ships (other than Ro-Ro passenger ships) built before July 1st 2002, but not later than January 1st, 2004
- Ships (other than passenger ships) of 3,000 GT and upwards, built on or after July 1st, 2002.

VDRs must meet the minimum performance standards specified by the IMO. A VDR consists of:

- A main unit that can be connected to a download device
- A protective capsule, which houses the device
- Records of the previous twelve hours of data
- External cables.
- A reserve power source
- An acoustic beacon.

The VDR automatically maintains records of a number of parameters on the ship for a period of the last twelve hours. These are:

Data	Source
Date and Time	Using a source external to the ship (GPS)
Ship's Position	Electronic positioning system
Speed (water or ground)	Ship's speed log or designated equipment
Heading	Ship's compass (Gyro)
Bridge Audio	8 microphones
Communications audio	VHF and other R/T units
Radar (post display)	Screen dump every 15 seconds (may be programmed at 5 seconds)
Water depth	Echo sounder
Main alarms	All mandatory alarms on the bridge
Rudder order and response	Steering gear and autopilot
Engine order and response	Telegraphs, controls, thrusters
Hull opening status	All mandatory status information displayed on the bridge
Watertight and fire door status	All mandatory status information displayed on the bridge
Acceleration and hull stresses	Hull stress and response monitoring equipment where fitted
Wind speed and direction	Anemometer where fitted
Last 12 hour data	Analysis report of data

The equipment should be approved before installation. Throughout the life of the ship, the VDR system and all its sensors should be tested annually. The test should be conducted in conjunction with the relevant statutory survey, i.e., for Passenger Ship Safety Certificate (PC), Cargo Ship Safety Certificate (CSC) or Cargo Ship Safety Equipment Certificate (SEC). The survey must be within the period permitted by the Harmonised System of Survey and Certification, which is 3 months before the due date for PC, and +/- 3 months of due date for CSC and SEC surveys. On successful completion of the tests and satisfactory performance, the administration will issue a performance test certificate to the ship, which must be kept on board.

The tests include verification of the accuracy and the duration and recoverability of the recorded data. In addition, tests and inspections must be conducted to determine the serviceability of all protective enclosures and devices fitted. To prevent any over-writing of data, it is important to turn off the VDR shortly after arrival into a port where the test is to be performed.

During an emergency, it is important for the Master to download the data early on to prevent any over-writing. This is important for investigation and evidence purposes. If the emergency situation continues for a significant period subsequent downloads, at intervals of less than twelve hours, should be performed. Some companies have procedures for VDR data to be downloaded at less than twelve hours in order to have access to entire voyage data for analysis and investigation, when required.

2 Passage Planning

Safety at sea is the primary concern of any mariner, but it must be achieved alongside the commercial requirements of a voyage. Therefore, it is critical that a vessel completes its operations safely and efficiently. The majority of studies into maritime casualties have highlighted human error as one of the most significant contributory factors in an incident. Careful planning plays a significant part in the reduction of these errors, creating an environment for the safety and commercial success. Passage Planning is a recommendation for ensuring safety at sea.

There are international, national and company specific recommendations for passage planning. These may be in the form of IMO guidelines, ICS - Bridge Procedures Guide, MCA - A Guide to the Planning and Conduct of Sea Passages, MCA – MGNs and MSNs and part of Company Safety Management System. In particular, the SMS will provide detailed instructions for it.

A bridge team consists of several individuals who may be at different levels of individual knowledge, skills and experience. As well as being a requirement, passage planning serves a useful purpose in ensuring that the bridge team follows agreed consistent procedures and standards. In looking at the technical skills, consideration must be given to the techniques involved in preparing for and conducting the proposed passage.

The passage plan should make it easier for the bridge team to navigate the ship safely. It should be comprehensive, detailed and easy to interpret. The full procedure has four stages:

- Appraisal
- Planning
- Execution
- Monitoring.

The first two are the preparatory stages. Items three and four are the essential elements of voyage execution and confirm that the voyage is being conducted according to the plan. The procedure must be supported by good information and data.

2.1 Appraisal

Before embarking on any venture, those persons controlling (or playing a part in it), must have an understanding of the likely risks involved. During appraisal, all information relevant to the passage is gathered and the risks are examined.

2.1.1 Use of Publications

Detailed information is required in order to make decisions regarding the overall conduct of the passage. This information is taken from a number of sources, such as regular publications or notices provided in response to events. Instructions from parties influencing the venture (e.g. owners, charterers) will also be part of the appraisal.

Choosing which authority's publication to use depends upon the Chart Outfit carried on board, the availability of local publications and legal requirements for carriage, for example, charts for coastal or inland waters.

2.1.1.1 Chart Catalogue

The United Kingdom Hydrographic Office (UKHO) publishes The Catalogue of Admiralty Charts and Other Hydrographic Publications (NP131) annually. It shows the area of coverage of BA charts and other BA publications. The Defence Mapping Agency (DMA) of the USA produces a similar document, titled as CATP2V01U. The US version shows the areas of coverage of US charts and other publications.

2.1.1.2 Navigational Charts

These are a very significant source of information. Most merchant vessels carry UKHO or US charts. Some areas of the world are covered in greater detail by charts that are published by local hydrographic authorities. In some parts of the world it may be a requirement to use local charts.

UKHO charts are published on a large scale that allows safe navigation in the coastal waters of the UK, the Commonwealth and some Middle Eastern countries. For other areas the policy is to publish enough charts to enable the mariner to cross the oceans and proceed along the coasts to reach the port approaches safely.

2.1.1.3 Sailing Directions and Pilot Books

'Admiralty Sailing Directions', or 'Pilot Books' as they are commonly known, are published in volumes by the UKHO. These provide worldwide coverage and are intended to complement the Admiralty charts.

They contain descriptions of:

- the coast
- off-lying features
- tidal streams and currents
- directions for navigation in complicated waters
- information about channels and harbours
- navigational hazards
- buoyage systems
- pilotage
- regulations
- general notes on countries covered by the volume
- port facilities
- seasonal currents
- ice
- climatic conditions with direct access to the sea.

Sailing directions are published by the DMA in the series SDPUB 121-200. Some of these provide information similar to Ocean Passages for the World and are referred to as Planning Guides. Other publications contain information similar to Pilot Books and are referred to en-route.

2.1.1.4 Ocean Passages for the World (NP136)

Published by the UKHO, it contains information on planning ocean passages, oceanography and currents. It also provides recommended routes and distances between the principal ports of the world and includes details of winds, weather, currents and ice hazards that may be encountered. Ocean Passages also contains diagrams and chartlets for the main ocean routes for power vessels and sailing ships.

2.1.1.5 Routeing Charts and Pilot Charts

These contain basic routeing instructions, together with meteorological details, and are published for the main oceans for the twelve-month period. The information includes limits of load-line zones, routes and distances between principal ports and focal points, ocean currents, wind roses and ice limits. Inset chartlets and texts include air, dew point and sea temperatures, barometric pressure, diurnal variation and the incidence of fog, gales and storms.

Routeing charts are published by the UKHO as Chart numbers 5124-8. Similar meteorological charts are published by the DMA and are known as Pilot Charts and they are available on the web at *http://pollux.nss.nima.mil*

2.1.1.6 Admiralty List of Radio Signals (ALRS)

The UKHO publishes this list in 6 volumes:

- Volume 1 - Maritime Radio Stations NP281, 2 Parts
  Global marine communications service, Ship reporting systems, Medical Advice by radio, quarantine reports, locust reports, CRSs, coastguard stations, piracy and armed robbery reports, alien smuggling reporting, Radio regulations in territorial waters
- Volume 2 - Radio Aids to Navigation, D/F, Radar beacons, Satellite Navigation Systems, Legal Time, Radio Time Signals and Electronic Position Fixing System
- Volume 3 - Maritime Safety Information Services, 2 Parts
  Radio facsimile broadcasts and weather services, Navigational warnings (WWNWS and NAVTEX), Weather routeing services, Global marine meteorological services, meteorological codes for shipping use. (See Chapter 11 for more on this)
- Volume 4 - Meteorological Observation Stations
- Volume 5 - Global Maritime Distress and Safety System (GMDSS) (See Chapter 11 for more on this)
- Volume 6 - Pilot Services, Vessel Traffic Services and Port Operations, 5 Parts

Similar information is available in the DMA publications of the USA.

2.1.1.7 List of Lights and Fog Signals

These are published by the UKHO in eleven volumes and provide worldwide coverage. A UKHO digital version of the List of Lights and Fog Signals is also available, covering the world in ten areas. The digital version is corrected using diskettes, which are issued weekly. The US Coast Guard (USCG) publishes seven volumes of Light Lists and Fog Signals, covering the US coast and Great Lakes. Light Lists published by the DMA cover the rest of the world.

2.1.1.8 Notices to Mariners

The UKHO and the DMA publish notices to mariners in weekly editions. The contents include:

- Index
- Admiralty notices to mariners
- Navigational warnings
- Corrections to the Admiralty sailing directions,
- Corrections to the Admiralty list of lights and fog signals
- Corrections to the Admiralty list of radio signals (ALRS)

Digital versions of Notices to Mariners are also available. These are used for correcting digital charts (ECDIS, ENC, and ARCS) and digital lists of lights.

2.1.1.9 Ship's Routeing

This book is published by the IMO. It contains information on all routeing, traffic separation schemes, deepwater routes and areas to be avoided. Similar information is also shown on charts and is contained in the sailing directions.

2.1.1.10 Tide Tables

The UKHO annually publishes four volumes of the Admiralty Tide Tables (ATT). These cover the world. 'TOTAL TIDE',- a digital CD version of UKHO Tide Tables uses computers to provides tidal information and covers the world in ten areas. Paper and digital versions also provide tidal stream data. The US National Ocean Service also publishes worldwide tables.

2.1.1.11 Tidal Stream Atlases

These are published by the UKHO and cover the waters of North West Europe and Hong Kong. Total Tide provides tidal stream information worldwide. Some port authorities publish their own tidal stream atlases. The US National Ocean Service publishes tidal current tables that cover the Atlantic Coast of North America and the Pacific Coast of North America and Asia.

2.1.1.12 Co-Tidal and Co-Range Charts

These are published for waters where tidal conditions are particularly significant to safety -critical navigation.

2.1.1.13 Load Line Chart

Load line zones are shown in Ocean Passages for the World, and on the BA Chart D6083. The chart provides the boundaries of the zones and the applicable dates for seasonal zones.

2.1.1.14 Nautical Almanac and Tables

Provide essential navigational information of certain events, for example, sunrise.

2.1.1.15 Distance Tables

The UKHO and DMA produce tables giving coastal and ocean distances. Some independent companies, such as Reed's or BP, also produce distance tables.

2.1.1.16 The Mariner's Handbook

This book is published by the UKHO. It contains advice and recommendations on navigation and general information that is of interest to the mariner.

2.1.1.17 Passage Planning Charts – 5500 Series

These are available for certain parts of the world (for example, Dover Strait, Malacca Strait) and contain useful information in the form of text and diagrams.

2.1.1.18 Annual Summary Of Admiralty Notices To Mariners

Published by the UKHO, it contains information and UK legislation that is relevant to British shipping.

2.1.1.19 Merchant Shipping Notices

These are a series of notices published by the MCA and MAIB.

MSNs (white) contain statutory information that must be complied with.
MGNs (blue) contain advice and recommendation on matters concerning safety of life at sea and pollution prevention.
MINs (green) contain information that is for limited readership and is intended to support information about the services available to the industry. These have an expiry date.

2.1.2 Other Sources of Information

2.1.2.1 Climatic Information

Climatic information can be obtained from:

- Pilot books
- Pilot charts
- The Mariner's Handbook
- Ocean Passages for the World
- Meteorology for Mariners.

2.1.2.2 Weather Reports

These are of significance just before the commencement of the voyage and during the voyage. They are used for reviewing the passage plan once the ship has embarked on the voyage. Sources of weather information include:

- Radio weather reports
- NAVTEX (See Chapter 11)
- Port authorities
- Other shipping.

2.1.2.3 Navigational Warnings

These contain up-to-date changes to navigational aids and hazards. They are obtained from:

- Radio
- INMARSAT / SafetyNET (See Chapter 11)
- NAVTEX
- Vessel Traffic Services (VTS)
- Harbour authorities.

Navigational warnings are also published in the Annual Summary of Admiralty Notices to Mariners and the weekly editions of Notices to Mariners.

2.1.2.4 Onboard Navigation Systems Technical and User Manuals

These are supplied with the navigational equipment when it is installed on board. The user manuals should be thoroughly understood by all officers who are using the equipment.

2.1.2.5 Manoeuvring Data and Draught Information

Full manoeuvring characteristics information in various conditions throughout the voyage are needed to determine the wheel-over positions and the ability of the ship to follow the track in safety, while taking into account the width of channels and planned speeds. These characteristics will determine the amount of sea room required by the ship, and the clearances over and under obstructions.

2.1.2.6 Owner's and Charterer's Instructions

Instructions relating to bunkering, storing and routeing from the C/P may leave the Master with limited choice. In complying with these instructions, it must be remembered that the ultimate responsibility for the safety of the ship rests with the Master, who has overriding authority in all cases concerning safety and pollution.

2.1.2.7 Routeing Advice

Some routeing agencies may provide advice on the route to be followed, based upon the vessel and the weather likely to be experienced.

2.1.2.8 Passage Records and Personal Experience

Records of past performance of the vessel under similar conditions are of value when deciding upon the route. Personal experiences of the Master, officers and crew members who have been to the intended ports and areas may also be useful sources of information

2.1.2.9 Other Publications and Authorities - Information from other Ships

Consult the Guide to Port Entry, any Port handbooks and information from Agents and P&I correspondents regarding local regulations, facilities, approaches, mooring and watchmen requirements. Observations made by other ships regarding weather encountered and conditions experienced in the areas and ports to be visited may be considered up-to-date, but should always be used with caution.

Use an appropriate checklist to ensure that nothing is left to chance and that all aspects have been covered. Table 2.1 is combined checklist for appraisal, planning and other aspects of passage planning and provides a good example

Table 2.1 - Checklist

Checklist Questions		References/Remarks
1. General Information		
1. Are there any Port/Pilot/Agent/Charter's instructions for intended passage?	☐	....
2. Does the Company have any special instructions pertaining to the route?	☐	....
3. Has Master given any particular instructions?	☐	....
4. Has the ship been to the present destination port(s) in the past? (If so, the record of previous passage can help identify the route and the navigation officer can construct an updated plan with amendments)?	☐	Date of Voyage/Copy of previous Passage Plan ....
5. Is there any Watchkeeping officer on board who has already been to that area/port?	☐	Name/Record of Information obtained ....
2. Publications		
1. Is there any requirement for the use of local publications/navigational charts?	☐	Yes/No (If YES, Sheet No.) ....
2. Are there any local publications required & available for departure and destination port?	☐	Yes/No (If YES, Sheet No.) ....
3. Are the following publications present on board & corrected up to date?		

1. Chart Catalogue (NP 131)	☐	Edn. … … … … ....
2. Navigational Charts - the largest scale available	☐	Corrected to ANM … … … ....
3. Routeing Charts	☐	Edn. … … … … ....
4. Admiralty Notices to Mariner/Annual Summary	☐	Latest ANM on board … … ....
5. Sailing Directions	☐	Edn. … … … Corrected to ANM ....
6. Tide Tables	☐	Edn. … … … … ....
7. Tidal Steam Atlas		Edn. … … … … ....
8. List of Lights	☐	Edn. … … … Corrected to ANM ....
9. List of Radio Signals	☐	Edn. … … … Corrected to ANM ....
10. Guide to Port Entry	☐	Edn. … … … … ....
11. Mariner's handbook	☐	Edn. … … … Corrected to ANM ....
12. Ocean Passages for the World	☐	Edn. … … … Corrected to ANM ....
13. Ships Routeing (IMO)	☐	Edn. … … … … ....
14. Load line chart	☐	Edn. … … … … ....
15. other	☐	Edn. … … … … ....
3. Additional Publications		
1. MSNs. MGNs, MINs		Location on ship's PC/Bridge ....
2. Manual for all the navigational equipment on bridge		Location on bridge ....
3. International Code of Signals		Edn. … … … … ....
4. Admiralty/other Distance Tables		Edn. … … … … ....
5. Chart Correction Log (NP133A)		Edn. … … … … ....
6. IALA Buoyage System (NP735)		Edn. … … … … ....
7. Symbols and Abbreviations (BA Chart 5011)		Edn. … … … … ....
4. Vessel and Cargo		
1. Is there any bunker port diversion to consider bunkering?	☐	Yes/No (If YES, Sheet No.) ....
1. Whether the ship is loaded or in ballast? (For ships manoeuvring data)	☐	Loaded / In Ballast
2. Has the pilot card been updated? (If possible, obtain a copy and attach with passage plan)		Yes/No (If YES, Sheet No.) ....
3. Would the ship have sufficient UKC?	☐	UKC .... m/ft

4. Has the pilot boarding area been considered for manoeuvring to provide lee for pilot boat?	☐	Yes/No (If YES, Sheet No.) ....
5. Are there any overhead cables/bridges in the passage for consideration of air-draft?	☐	Yes/No (If YES, Sheet No.) ....
6. Are there any special Cargo Condition/Requirements that may affect the passage plan?	☐	Yes/No (If YES, Sheet No.) ....
5. Weather		
1. Does the plan take Meteorological conditions into account?	☐	....
2. Have the latest Weather forecasts/warnings been obtained and checked?	☐	.... Sheet No. ....
3. Does the ship follow advice from any weather routeing service?	☐	.... Sheet No. ....
4. Have the latest Navigational Warnings been taken into account?	☐	....
6. Watchkeeping Personnel		
1. Has the requirement for OOW/Lookout doubling up watches been considered with respect to adverse weather/restricted visibility?	☐	.... Sheet No. ....
2. Has the crew calling points for anchor/berthing stations, piracy watches been established and noted on chart/passage plan?	☐	.... Sheet No. ....
3. Has the rest hours for watchkeepers been considered?	☐	.... Sheet No. ....
7. Passage		
1. Are there any mandatory ship reporting schemes?	☐	....
2. Has the Position of pilot boarding/disembarkation been established?	☐	....
3. Has clock adjustment with respect to local times been considered and which dates to advance/retard clocks?	☐	

4.	Has Condition and availability of anchorage berths been considered?	☐	....
5.	Has a Risk Assessment been carried out for any Predicted areas of danger?	☐	....
8.	**Plan**		
a.	Have the following been marked/drawn on the chart		
i.	Courses as recommended by local/international regulations, company and Master's instructions.	☐	References.............. ....
ii.	Margins of safety as required by Master/company.	☐	References.............. ....
iii.	Wheel over points.	☐	....
iv.	VTS or other reporting points marked on the chart and noted in the Passage Plan sheet.	☐	.... Sheet No. ....
v.	Pilot boarding position & Alternate pilot boarding position in case of adverse weather.	☐	References.............. ....
vi.	Speed reduction points.	☐	.... Sheet No. ....
vii.	Notices to engine room.	☐	.... Sheet No. ....
viii.	Abort points	☐	.... Sheet No. ....
ix.	Point where call is given to ship's Crew for anchor/berthing stations.		.... Sheet No. ....
x.	Sequence of charts for the passage.	☐	marked on charts
xi.	Cross Index Range (CIR) for Parallel Indexing.	☐	.... Sheet No. ....
xii.	Tides & currents.	☐	.... Sheet No. ....
xiii.	Predicated areas of danger and no-go areas.	☐	marked on charts
xiv.	Radar Conspicuous objects e.g. hills, RACONS etc.	☐	marked on charts
xv.	Transit & clearing bearings	☐	marked on charts
xvi.	Position from where to move onto next chart along with Chart Number	☐	marked on charts
xvii.	Waypoint number on each waypoint	☐	marked on charts
xviii.	Position on chart where additional navigation aids are required switched on	☐	marked on charts
xix.	Specific meteorological information related to any area e.g. haze, dust storms, areas of restricted visibility	☐	marked on charts References...............
xx.	Navigational warnings, preliminary and temporary chart corrections from notices to mariners.	☐	marked on charts References...............

xxi.	Areas of special marine environmental protection consideration.	☐	marked on charts References................
xxii.	Minimum under keel clearance (UKC) required particularly in shallow waters.	☐	marked on charts References................
b.	Have the primary and secondary means of position fixing been agreed upon?	☐	Recorded in passage plan sheet
c.	Has the position plotting interval been agreed upon for each leg?	☐	Recorded in passage plan sheet
d.	Have means been identified to verify datum on navigational chart with the Datum in the GPS	☐	Recorded in passage plan sheet
e.	Are there any Contingency plans available for the following?		
i.	Failure of electronic navigational aids		.... Sheet No. ....
ii.	Man overboard	☐	.... Sheet No. ....
iii.	Fire	☐	.... Sheet No. ....
iv.	Steering Gear Failure	☐	.... Sheet No. ....
v.	Main Engine Failure	☐	.... Sheet No. ....
vi.	Helicopter Operations	☐	.... Sheet No. ....
vii.	Radar Failures	☐	.... Sheet No. ....
viii.	Piracy/Armed Robbery/Terrorist Activity	☐	.... Sheet No. ....
ix.	Distress	☐	.... Sheet No. ....
x.	Unavailability of Pilot/ OOW/Lookouts/Helmsman	☐	.... Sheet No. ....
xi.	Adverse Weather/Visibility	☐	.... Sheet No. ....
f.	Are all officers and crew fully familiar with relevant bridge equipment and procedures	☐	Yes / NO, If not reference to company procedure ....
g.	Have OOWs and crew been briefed about the passage plan.	☐	Signature on passage plan sheet
h.	Have all OOWs seen, understood and signed the passage plan?	☐	Signature on passage plan sheet
i.	Has the Master checked and approved the plan?	☐	Signature on passage plan sheet

Through appraisal, the Master should be satisfied that the charts are the largest scale for the passage, are onboard and that all charts and publications are corrected up to date, having taken the navigational warnings into account. Apply all T & P corrections that are in force.

The appraisal process should result in the navigation officer and the Master gaining knowledge of the following (but not limited to):

- The general choice of routes that can be followed
- The availability of the largest scale charts and the relevant publications on board, along with any corrections
- The distances between departure and destination positions on the various route options
- The draught at departure and various stages of the passage, taking into account the passage consumption, bunkering options and any transfers of fuel and cargo on passage
- Minimum depths on the various route options
- The tidal conditions at critical stages of the various route options
- Proximity to hazards on the various route options
- Reliability of the ship's machinery and equipment
- The load line zones to be passed on the various route options
- Recommendations in Ocean Passages and Sailing Directions
- Advice from shore routeing services
- The climatic conditions on various route options
- Past, present and forecast weather
- The routeing schemes expected to be used on various route options
- Type, volume and direction of flow of traffic likely to be encountered
- Times of sunrise, sunset and duration of daylight and darkness
- Navigational aids, radio and terrestrial, that will be available for position monitoring
- The ship's manoeuvring characteristics and how she would manoeuvre or handle in different areas
- Search and Rescue arrangements along the route
- Likely ports of refuge, shelter locations or anchorages
- Considerations for a suitable landfall for the various route options
- Restrictions created by the nature of the cargo or the type of operations
- Security threats or guidance from flag or coastal states

Having studied the relevant sections of the applicable publications, and all associated material, reports, requirements and warnings, the navigation officer will provide outline route options to the Master. Based upon the available information, while keeping the safety of vessel, crew, passengers and cargo as a priority, the Master will select the most appropriate option.

2.1.3 Chart 5500

The 5000 series of charts is the British Admiralty (BA) Series of World Passage Planning Charts. Chart 5500:

- Is of critical importance for all vessels transiting the English Channel and using the ports of NW Europe
- Contains details to assist with the passage planning and to ensure a safe passage through the Channel.
- Includes advice on appraisal, planning, execution and monitoring.
- Has pilot boarding areas specially marked for deep draught vessels, where the pilot comes aboard by helicopter.

2.1.3.1 Passage planning for special classes of vessels

- Deep draught vessels and vessels bound for Europort are given specific instructions regarding the routes to be followed by them, reporting points, pilot boarding points and alteration points for joining and leaving the TSS
- For vessels constrained by their draught, information is given regarding the need for adequate UKC

2.1.3.2 Routeing

- Routes used by ferries and passenger vessels are marked.

General recommendations

- The Dover strait is an area of high traffic congestion and the details of the TSS in use and the Master's legal obligations under Colregs are discussed in detail.

Specific regulations

- The special regulations that apply to the TSS are summarised within the passage plan chart
- With regard to the electronic position fixing equipment to be fitted on board to improve the navigation, recommendations for vessels of over 300GT are included
- The limits of the chart and the numbers used for the passage are printed on the chart.

2.1.3.3 Radio Reporting System

- All vessels using the English Channel are required to report at various points to the UK and French maritime authorities while using the TSS off Ouessant, Cape Gris Nez and Dover coast guard
- Guidance regarding special reporting arrangements and reporting points for vessels carrying oil or dangerous cargo is given in detail
- Radio reporting procedures to the port of destination, along with complete details of cargo and vessel's navigation capabilities, are mentioned
- Tanker checklists and documents to be produced to authorities are given.

2.1.3.4 Maritime Radio Service

- Details of stations operating in the area, together with their times of transmission, types of messages (Navigational warnings, weather messages, storm warnings) are given. Details of NAVTEX service.

2.1.3.5 Radio Beacon Service, Tidal Information and Services

- Offshore tidal data with an illustration/examples of the use of co-tidal, co-range lines are explained
- Maximum tidal stream rates in relation to HW Dover are included.

2.1.3.6 Pilotage Services

- Details of requests for deep sea pilots for respective ports, and the relevant communications required, are available
- Rendezvous points for helicopter/pilot transfer and procedural action are provided.

2.1.4 Charts and Associated Publications – Reliance

The Admiralty (and other establishments that publish charts and associated publications), try to make sure that their published information is accurate. However, it is possible that the information may not always be complete, and so the Master decides how much reliance should be placed on a chart or publication.

2.1.4.1 Factors Affecting Chart Reliability

To establish reliability, examine the chart. The mariner checks:

Source Data:
A chart uses information from many sources, the most important of which is the survey. Recent charts will either have source data information printed on them or will include a source data diagram.

Careful examination will show:

- When the survey was done
- The method of the survey (by echo sounder, hand lead, side sonar)
- The authority conducting the survey (Royal Navy, port authorities, foreign governments, oil companies)
- The method of determining positions (for example, DGPS or other, close to/away from land, the accuracy of survey of positions on land)
- The scale of the survey.

A major factor that contributes to the accuracy of a chart is the ability of the hydrographer to assimilate/collate all the information. In this respect, Information Technology has added to the reliability to a published chart. However, the mariner should note that certain areas of a chart may not have been covered by any survey.

Scale:
The scale of the chart is very important. Use the largest scale charts as they contain the most-detailed information and are generally corrected first. On smaller scale charts (especially of ocean areas), the information is sparse and charted dangers may be in error with regard to position, least-depth and extent.

The scale of a chart is normally the same as the scale of the survey, especially with the modern larger-scale charts. Small-scale charts may be published from a larger scale survey, but it is unlikely that an older small-scale chart will have been published from a larger scale survey.

Area Of Usage:
If a particular area of a sea or ocean is not frequently used for navigation, it is unlikely that detailed information on it will be available.

Positioning:
The datum is related to a particular positioning system (for example, WGS 84 or PZ 90). Position-fixing devices have the facility to relate WGS 84 to another datum, but positions may not always agree with the charted positions used by the Hydrographic Office, even if the stated horizontal datum was the same.

Graduation On Plans:
Some older charts did not have graduations on the plans of ports and harbours. On such un-graduated plans, it will be difficult to determine position with accuracy. However, newer charts have been published with graduations on the plans and older charts are being revised.

Distortion of Paper:
The paper on which a chart is printed can become distorted, although the resulting errors are unlikely to be significant.

Depth Criteria:
Many hydrographic offices use different depth criteria for dangerous and non-dangerous wrecks.

Soundings:
The normal method of obtaining soundings of the seabed uses the surveying vessel to produce a systematic series of profiles that cover the entire area. The scale of survey should allow sufficient plot lines to indicate the configuration of the seabed.

- A line, which could be many miles wide on a chart, only represents the narrow width of the beam of the echo sounder. Soundings by lead line only represent an area of a few centimetres
- Older exploratory surveys indicate random soundings where checks were carried out.

Changes In Depths:
An unstable seabed may cause a change of soundings.

Quality of Bottom:
On a chart, the nature of the bottom shown only represents the upper layer.

Magnetic Variation:
Charts indicate the magnetic variation and yearly change. The actual change can be very different to the charted change.

Corrections:
Some charted areas generate many corrections. Always ask these questions:

- Is the chart corrected up to date?
- Have all the corrections been made?

2.2 Planning

A plan cannot be made without the required information being available. The planning stage must necessarily follow the appraisal. This involves laying out tracks, calculations, instructions, setup of equipment and programmes and relevant references. A plan may be prepared in a number of formats. Almost all companies under the ISM Code have laid down detailed procedures in the SMS about passage planning. It is likely to be a combination of tabular, narrative, plotting and digital file format.

2.2.1 Berth-to-Berth Planning

At all times, the responsibility for safe navigation of the vessel rests with the Master and OOW. During the planning stages, pay due regard to all possible dangers of navigation. The passage plan acts as a benchmark for the bridge team and the Master must ensure that all relevant information was considered in the preparation of the plan. Then the bridge team can execute the passage plan and monitor the progress of the ship effectively. If there is no plan, execution and monitoring have no comparison points.

The passage between the pilot ground and the berth is critical. It may be through congested waters, in close proximity to hazards and with much reduced UKC. The passage may also take the vessel close to expensive property, in the form of port facilities and other vessels. Pilots are employed for their local knowledge and expertise and may have more information than the bridge team. The pilot arrives on board with a plan to guide the vessel and outlines the planned the passage to the berth (or pilot station) to the Master. The pilot also advises the Master of the passage that the vessel will follow as advised. A berth-to-berth plan provides:

- Knowledge of all hazards and actions to be taken during voyage
- Agreement on a common plan for use in pilotage waters
- Allows position of the vessel to be monitored at all times
- An awareness of the pilot's intention at all times
- The pilot's advice, which can be cross-checked and clarified by the pilot in case of doubt.

If the pilot is unable to perform his duties (for whatever reason), this plan helps the bridge team to maintain the vessel in safety until a replacement pilot arrives.

2.2.2 Passage Plan Format

The end product should follow the preferred format of the company SMS. The best approach is to:

- Complete the plan on the largest-scale navigational charts
- Document the plan in a tabular format (Table 2.2 is a suggested format)
- Provide instructions to the bridge team in a passage plan note book (refer to Table 2.1). Computer-based files are also useful

Table 2.2 - Recommended Format for Passage Plan Notebook

Waypoint or Leg No	References	Notes / Instructions
Names/numbers and positions of waypoints Leg/Track references	• Coastal Features for position fixing • Navigational Aids • Directions • Hazards • Weather • Currents/Tides/Tidal Streams • Security threats • Routing schemes • Regulations	Specific instructions to the bridge team about conduct of passage

There have been debates concerning the inclusion of too much information on the chart. A navigator usually relies upon three basics:

- Sight and hearing
- Instruments
- Navigational charts/plans.

It may be prudent to have the maximum amount of detail on the chart, while leaving enough room for plotting fixes. Details can be left in the documents or booklets backing up the chart, with charts marked with references to them. In congested waters, where the navigator does not have the time to read a file of papers, more information may be added to the chart. To avoid overcrowding, write the information on land or away from the intended course line, with arrows pointing to the track.

Table 2.3 - Passage Planning Table

Passage Plan

Vessel.................
Voyage No. ......
From ....
To... Berth .....
(Name of Berth/Wharf/Anchorage)

Prepared by: .... (Navigation Officer)
Date: ....
Checked by: .... (Master)
Date: ....
OOW1: ......OO1....... OOW2: ......OO2...

References: (Write Vol. No. & Page Nos. for quick reference)
Publication Correction: Date .... ANM No. ....
Sailing Directions: ....
ALRS: ....
ATT: ....
ALL: ....
Ocean Passages: ....
Navtex Stations: . ...
VHF Channels: ....

Page ...1... of ...2...
Drafts F: m A: m

Chart(s) Number	Chart(s) Datum	Waypoint No	Waypoint Name / Lat / Long	Course° T	Speed ...... Engine Order	Distance and Time to Go: Next WPT Distance	Next WPT Time	Total Distance	Total Time	Min. Depth/UKC m	Parallel Index Reference Mark / CIR	WO Reference Mark / Bearing x Range	Position Fixing Freq (Min)	Primary	S'ndry	Current/Tidal Stream Set / Rate	Master's Instructions/Hazards/ Weather Contingencies /Remarks
														Visual Radar GPS	Visual Radar GPS		
														Visual Radar GPS	Visual Radar GPS		
														Visual Radar GPS	Visual Radar GPS		
														Visual Radar GPS	Visual Radar GPS		

2.3 Summary of General Principles

The navigation officer must adopt:

- a consistent pattern for work and then adhere to it throughout the passage plan. Frequent changes in the symbols/legends or abbreviations used on charts or passage plan lead to confusion.
- an advance warning system on charts and in passage plan sheets, for example, Next chart No. Similarly, other hazards, such as high traffic density, fishing grounds, crossing traffic, shallow waters, etc. can be indicated well before they are expected.

All charts should be studied carefully in conjunction with the sailing directions, navigational warnings and weather reports and areas of danger should be identified. These predicted areas of danger should be marked as No-go areas.

Courses should be plotted on the largest scale charts clear of predicted areas of danger allowing for a margin of safety as determined by local, company regulations and the Master's instructions. When establishing margins of safety, the navigation officer must keep contingencies in mind, for example, failure of the vessel's steering gear or an engine breakdown.

Whenever alterations of course are shown on the charts, identify the WO (wheel over) positions and range(s)/bearing(s) from clearly identifiable, conspicuous shore objects/radar targets. Where visual means of position fixing are available, use of the GPS should be secondary. Remember, the visual or even radar position fixing is from the objects you can physically observe. Where possible, try to use beam bearings for alterations.

When transferring positions or courses between charts, ranges and bearings from fixed objects must be used.

Establish 'Points of no return', especially in approaches to narrow passages, night passage or when passing over river bars with critical height of tide. These must be finalised by the Masters' specific instructions and preferences with respect to their own vessel handling characteristics. In any circumstances, these points are the areas beyond which vessel cannot be returned back to sea and must proceed to the next available exit where she can safely berth, anchor or return to sea.

Use this guideline to place marks on charts that will not cause clutter or confusion:

- Courses, always TRUE and in three digit notation and distance of each leg, DTG to destination, for example, pilot boarding ground
- Margins of safety as required by the Master/company
- Position fixing frequency for each leg of the passage

- Wheel-over (WO) points
- Reporting points. If there are any stations to be called, their IDs, VHF channel and the position at which it is to be called
- Pilot boarding/disembarkation position(s)
- Speed reduction points
- Position where notice is given to engine room
- Abort Points / Points of no return
- Indication on the course line where notices are to be given to additional watchkeepers, helmsmen and lookouts
- Sequence of charts for the passage
- Parallel Index Lines along with PI distances
- Set and rate of current, height of tide, tidal window for critical areas
- Areas of danger and no-go areas
- Radar/visually conspicuous objects. For example, peaks of mountains, RACONs, lighthouses
- Next Chart, along with its number and an indication of the position from where to move to the next chart
- Transit bearings for quick check of compass error and Clearing bearings, to clear a specific hazard, particularly when making approaches in narrow channels
- Waypoint number on each waypoint to refer it to the passage plan sheet and to the GPS and ECDIS (if used)
- Position on the chart where it is required to switch on certain navigation aids (such as the echo sounder)
- Navigation warnings, preliminary and temporary chart corrections from notices to mariners
- Specific meteorological information available, e.g., dust storms, restricted visibility, sea, swell and wind conditions
- Radio frequencies/channels, station identifiers and message types
- Areas requiring specific marine environmental protection considerations
- Minimum UKC, particularly shallow water areas
- Chart datum is usually given on chart. Highlight any chart that has a different datum to notify the OOWs
- References to contingency plans for alternative actions to maintain the safety of life, environment, vessel and the cargo.

Where an approved ECDIS (Electronic Chart Display Information System) is used for passage planning, routes and hazards can be marked on the display itself.

2.3.1 Explanation Of Planning Methods

2.3.1.1 Wheel-Over (WO)

At the planning stage, the wheel-over point calculations require these factors:

- Loaded condition of the ship (loaded, ballast or Intermediate. This is used to select the turning circle diagram / appropriate table)
- Change of course in degrees (between one track and the next)
- Helm angle to be used (this may vary with the proximity of hazards. The nearer the hazard, the larger the angle, to keep the vessel as close as possible to the planned track or to make a tight turn)
- Speed of the ship while making the turn
- Depth of water (for the effect of shallow water on the turning circle and the increase in draught while turning)

Obtain the advance and transfer from the appropriate turning circle diagram or the tabulated information. For example, a ship on a course of 270°T has to alter course to 310°T. Assuming the advance is 4.7 cables and transfer is 0.9 cables for a 40° alteration based upon 20° helm:

- At the way point 'B', extend the present course line 270° T
- At any point 'X' on this line, draw a perpendicular line 'XY' towards the alteration, so that 'XY' = Transfer

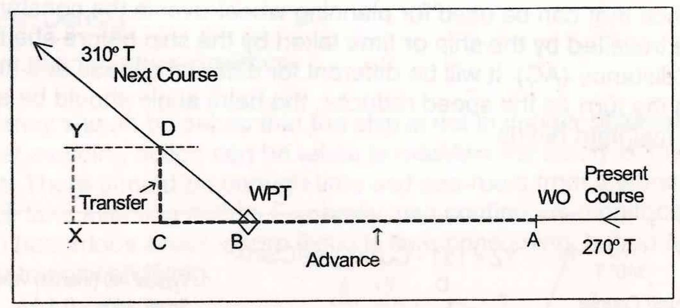


Figure 2.1 - Wheelover Point Determination

- At 'Y', draw a line parallel to 'BX', so that it cuts the next course line 310°T. The point at which the parallel line cuts the next course line is 'D'. Now if a line was drawn at 'D' which was parallel to 'XY', point 'C' would be obtained on the extension of the present course line
- From 'C', measure the Advance backwards, i.e., in direction 090° T (reciprocal of 270° T) to obtain point 'A'. 'A' is the wheel-over point, where 'CA' equals Advance

- A setsquare marked with the required transfer can be used to obtain point 'C' and 'D' by simply sliding it across the original course line until the transfer mark coincides with the new course line

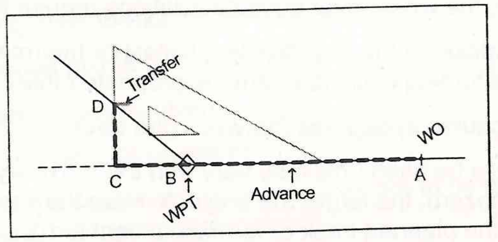


Figure 2.2 - Marking Wheelover with a Set Square

A formula can be used to determine the wheel over distance from the waypoint :

Distance backwards from WPT (AB) = Advance - (transfer ÷ tan of course alteration°)

Please note: this method is based upon the advance and transfer for the helm angle used and does not allow for any steadying helm to counteract the swing of the ship. Further, during the execution and monitoring, sea state, current or tidal stream and wind effect on the ship may cause errors. Cross track error would require adjustment of wheel-over point.

Another method that can be used for planning wheel-over is the constant radius turn. The distance travelled by the ship or time taken by the ship before she begins to turn is the inertia distance (AC). It will be different for different speeds and helm angles used. During the turn as the speed reduces, the helm angle should be adjusted (reduced) to maintain radius.

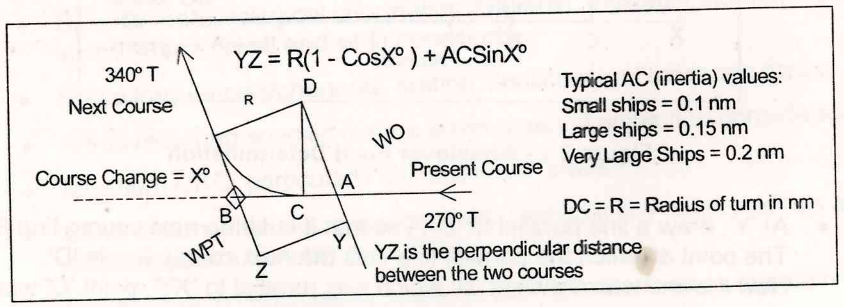


Figure 2.3 - Wheelover - Constant Radius Turn

Parallel indexing can be used to monitor the ship during the turn (see 6.5.1). Alternately, VRM set at the required range from a fixed object (clearing range) may also be used to monitor the turn, especially if it is a constant radius turn. The object selected in this case should be at the centre of curvature of the turn.

2.3.1.2 Position Fixing Frequency

Decide this frequency for every leg of the passage. These are the main factors affecting the frequency of the fix:

- Proximity to hazards
  If hazards are close to the intended passage, plot positions more frequently to take corrective action before the vessel gets too close.
- Speed
  A faster vessel will cover more distance in a given time than a slower one, and may get close to dangers more rapidly.
- Draught
  Vessels with deeper draught have limited sea-room to manoeuvre. Plot positions more frequently to ensure that the vessel remains within the intended channel.
- Displacement
  Larger displacement means more momentum and such vessels will take time to turn or manoeuvre.
- Environmental factors
  In areas where extraordinary set, drift or leeway is being experienced, especially towards a hazard, the fixing frequency should be increased.
- Traffic Density
- Manoeuvring characteristics

The fix frequency should be set so that the ship is not in danger between fixes and to guarantee that avoiding action can be taken to maintain the safety of the ship in case of a deviation. There should be enough time and sea-room from a worst-case position to still take avoiding action. Generally, use continuous-monitoring techniques in hazardous areas where fixing is time-consuming, but do not treat it as an alternative to position fixing.

Authors Note:

A rule of thumb on coastal passages is that the position fixing frequency should be such as to space positions about 5 cm apart.

2.3.1.3 Abort and Point of No Return

An abort is a position from where the ship may abandon her passage and maintain safety or return. This may be used in a case of:

- Change or deviation from the approach line
- Machinery, equipment or instrument malfunction or failure
- Instructions by the harbour authority – pilot, tug or berth availability
- Change in the elements of nature – wind, poor visibility, etc
- Blockage of the approach, channel or berth – navigational hazard, other ship or for reasons of security.

The marking of an abort requires careful consideration and there should be sufficient sea room for the ship to undertake any of these manoeuvres in safety:

- Turn around
- Stop in safe waters
- Anchor.

A passage plan should incorporate a return or manoeuvre plan for execution at this position, should it become necessary.

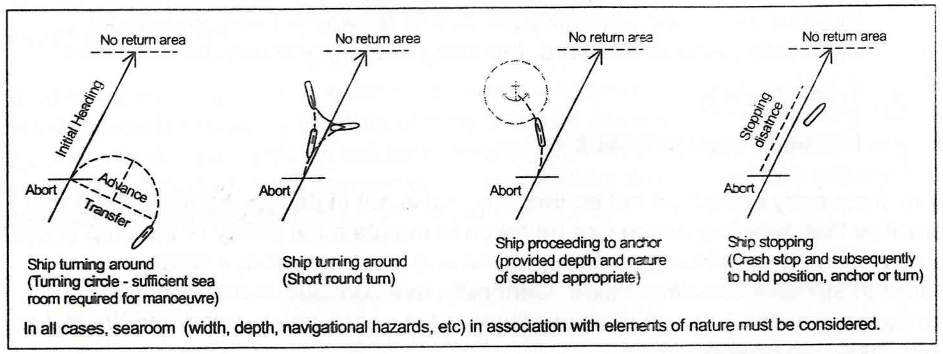


Figure 2.4 - Abort Manoeuvres

Once the abort has been passed, the ship enters the no return part of the passage and remains fully committed. Any problems or changes to circumstances would now have to be dealt with through the initiation of contingency plans for the passage.

2.3.1.4 Under Keel Clearance (UKC)

Use this formula to calculate the 'least-charted depth' a ship should be able to navigate in safety:

UKC + Draught	=	Least-charted depth + predicted height of tide

When determining UKC, consider:

- Weather conditions and state of sea, on all legs of passage
- The vessel's rolling and pitching movement
- Uncertainties in charted depth
- Uncertainties in vessel's draught, the accuracy of draught measurement, variation in consumption and resulting errors in draught or change of trim
- Tidal levels below expected (negative tidal surges)
- Squat of the ship at a given speed (maximum speed should be stated)
- Possible alterations in depth since the last survey
- Areas of mobile bottom
- Offshore areas with development resulting in reduced depths (sometimes up to 2 m.) over pipelines and similar underwater objects
- Recommended routes for deep draught vessels
- Inaccuracies in tidal predictions and offshore depths
- Possibility of determining tidal height in all areas (including offshore)
- The fact that high pressure is known to reduce the water level by few centimetres
- Skills of the navigator to determine tidal height and refer it correctly to the chart datum.

2.3.1.5 Squat

A ship experiences different effects in shallow water, often known as shallow water effect. The speed in shallow water leads to a lowering of the water level around her hull and may cause a change of trim. This is called squat and it is quite difficult to quantify. It is expected to occur when the depth is less than 1.5 the draught.

A ship's manoeuvring data provides information on squat values. During passage planning, the UKC should take squat into account.

The allowance for squat should be the greater of these values:

- Value of squat from the ship's manoeuvring data
- $Speed^2$ (in knots) ÷ 100 in metres
- 10% of the draught
- 0.3 metres for every 5 knots of the ship's forward speed

2.3.1.6 Landfall

Consider these factors when planning for landfall:

- Use the largest-scale charts
- At landfall points, there should be clear water all round and in the vicinity of the line of approach
- Avoid areas of poor visibility if landfall is to be made on a lighthouse
- When making landfall on a light, raising distances should be determined for the various conditions of visibility you may encounter
- Where ground is open to weather, low clouds may form. Avoid approaching land or islands from windward
- Use caution in areas subject to strong tidal streams
- Points of landfall and approaches should provide more than one method of monitoring your position, visual, radar and electronic aids to navigation, including the echo sounder
- Avoid low-lying islands as they may not be visible at a reasonable distance, even during clear daylight
- Avoid straight coastlines. Instead, go for areas with prominent headlands or coastal features
- Avoid lee shores with strong onshore winds
- Avoid (or consider carefully) areas of high traffic density
- Avoid the use of floating aids (even LANBY's with RACON), unless absolutely necessary. If you have to use them, confirm their position by other means
- Celestial observation can be used for checking landfall approaches
- Determine conditions, contingency plans and abort positions
- When a landfall position has been chosen, assess its adequacy for daylight, darkness and reduced visibility

2.3.1.7 Changing Charts

Use the range and bearing from a common fixed point to transfer a position from one chart to the next.

As an alternative, use the latitude on a common meridian to transfer the course from one chart to the next. Use meridional parts (MP) of the latitude at the common meridian.

For a rhumb line, the tangent value of course is always the same: d.long is obtained between the initial longitude 'A' and the common meridian between two charts 'C'.

DMP2 = d.long/tan course
MP2 = MP1 +/– DMP2

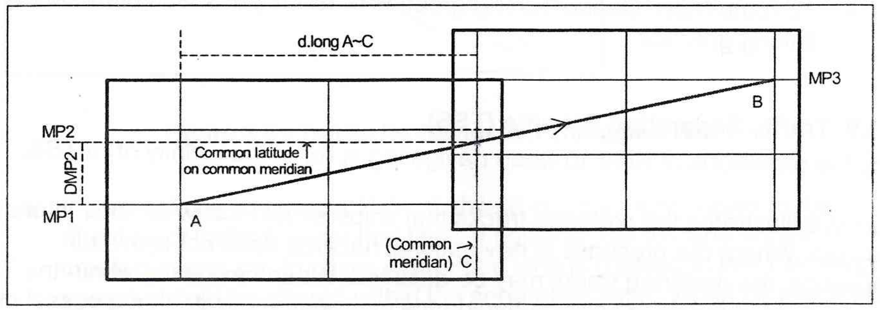


Figure 2.5 - Plotting a Course Using DMP

This method can be used for laying courses on the charts in general. Between two waypoints, the course may not be an exact degree of the true direction from 000° to 360°. If any fraction is involved, using the above method simplifies the plotting.

2.3.1.8 Traffic Separation And Routeing Schemes

This is an extract from the IMO Routeing Guide for Ships.

The purpose of ships' routeing is to improve the safety of navigation in converging areas and in areas where the density of traffic is great or where freedom of movement of shipping is inhibited by restricted sea room, the existence of obstructions to navigation, limited depths or unfavourable meteorological conditions.

The precise objectives of any routeing scheme will depend upon the particular hazardous circumstances which it is intended to alleviate, but may include some or all of the following:

- The separation of opposing streams of traffic so as to reduce the incidence of head-on encounters
- The reduction of dangers of collision between crossing traffic and shipping in established traffic lanes
- The simplification of the patterns of traffic flow in converging areas
- The organisation of safe traffic flow in areas of concentrated offshore exploration or exploitation
- The organisation of traffic flows in or around areas where navigation by all ships or by certain classes of ship is dangerous or undesirable
- Organisation of safe traffic flow in or around or at safe distance from environmentally sensitive area(s)
- The reduction of risk of grounding to providing special guidance to vessels in areas where water depths are uncertain or critical
- To route traffic clear of fishing grounds or the organisation of traffic through fishing grounds

2.3.1.9 Traffic Separation Scheme (TSS)

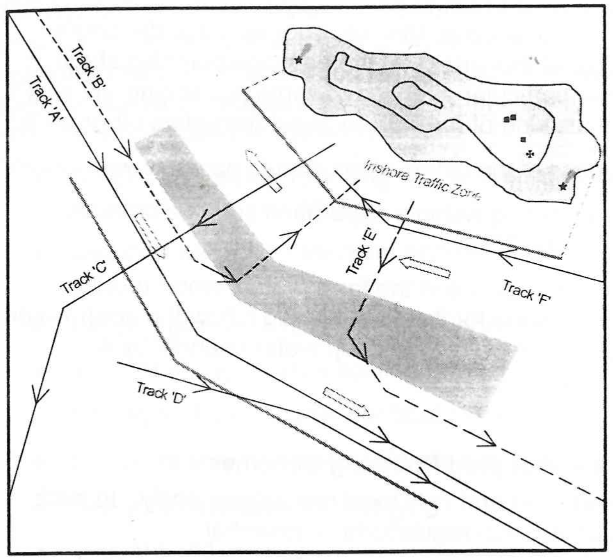
Apply the provisions of Rule 10 when navigating in (or in the vicinity of) a TSS.

Figure 2.6 illustrates the preferred tracks that ships should follow for their intended passages. Where the presence of navigational hazards does not allow full compliance, the preferred tracks may be adjusted. When navigating within the TSS, pay particular attention to collision-avoidance manoeuvres. Note that a vessel must comply with Rule 10 and all other collision avoidance rules simultaneously.

Exercise care in precautionary areas and at roundabouts, where traffic could be converging and exiting in different directions.

Comply with these rules:

- If your vessel is not using a TSS, avoid it by a wide margin
- A vessel using a TSS should proceed in the appropriate traffic lane in the general direction of traffic flow for that lane. This means that the track of the vessel should be parallel or nearly parallel to the sides of the lane
- The vessel should try to join or leave at the termination points of the TSS. But when joining or leaving from the side, it should do so at as small an angle as possible to the general direction of traffic flow.



Track 'A' - Through traffic

Track 'B' - Traffic using a lane and crossing other lane to reach inshore zone. Notice the small angle at which it leaves the lane to reach separation zone and altering course within the separation zone

Track 'C' - Traffic crossing TSS at right angles

Track 'D' - Traffic joining lane from the side

Track 'E' - Traffic leaving the inshore zone, crossing one lane and joining the other lane at a small angle

Track 'F' - Traffic leaving the lane at a small angle

Figure 2.6 - Tracks for Navigation Through a TSS

- If a vessel has to cross a TSS, it should cross at right angles to the general direction of traffic flow for that lane. If possible, the full lane should be crossed in one go. In cases where one lane is crossed to join the next, course should be altered within the separation zone. When proceeding in a lane, it is poor practice to make a 90° turn within that lane to cross, partly cross or join another lane
- The penalty for vessels in UK waters not complying with a TSS is £50,000 GBP ($90,000 US)

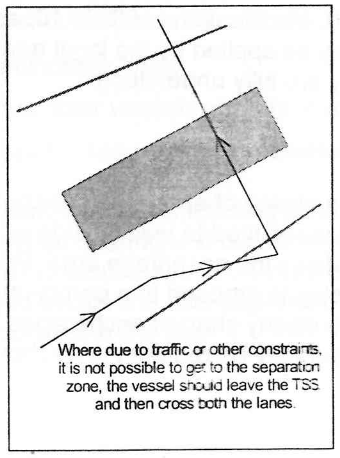


Figure 2.7 - Crossing a TSS

- A vessel should keep clear of separation lines or zones. Unless the ship is joining or leaving from the sides, this rule suggests that the course should be plotted clear of the sides,. At the passage planning stage, navigators should pay particular attention towards positioning the ship's track on the appropriate side of the TSS to avoid disrupting other traffic
- At the termination points of the lanes, ships should navigate with caution
- Ships should avoid anchoring within a separation scheme or in areas near the termination of the TSS
- Additional routeing measures are in the form of deepwater routes. Vessels satisfying the criteria for their use should follow the deep water route. Other vessels should avoid the deep water channel by a reasonable margin.

2.3.1.10 Adopted and Non-Adopted Routeing Schemes

Some schemes are not IMO adopted and only local regulations apply. In such cases a clear understanding of the local regulations is essential.

Adopted Schemes:

- These are routeing schemes adopted by IMO
- Provisions of Rule 10 of COLREGS apply fully
- They are intended for use by all vessels, by day, by night, in all weathers, in ice-free waters or under light ice conditions where no extraordinary manoeuvres or assistance by ice-breakers is required.

Non-Adopted Schemes:

- These are routeing schemes established by national governments or local authorities and have not been adopted by the IMO
- The rules and regulations are laid out by these authorities and may not conform to Rule 10. Modifications of Rule 10, as well as other rules of the COLREGS may be applied by the local administration and it is important that they are fully understood.

2.3.1.11 Anchor Plan

Various factors influence the choice of an area for anchorage. For routine anchoring, when the vessel is required to wait outside or inside the harbour area, the port authority usually defines the anchorage area. Port, pilotage or VTS authorities may advise the ship to proceed to a particular anchorage or position for anchoring. Some ports have clearly charted anchorages for use by vessels. For commercial reasons, a vessel may be required to anchor within the commercial limits of the port.

There may be circumstances when the vessel will have to anchor either without appropriate instructions or in cases of emergency. Careful appraisal of the navigational chart, Pilot Books and current and forecasted weather conditions will enable the Master to choose a safe area for anchoring. The choice of anchoring position depends upon the following factors:

- Size of the vessel, including windage area of the vessel's hull, superstructure and cargo
- Depth of water for maximum anchoring depth as well as for draught and UKC
- Holding ground, which depends upon the nature of seabed
- Type of anchor and its holding power
- Strength of wind, current or tidal stream
- Length of time the vessel intends to stay at anchor
- Sea room available for swinging
- Draught and windage area
- Proximity to dangers, submerged or on the surface
- Underwater obstructions
- Proximity to routes taken by passing or harbour traffic
- Forecast and actual weather conditions
- Availability of shelter
- Commercial limits of the port
- Availability of position monitoring landmarks (transit/anchor bearings)
- Instructions from the port authority, agent or owners/charterers
- Security, as piracy is common in some areas
- Health, as vessels should stand off ports where malaria is prevalent
- On arrival at the anchorage area:
    - Distance from other vessels already at anchor
    - Distance from the line astern of vessels already at anchor

The plan should include a marking of the anchoring position, any wheel-over bearings, steering bearing, let-go bearing and distances to go. You can also add details of engine manoeuvres to reduce speed during the approach. Use current/tidal stream or wind to decide the final approach. Where this is known in advance, it should be incorporated in the plan.

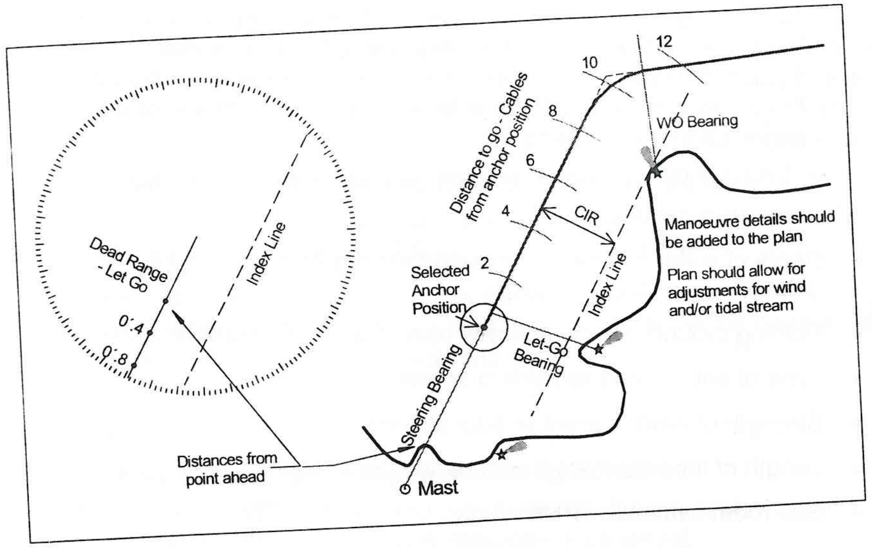


Figure 2.8 - Anchor Plan and Radar Set-up

- Scope of cable: depth m x 3 = X m ÷ 27.5m = Y Shackles, minimum of 3 shackles in any case (add distance from deck to water level).
- In depths of 30 m or over, lower one shackle in water and then let go.
- In depths of 60 m or over, walk back anchor all the way and do not let go.
- At the time of letting go, take a range and bearing from the beacon and note the ship's heading. Also, note the GPS position.
- To mark the anchor position on the chart, apply the ship's length forward of the wheel house, in the direction of the ship's heading at the time of 'let go'.
- Draw the anchor circle with a radius = Ship's Length + Forecastle to anchor position:
- (Forecastle to anchor position)2 = $(\text{Scope of Cable})^2 - (\text{Depth})^2$.

2.3.1.12 Risk Assessment (also see 5. 7)

The plan should take into account all risks that are likely on the passage. The navigational risk assessments for all such hazards should be completed and recorded. These should be available for the execution and monitoring stages.

2.4 Execution

Once the plan is prepared, discussed among the bridge team and finally approved by the Master, execution of the plan can take place at departure of the vessel. The execution is based upon the methods and resources determined in the planning stage. The time of commencement of the voyage and arrival at various critical stages is important, because some of the initial and subsequent details depend on this time. The ETD and ETAs are calculated with accuracy and passed on to the relevant parties. The strategy to execute the passage plan depends upon:

- Availability, reliability and status of the navigational equipment on board
- ETAs at focal points, considering the tides and traffic congestion. Other ships in the same location may be planning to catch the same tide
- Use of ship's personnel at various stages of the passage
- Possibility of reduction in visibility and change in meteorological conditions
- Reliance of navigational marks with reference to day versus night approach, particularly around predicted areas of danger.

Execution includes these tasks:

- Operation of the ship's navigational aids and communications equipment
- Ship's propulsion, manoeuvring and handling
- Maintenance of navigational and other charts, publications and their status with regard to dates of publication
- Navigational observations and calculations
- Maintenance records
- Amendment of passage plans as required and making note of deviations
- Obtaining meteorological/navigational warnings and/or forecasts.
- Participation in local and/or international Ship Reporting Schemes (for example, local VTIS, AMVER, AUSREP, JASREP).

2.4.1 Bridge Resource Management

Many accidents have been caused by organisational errors. These include insufficient information at the planning stage and/or a lack of communication between the members of bridge team.

Here are some examples:

- Failure to identify hazards
- Failure to allocate responsibilities
- Failure to prioritise tasks
- Inadequate assistance to the OOW, Master and/or pilot
- Insufficient monitoring
- Reliance on unsupported information
- Over-reliance on electronic navigational aids
- Hesitation in reporting a deviation from the passage plan and a failure to seek assistance

Bridge Resource Management or Bridge Team Management is the skill that balances efficient and successful administration with the organisation of all available resources so that voyages are conducted safely. Available resources vary from ship to ship, just as individual capabilities vary from person to person. First, establish the resources available and then balance the abilities and limitations of the ship's personnel to achieve a safe passage. These are the key areas that require the allocation of available resources:

- The Ship's Navigational Aids and electronic equipment (GPS, Radar(s), ARPA, ECDIS, Echo Sounder, NAVTEX, Compass (gyro, magnetic or satellite compass), communication equipment (GMDSS), sextant, AIS
- Characteristics of the ship, for example, propulsion, manoeuvrability, bow/stern thrusters
- Navigational and other charts and publications and their validity
- Meteorological conditions (visibility, wind, tide and currents)
- Local and/or international Ship Reporting Schemes (local VTIS, AMVER, AUSREP, JASREP)
- Experience and availability of the officers and ratings, particularly those involved in watchkeeping, with attention to fatigue and rest hours for each person involved
- Availability (or non-availability) of pilot(s) in certain areas
- A comprehensive passage plan in which all the resources are identified and used

Bridge resource management highlights internal dangers (machinery, equipment and personnel) and external dangers (weather, UKC and navigational hazards) to the ship. To maximise the available resources, the bridge team must be aware of their responsibilities. They must know the agreed procedures for the intended passage and, to avoid confusion at a later stage, any concerns must be raised immediately. Decisions may be questioned to clarify a situation, but not to challenge the authority of the Master or to disregard the onboard chain of

command. All team members must know their roles and responsibilities before the voyage begins.

Members of the bridge team should know their individual tasks and schedule the time required to complete them, such as the position-fixing intervals as defined in the passage plan.

During execution and monitoring, variations and deviations to the plan should be recorded in the appropriate logs and in the remarks column of the checklists.

2.5 Monitoring

It is essential to make sure that the vessel is proceeding safely and efficiently on the intended passage. The final stage is to monitor progress of the vessel, along the planned route, closely and continuously. Monitoring begins immediately on commencement of the passage and runs alongside execution. There are times when an early warning from monitoring may cause a change in execution.

It is the duty of the Master to ensure that the watchkeeping officers are comfortable in calling whenever they are in any doubt (or have problems) in following the planned route. Generally, watchkeeping officers are not authorised to amend the passage plan without the Master's specific instructions. But in circumstances requiring immediate action, and in the absence of the Master, the watchkeeping officers can take action to maintain the safety of navigation. This is only possible if efficient monitoring makes them fully aware of the position and movement of the vessel.

The navigator is also required to keep a check on all aspects of the passage plan, including heavy weather or navigational warnings, which may force the bridge team to deviate from the existing plan. Contingency planning should be part of the overall passage plan.

2.5.1 Position Fixing

Use these methods to obtain the position of a ship:

- Visual bearings and observations of terrestrial objects
- Ranges by visual observations
- Radar ranges and bearings
- Use of soundings
- Terrestrial radio aids to navigation
- Satellite systems
- Celestial observations.

In addition, there are methods that can be used to monitor the progress of the ship continuously. These may be based on visual techniques, parallel indexing using radar and satellite systems with (or without) the use of an ECDIS system.

2.5.1.1 Choice of Objects

- The objects to be used for visual and radar position fixing should be charted as the bearings or ranges will have to be plotted on the chart from their symbols. Objects should be easily identifiable
- Objects should be well spread to provide a good angle of cut between the position lines or ranges. The preferred angle is 90° between two objects and three marks at 60°. The angle should not be less than 30°
- Objects should be selected so that the objects and the ship do not end up on the perimeter of a circle, as the position may be plotted anywhere on the circle and errors in the compass may not be evident from the fix. If the objects are on a straight line, this problem can be avoided
- Objects should be observable from the same compass repeater to save time between observations
- It is preferable to select objects that are closer to the ship, as any error in the fix due to errors in position lines will be less significant over shorter distances
- When the ship is in a channel, the objects should be on the same side of the channel to avoid any errors caused by datum inaccuracies
- Objects in transit are a good option as the bearing is not subject to compass error. In fact, the compass error can be determined from a single observation
- The objects should be ahead of the ship rather than astern.

2.5.1.2 Procedure for Fixing

- The navigator should check the chart to identify the best objects to be used for fixing the position. Note the names of these objects and the expected bearing or range based on the projected EP or DR. Select at least three objects
- Locate the objects visually (or on radar) and identify them correctly
- At the required time, take bearings (or ranges on radar) and note them along with the exact time
- Bearings of objects forward and aft of the beam should be observed first and the bearings of objects near the beam should be observed last at the required time of position. This is because the bearings abeam are likely to change more rapidly
- With ranges, take the ranges of points abeam first as these would change the least. Then take those ahead and aft.

- Plot bearings and ranges on the chart. Use the correct symbols to mark the point of intersection. Write the time to the fix symbol
- Any cross-track tendency and speed/course made good should be checked. Any required course correction should be allowed
- The EP/DR should be run-up for the next time of observation as set by the planned fix frequency. Recheck the chart for any hazards that the ship may pass before the next fix. From the run-up EP/DR, note the bearings and ranges for the next fix
- Give the highest priority to position fixing by visual bearings
- Floating objects (like buoys or beacons) should not be used for position fixing unless the accuracy of their position has been established
- Allow for errors of compass, sextant and other navigational aids/equipments
- The interval between fixes should be pre-agreed and consistent. This helps make judgment on the estimated position of the vessel in future.

2.5.2 Visual Monitoring Techniques

Visual monitoring techniques should be employed where they are available. After correct identification, visual observations of fixed objects are the most reliable. Some of the significant methods are explained below.

2.5.2.1 Vertical Danger Angle

If the ship is to pass a total distance of 13.5 cables (7 + 6.5) [13.5 x 185.2m = 2500.2m] from the light house, draw an arc with a radius of 13.5 cables and with the lighthouse at centre on the chart. At any point on this arc, the angle at the ship between sea level and the lantern should be the same.

If the light is 36m above MHWS, which is 5m above chart datum and the height of tide is 3m, the effective height of light above sea level is 36 + 5 – 3 = 38m.

$$\tan\theta = \text{Height} / \text{Distance}$$
$$\theta = 0^\circ\, 52'.2$$

Using the sextant, if the reflected image of the lantern appears below sea level, the ship is in safety and outside the arc. If the charted height is used (instead of allowing for the height of the tide), the ship will be further away from danger at the calculated angle.

If no allowance is made for the height of tide and the same angle is used with charted height (MHWS or MHHW) of the light (36 + 5 = 41m), the calculated distance is less than the actual distance:

$$\text{Distance} = 41 / \tan 0^\circ\, 52'.2 = 2700\text{m} = 14.6 \text{ cables}$$

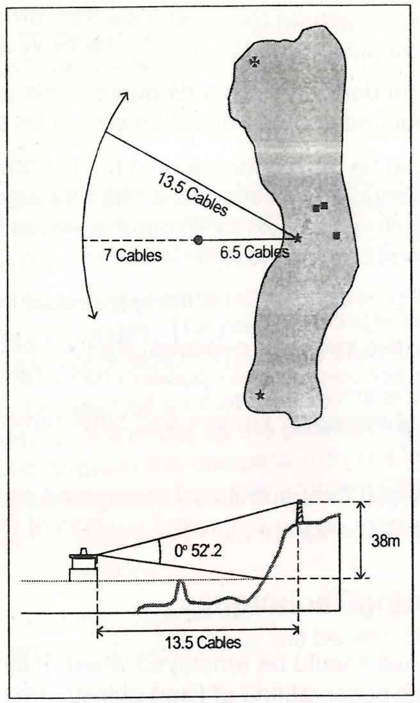


Figure 2.9 - Vertical Danger Angle

This will have added to the safety margin, unless there was also danger on the other side of the ship. Note that the height of observer on the ship makes very little difference and is not used in this calculation. As the angle is so small, the angle (angle of elevation) at the foot of the lighthouse (waterline) is treated as 90°, or top of the lighthouse (lantern) is treated as 90° (angle of depression).

2.5.2.2 Clearing Marks

The safe approach of the ship can be monitored where two marks are used in conjunction. Having determined the safe bearing, the furthest of the selected marks should remain open to the side on which the ship lies. In the Figure 2.10, the ship will be safe if the island remains open to left of the North Cardinal buoy.

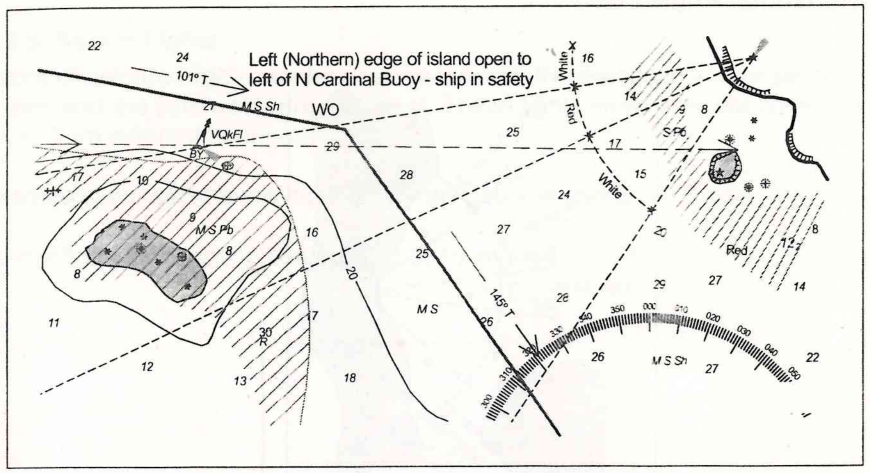


Figure 2.10 - Use of Clearing Mark

2.5.2.3 Horizontal Danger Angle

Having determined the safe distance from a hazard, i.e.7 cables, mark the chart with the safe distance to pass. Then determine the horizontal angle between two fixed objects which, by preference, should be the same distance either side of the hazard. In Figure 2.11, this is 81°. If the angle measured at the ship is equal to or less than the danger angle, the ship remains in safety.

Where there are hazards either side of track, repeat the same procedure for a point the same distance inside of the other hazard. In Figure 2.11, this is 50°. In this case, if the angle is more than 50°, the ship remains in safety.

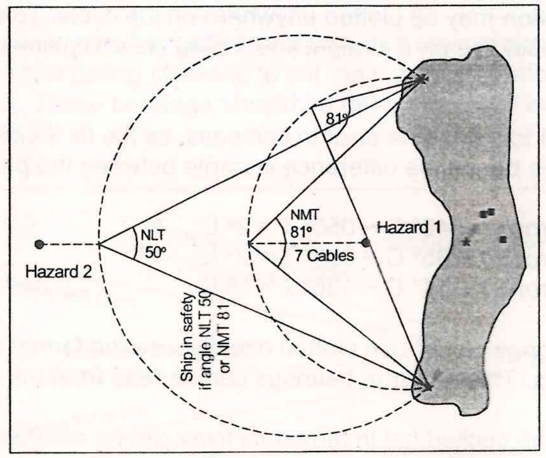


Figure 2.11 - Horizontal Danger Angle

If the angle at the ship is not less than (NLT) 50° or not more than (NMT) 81°, the ship remains in safety.

2.5.2.4 Horizontal Angle Fix

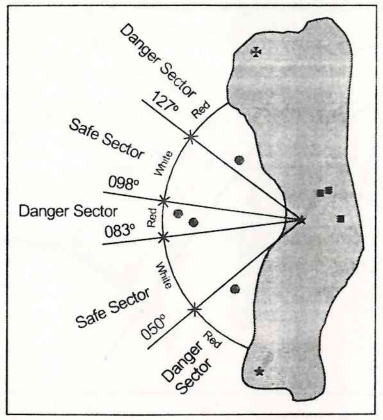


Figure 2.12 - Fix using Horizontal Angle

In Figure 2.12:

C Brg 1 = 048° C	Difference between 1 and 2 = 47°
C Brg 2 = 095° C	Difference between 2 and 3 = 39°
C Brg 3 = 134° C	Complement 1-2 = 90° - 47° = 43°
	Complement 2-3 = 90° - 39° = 51°

The Horizontal Angle can be used for fixing. In this case, objects should be selected so that they and the ship do not end up on the perimeter of a circle. This is because the position may be plotted anywhere on the circle. To avoid this problem, objects should be on a straight line. Using the complements, two position circles are plotted.

The fix can be used to determine error in compass, as the fix is not based on the bearings themselves but on the difference in angle between the pairs.

Compass error 1 = 048° C ~ 050° T = 2° E
Compass error 2 = 095° C ~ 097° T = 2° E
Compass error 3 = 134° C ~ 136° T = 2° E

If the incorrect bearings have been plotted directly, use the format station pointer to obtain the correct fix. Then the true bearings can be read from the chart.

In both the cases, the cocked hat in terrestrial fixes can be resolved.

2.5.2.5 Sector Lights

Sectors of coloured lights can be used to indicate the presence of navigational hazards and the safe water around them. These lights show different colours when viewed from different bearings.

The limits of the sectors are marked on navigational charts.

This method of monitoring can only be used in good visibility.

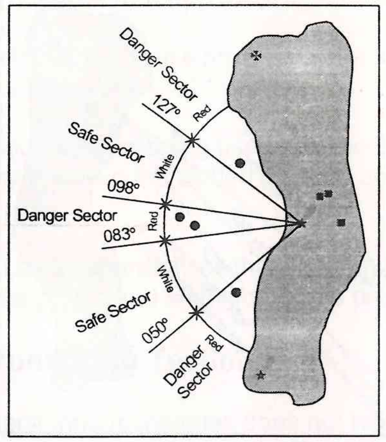


Figure 2.13 - Use of Coloured Sectors

2.5.2.6 Clearing Bearings

In the vicinity of hazards, clearing bearings of selected objects should be determined and marked on the chart during planning to set the margins of safety and for monitoring purposes. These bearings should be determined as Not More Than (NMT) or Not Less Than (NLT).

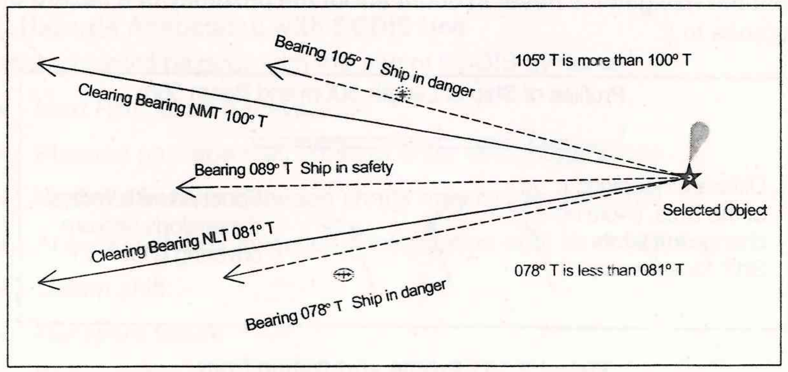


Figure 2.14 - Explanation of use of Clearing Bearings

2.5.2.7 Leading Lights / Marks

The principle is to keep the marks or lights in transit.

- If the nearer mark is opening to starboard, the ship is to the left of the intended track
- If the nearer mark is opening to port, the ship is to the right of the intended track.

This method of monitoring can only be used in good visibility.

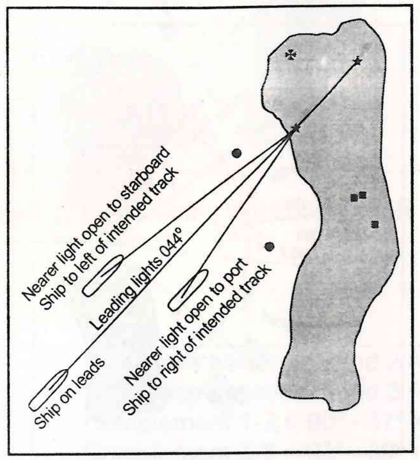


Figure 2.15 - Use of Leading Lights

2.5.3 Ship's Profile and Datum Shift

The position plotted on the chart represents a part of the bridge or the position of the scanner. Some parts of the ship are away from this point. Depending on the scale of the chart being used and the size of the ship, these points may be in (or approaching) danger. It is important to know the corresponding size of the ship for the respective chart so that the navigator is never in doubt about the proximity of a hazard and the time or distance to it.

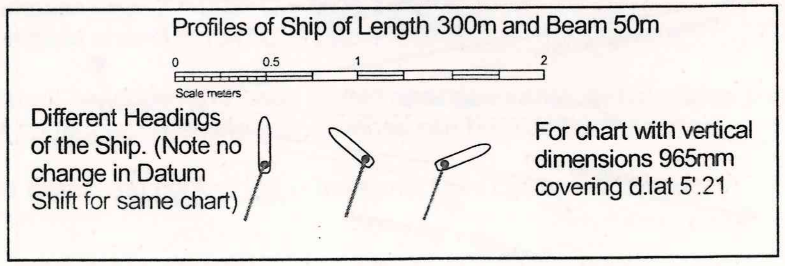


Figure 2.16 - Profile and Datum Shift

Simple cardboard models of the profile and shift for the different charts to be used during the passage can be a valuable addition to the chart table.

Use natural scale, dimensions of the chart and correction for datum to work this out. You cannot use the models on a smaller-scale chart as the ship's profile would be the size of a dot.

> Natural scale 1:12,500 at latitude 21° 30′ N
> Dimensions 965 mm x 635 mm (d.lat = 0° 5′.21) [i.e. 1 NM = 185.2 mm]
> Corrections for datum 0′.17 N, 0′.06 E
> Ship's profile (for L=300 m x B=50 m) is 30 mm x 5 mm
> Datum shift is 019°T x 33.4 mm (0′.18)

In the case of electronic charts, the ship's profile may be automatically generated for the scale in use.

Depending on the navigation system being used and the datum of the chart, there may be some discrepancy between the plotted position and the actual position, i.e., if it is not corrected before plotting.

It is better to apply datum shift separately as the ship may not always be on the same heading as when the profile and shift model was prepared.

2.5.4 Non-Visual Monitoring Techniques

The use of continuous monitoring techniques does not relieve the OOW from plotting positions of the ship at the planned fix frequency. Parallel indexing, maps and navigation lines are used on radar for continuous monitoring. This will be explained in detail in sections 6.5.1, 6.5.2 and 6.5.3.

Terrestrial radio navigation systems and satellite navigation systems can be used for continuous monitoring through use of cross track error and alarm, arrival alarm and course to steer alarm. Reliance on continuous monitoring systems must remain within the limitations of the base system in use. If the positioning system has an error of 0′.5, the monitoring may be constantly in error.

2.5.4.1 Hazards Associated with ECDIS Use

Note these potential hazards with the use of ECDIS systems:

- Next RNC chart not available
- Planned passage may cross or enter designated areas
- Vessel's position between charts may not be the same
- Accuracy of the navigational information may be doubtful
- Datum shift
- Hardware failure
- Software failure

- Power failure
- Failure to update charts
- Input information failure (Position, Course, Speed)
- Virus infection of computer files
- Competency of the ECDIS operator/OOW
- Complacency/over reliance by the OOW

2.6 Summary

Table 2.4 - Primary and Secondary Position Fixing/Monitoring Methods

Waters	Congested		Coastal		Open	
Method/Visibility	Good	Poor	Good	Poor	Good	Poor
Visual	P		P			
Continuous visual monitoring techniques	P		P			
Parallel Indexing / Electronic monitoring	S	P	S	P		
Radar	S	P	S	P		
LORAN C			S	S	S	S
DGPS		S		P/S		
GPS				S	P	P
Celestial					S	

Authors Note:

The operation of ship is a complex task. The navigation officers and Master are required to perform a number of tasks simultaneously. The environment can be hostile. The legal requirements surrounding shipping are very stringent. Any error or omission can result in a disaster. With the costs high and public and environment damage liability bills increasing all the time, the mariner and the ship operators need to ensure that ships are operated as safely as possible. Effective voyage planning is only one step towards ensuring safety of operations.

3 Sailings

We use basic mathematics to determine the course, distance and other relevant details of the passage between two points on the surface of the earth. Some methods make use of plane trigonometry, while others use spherical trigonometry.

Before moving on to actual principles and calculations involving sailings, it is useful to identify and explain some of the relevant terms.

3.1 The Terrestrial Sphere

Spherical trigonometry is based upon a perfect sphere. For relational purposes, the Earth is assigned a grid system and reference identifiers. The reference system is based upon arithmetic, geometric and trigonometric terminology.

The Earth is not a perfect sphere, it has the shape of an oblate spheroid. It spins on an Axis and the extremities of this axis are identified as Poles, which are designated North and South to provide the basic direction reference on the surface of the earth. The true directions are measured as angles from the line(s) joining the North and South Poles. The imaginary lines running from north to south poles are called Meridians. The meridian passing through Greenwich, London is called the Prime Meridian or Greenwich Meridian and is assigned 0°. An imaginary line divides the earth in to two halves and is called the Equator. Meridians are perpendicular to the equator and the equator is a Great Circle. Meridians are semi-Great Circles. A meridian on which an observer is located is called the Upper Meridian. A meridian on the other side of the Earth, i.e., 180° away from the observer, is called the Lower Meridian.

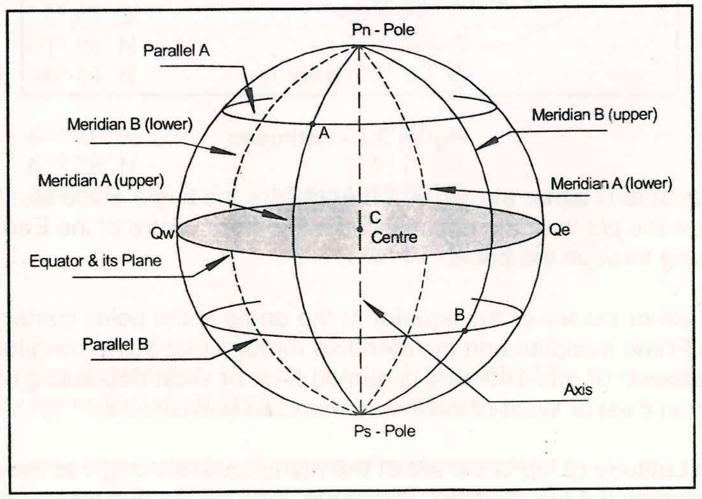


Figure 3.1 - Terrestrial References

A circle on the surface of a sphere, the plane of which passes through the centre of the sphere, is called a Great Circle. There is only one Great Circle possible through two points on the surface of the sphere, unless the points are 180° apart, that is, the points are at two ends of a diameter, allowing infinite Great Circles through the two points, for example, meridians as Great Circles through the poles.

A circle on the surface of a sphere, the plane of which does not pass through the centre of the sphere, is called a Small Circle.

Lines running East-West on the Earth's surface, the plane of which is parallel to the plane of the equator, form small circles known as Parallels of Latitude.

3.1.1 Position Reference

On the earth's surface, positions are referred to using the plane of the equator and the plane of the prime meridian.

The Latitude of a location is the angle between the plane of the equator and the line perpendicular to the surface of the earth at that place. It is measured north or south of the equator from 0° to 90°. (0° is the equator and the 90° points are the poles). This is the Geographic Latitude of a Place (indicated as xx° yy´.y).

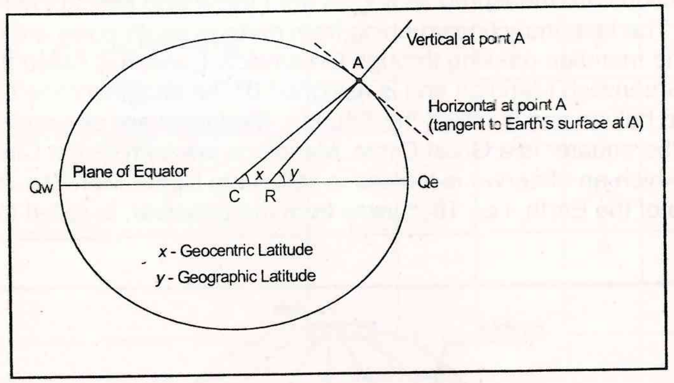


Figure 3.2 - Latitudes

Geocentric latitude is either the arc of a meridian or the angle at the centre of the Earth between the plane of the equator and a line from centre of the Earth through a parallel passing through the point.

Longitude is either the arc of the equator or the angle at the poles contained between the Prime meridian and the meridian through that point. Longitude is measured between 0° and 180° and is named East or West depending on the relative location East or West of the Prime meridian (indicated xxx° yy´.y).

Difference in Latitude (d.lat) is the arc of the meridian or the angle at the centre of the Earth, between the two parallels of latitude, through the two places. It is named North or South depending on the direction of the second place from the first.

Difference in Longitude (d.long) is the shorter arc of the equator or the smaller angle at the pole between the meridians passing through the two places. It is named East or West depending on the direction of second place from the first.

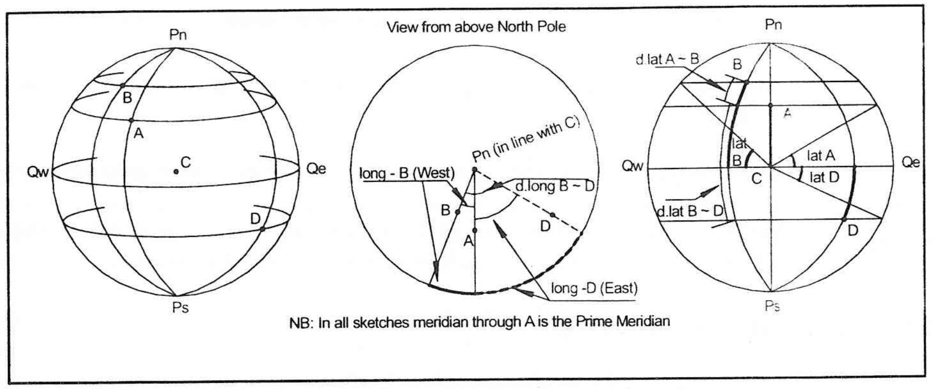


Figure 3.3 - Latitude, Longitude, d.lat and d.long

Example 3.1
Find the d.lat and d.long between the following pairs of positions.

A:		50° 35´ N		000° 00´
B:		61° 28´ N		013° 35´ W
	d.lat	**10° 53´ N**	**d.long**	**13° 35´ W**
B:		61° 28´ N		013° 35´ W
D:		36° 42´ S		093° 45´ E
	d.lat	**98° 10´ S**	**d.long**	**107° 20´ E**
D:		36° 42´ S		093° 45´ E
B:		61° 28´ N		013° 35´ W
	d.lat	**98° 10´ N**	**d.long**	**107° 20´ W**
B:		61° 28´ N		013° 35´ W
E:		61° 28´ N		175° 28´ E
	d.lat	**00° 00´**	**d.long**	**189° 03´ E**
				-360°
				170° 57´ W (- 170° 57´)

Remember:
d.lat

SAME NAMES	–	SUBTRACT
DIFFERENT NAMES	–	ADD

and always name it towards the direction of movement N or S.

d.long

SAME NAMES	–	SUBTRACT
DIFFERENT NAMES	–	ADD

and always name it towards the direction of movement E or W.

If the result is over 180°, subtract from 360° and reverse the sign as d.long is the shorter arc or smaller angle.

The earth's maximum diameter is across the equator and the minimum is across the poles. The difference between these two diameters is about 24 miles and this is so small, compared to the average diameter of 6876 international nautical miles, that for most practical purposes the earth is considered to be a perfect sphere.

3.1.2 Direction Reference

For the purposes of navigation, the direction on the Earth's surface is measured as an angle from the meridian where the observer is located. There are two commonly used systems for indicating direction:

Quadrantal notation
The angles are measured from the North to East or West and South to East or West, 0° to 90°.

Three figure notation
The angles are measured clockwise from the North 000° to 360° (000° and 360° are the same and indicate the direction of true North).

000° is North
045° is N 45° E
090° is East
162° is S 18° S
259° is S 79° W
312° is N 48° W

Angles are measured in degrees and minutes. For practical purposes (and examinations), the courses should be reported to the nearest half degree.

Angle of 45° 12′ north of east is reported as 045°
Angle of 45° 35′ north of east is reported as 045°.5
Angle of 45° 48′ north of east is reported as 046°

True Course is the angle between True Meridian and the ship's head, measured between the meridian and the ship's fore and aft line. Do not confuse the ship's heading with the true charted tracks, as a correction may have been applied.

True Bearing of an object is the angle at the observation point between True Meridian and the line joining the observation point and the object. Ships obtain bearings of fixed objects for plotting position, but state their bearing from fixed objects when reporting their own or other positions.

A Gyro compass points along the meridian to the true north, but it may develop errors. In the absence of errors, the courses or distances measured are true. The error needs to be known and applied. As a rule:

Gyro High	Steer High
Gyro Low	Steer Low

If the gyro error is 2° High, and the course to steer is 315° T, the gyro course would be 317° G. Any bearings observed would have the same error. For the same error, if a gyro bearing is 124° G, the true bearing is 122° T.

Similarly, if the gyro is 2° Low and the course to steer is 315° T, the gyro course would be 313° T and for a gyro bearing of 124° G, the true bearing would be 126° T.

Relative Bearing is the angle between the ships fore and aft line and the line joining the observation point and the object. The main purpose of relative bearings is to know where objects of interest are in relation to your own ship. To convert these bearings into true bearings, apply the ship's true heading.

Relative Bearing	135° R	(R is always after the degrees)
True Heading	210° T	
True Bearing	345° T	(if over 360°, subtract 360°)

Relative bearings can be stated from 000° to 360° relative, or 0° to 180° Red or Green, depending on whether the object is on the port or starboard side. G for green and R for red is always used as prefix, thus R 45° is 315° R.

Magnetic meridians are the lines joining the magnetic poles of the Earth. As the magnetic poles are not at the same place as the Earth's geographic poles, there is a difference between the magnetic and geographic meridians. The difference is measured as an angle and is known as Variation. Since the Earth's magnetic field is not uniform, variation is different at different places. As the Earth's magnetic poles change constantly, the value of variation at a place is not the same at all times. On navigational charts, the value and the annual change are stated either on the compass roses or on lines of equal magnetic variation, the isogonic lines.

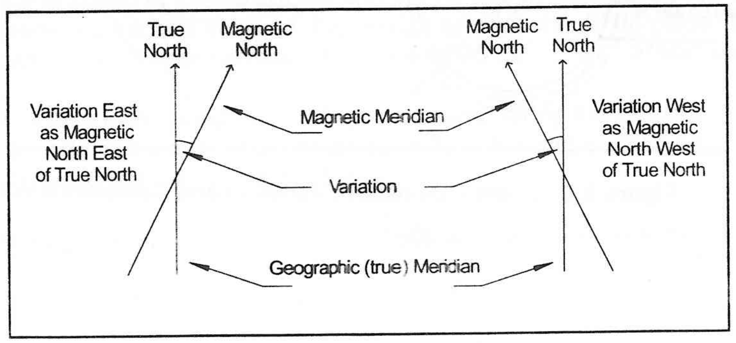


Figure 3.4 - Variation

As the ship is made of mild steel, the magnetism of the ship's structure creates a magnetic field of its own, which also has an effect at the compass position. This magnetism causes deviation of the magnetic compass needles. Deviation is the angle between the magnetic meridian and the line joining the North and South marks on the compass card (pointing to the Compass North). Deviation is measured East or West from magnetic north. Deviation changes with the ship's heading but remains constant for that same heading.

Compass Error is the combined effect, that is the arithmetic sum, of variation and deviation. As a rule:

Error E***ast*** Compass Le***ast***
Error Wes**t** Compass Be**st**

The relationship is demonstrated in the table below and Figure 3.5

Table 3.1 - Magnetic Variation

True Co	Variation	Magnetic Co	Deviation	Compass Co	Compass Error
315° T	14° W	329° M	12° W	341° C	26° W
034° T	10° W	044° M	5° E	039° C	5° W

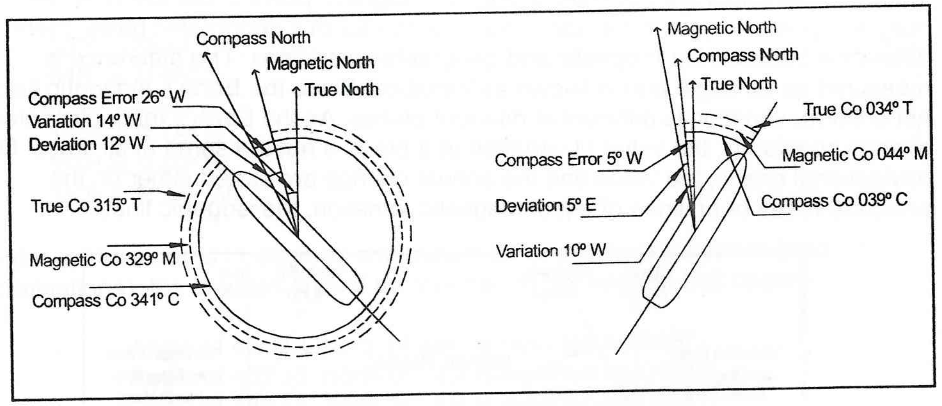


Figure 3.5 - Course, Deviation, Variation and Compass Error

3.1.3 Distances

For general navigational purposes the distances are measured in Nautical Miles. However, there are a number of different units used for distance measurement.

The Sea Mile is the length of one minute of arc measured along the meridian in the latitude of a given position. The one minute of arc (1´) subtends an angle of 1´ at the centre of curvature of that place.

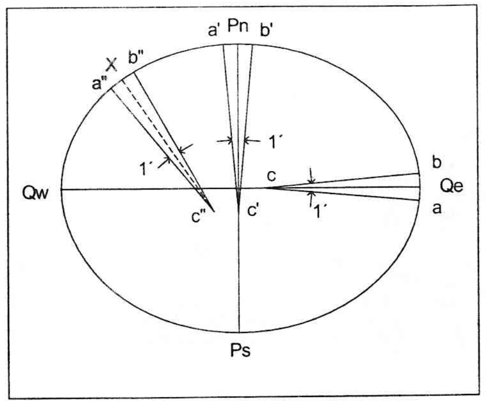


Figure 3.6 - The Sea Mile Measurement

At a given place X, the centre of curvature of the Earth is c", with the radius of curvature as c"X. At c" an angle of 1´ subtends an arc a"-b", with X at its middle. The arc (a"-b") is the sea mile in that latitude X. In Figure 3.6, the sea mile, a-b, is shortest at the equator and is 1842.9 m. At the pole, a'-b' is the longest and is 1861.7 m. It has a mean value of 1852.3 m at 45° latitude.

A standard fixed length of 1852 m is known as the International Nautical Mile.

The distance is stated in minutes of arc and the minute symbol (´) is used to indicate it. Where there is a fraction involved, the minute symbol should be placed before the decimal place, so 25.3 nautical miles is written as 25´.3.

Geographical Mile is the length of 1´ of arc measured along the equator. As the equator is a circle, the length of geographical mile is the same, 1855.4m. With WGS 84, the geographical mile is 1855.32 m

The Statute Mile is a length of 1760 yards (1609.3 m) and is also termed Land Mile.

A Kilometre equals 1000 m. (In all cases, m stands for metres)

3.2 Parallel Sailing

A ship that steers at 090°T or 270°T would not change its latitude, provided that no external forces act on the ship. This means that the departure and arrival positions are on the same latitude. This type of sailing is called Parallel sailing. The distance covered by the ship can be related to a change of longitude (or vice versa) and is equal to departure between the two positions along the given parallel of latitude. This is a type of sailing commonly used by Sailing Ships prior to and during the 19th Century

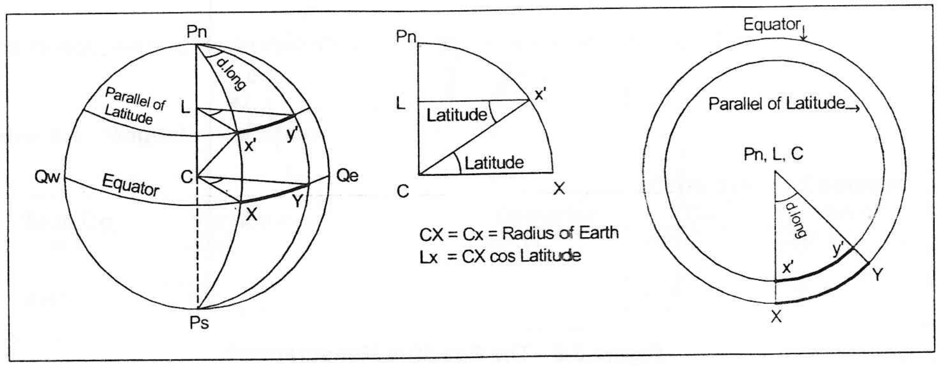


Figure 3.7 - Parallel Sailing

When the ship is travelling along any parallel of latitude, x´y´, the d.long is XY. Numerically the distance x´y´ is less than XY. As an angle, x´y´ and XY are the same, i.e., d.long is the same. CX is the radius of the earth and Lx´ is the radius of the parallel and is equal to CX cos Latitude. The nearer the parallel of latitude is to the pole, the shorter x´y´ becomes (that is, at higher latitudes). It becomes zero at the pole (90° latitude).

When viewed from the pole, the equator and the parallel of latitude are concentric circles.

Arc x´y´ / Arc XY = dep / d.long = radius Lx´ / radius CX

or,

dep / d.long = radius Lx´ / radius Cx´ (as CX = Cx´ = Radius)

Since triangle CLx´ is right angled:

Lx´ / Cx´ = cos Latitude

That is:

dep / d.long = cos Latitude

or,

departure = d.long x cos Latitude

Parallel sailing uses the conversion of departure along the parallel of latitude into difference of longitude, assuming the earth is a perfect sphere.

Example 3.2

Find the distance travelled by a ship on a course of 090° T at latitude 45° N, if its longitude changed by 20°. If latitude was 60° N, find the distance

20° = 20 x 60 = 1200´ of arc

For 45° N:

dep = d.long cos Latitude

x´y´ = XY cos Latitude

dep = d.long x cos Latitude = 1200 x cos 45°

= **848´.5**

For 60° N:

dep = 1200 x cos 60°

= **600´**

Example 3.3

A ship in position 41° 10´ S 032° 45´ W is steering a course of 090° T at a speed of 16 knots. Find the longitude reached after 22 hours of steaming.

Distance covered in 22 hours = 22 x 16 = 352´ = dep

d.long = dep / cos Latitude

= 352 / cos 41° 10´ = 352 / 0.752798

= 467´.6 ÷ 60= 7° 47´.6 E (E as course is 090° T)

Longitude reached

= 032° 45´ W ~ 7° 47´.6 E = **024° 57´.4 W**

3.3 Plane Sailing

Plane sailing is where the ship sails along any rhumb line between positions that are not situated on the same parallel of latitude or meridian of longitude. In plane sailing, the d.lat, departure, distance and course may be considered as forming the plane of a right-angled triangle. Various trigonometric functions can be applied to obtain a few navigational formulae.

departure = distance x sin course

d.lat = distance x cos course

tan course = departure ÷ d.lat

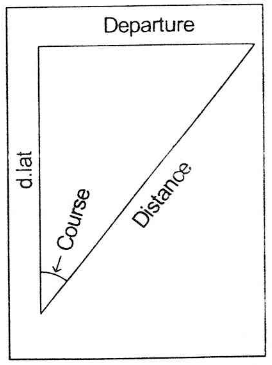


Figure 3.8 - Plane Triangle

Plane sailing is a method of solving d.lat, departure, distance and course related problems. As the earth is not flat, plane sailing only provides reasonably accurate results up to a distance of 600′.

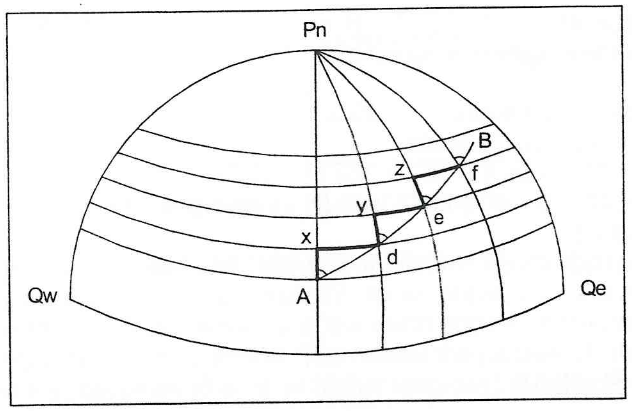


Figure 3.9 - Plane Sailing

Refer to Figure 3.9 and assume that a rhumb line AB is cutting a number of parallels and meridians, so that the parallels are an equal d.lat apart. The rhumb line cuts the parallels at A, d, e, f and B. Through these points, the meridians cut the parallels at x, y and z forming right-angled triangles Axd, dye and ezf.

In these triangles, the angles at points x, y and z are right angles. Angles xAd, yde and zef are equal and are the course angles from Pn, i.e., North Pole. As the parallels are an equal distance apart, lines Ax, dy and ez are also equal in length.

The small triangles are equal in all respects. As the triangles are very small, they are considered as plane right-angled triangles. In triangle Axd:

For d.lat

Ax = Ad x cos course
multiples of Ax = multiples of Ad x cos course
d.lat = distance x cos course

For departure

xd = Ad x sin course
multiples of xd = multiples of Ad x sin course
dep = distance x sin course

For course

tan course = xd / Ax (or multiples of xd , Ax)
tan course = departure / d.lat

Example 3.4
Find the distance travelled and course steered by a ship that has moved 45′ to the south and 30′ to the west of its initial position.

Here d.lat = 45′ and dep = 30′

tan course	=dep / d.lat	= 30 / 45	= 0.66667	
course	=33°.7or	= S 33°.5 W		**= 213°.5 T**
distance	=d.lat ÷ cos course	= 45 ÷ cos 33.7		**= 54′.1**

Example 3.5
If a ship covers a distance of 35′ in a general north easterly direction and changes its latitude by 20′, find the course that it has steered.

d.lat	=	distance x cos course	
20	=	35 x	cos course
cos course	=	20 / 35	= 0.57143
course	=	55°.1 =	**N 55° E or 055° T**

3.3.1 Use of Mean Latitude

The Earth's surface is not flat. When a ship is on a rhumb line (not sailing either north-south or east-west), you must consider the curvature of the Earth when calculating a position.

In Figure 3.10, for a rhumb line between positions A and B, the d.long is a"b". The departure along the parallel through A is Ab' and departure through parallel of B is a'B. As can be seen in the diagram, Ab' is larger than a'B.

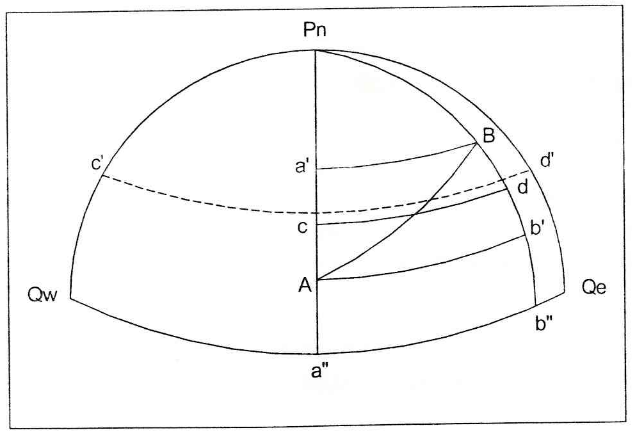


Figure 3.10 - Mean Latitude

To calculate the correct position of B, the departure from A to B should be along a parallel between that of A and B, shown here as c'd'.

Where latitudes of A and B are not too high, and the d.lat between A and B is fairly small, this departure can be taken as the latitude at the mathematical mean between latitudes of A and B, that is, cd. It is called the Mean Latitude.

Using:

cd	=	a"b" x cos a"c	(a"c = b"d)
departure	=	d.long x cos mean latitude	

Plane sailing should not be applied for distances exceeding 600´. The formula above lacks mathematical accuracy, except where A and B are on the same parallel of latitude. In low latitudes, the discrepancy caused by the curvature of the earth is less. Nautical tables make reference to Middle Latitude, which is the Corrected Mean Latitude between two parallels, say c'd'. It is particularly useful in high latitudes as the use of Mean Latitude alone in these conditions may result in a larger discrepancy in your position.

For corrected mean lat:

sec Lat = DMP / d.lat (minutes of arc)

Example 3.6
If a ship departs from position 24° 30´ N 038° 20´ W for 22° 45´ N 039° 35´ W, Calculate the course and distance travelled by the ship.

	24° 30´ N		038° 20´ W
	22° 40´ N		039° 35´ W
d.lat =	01° 50´ S	dep =	001° 15´ W
	(110´)		(75´)

mean lat = ½ (24° 30´ + 22° 40´) N = 23° 35´ N

dep	=	d.long x cos mean lat				
	=	75 x cos 23° 35´				
dep	=	68´.74 W				
tan course	=	dep / d.lat	=	68.74 / 110	=	0.62487
course	=	S 32° W	=	212° T		
distance	=	d.lat / cos course	=	110 / cos 32° = **129´.7**		

Example 3.7
If a ship departs from position 34° 20´ S 040° 30´ W on a course of 033°T for 350´, determine the position reached.

d.lat	=	distance x cos course		
	=	350 x cos 33 =	293´.5 = 04° 53´.5 N	
arrived lat	=	34° 20´ S ~ 04° 53´.5 N		= **29° 26´.5 S**
mean lat	=	½ (34° 20´ + 29° 26´.5) S		= 31° 53´.25S
dep	=	distance x sin course		
	=	350 x sin 33 =	190´.6236623	
d.long	=	dep / cos mean lat		
	=	190´.6236623 ÷ cos 31° 53´.25		
	=	224´.5 ÷ 60 =	3° 44´.5 E	
arrived long	=	040° 30´ W ~ 3° 44´.5 E		= **036° 45´.5 W**

3.3.2 Application of Traverse Sailing

Where a ship sails on a number of consecutive legs, the combination is known as traverse sailing. The individual legs of the ship's track form part (hypotenuse) of the plane of the right-angled triangles. A traverse table can be used to obtain d.lat and departure for any course and distance up to 600´. It can also be used to convert departure to d.long or vice versa. To calculate more accurate results, use the plane sailing formulae.

A calculator with the formulae will avoid the need for interpolation between sets of figures. Traverse sailing can be very useful where the ship has steered various legs during the working day.

To determine the final position, calculate the net d.lat and departure from the start position. This can be achieved through a tabular presentation as demonstrated in Example 3.8.

Example 3.8

A ship in position 22° 30′ N 061° 40′ E at 1230, is engaged in an exercise and steers the following courses and speeds for the stated time intervals.

Time Interval	*Course*	*Speed*
1230 – 1300	*155° T*	*14 kts*
1300 – 1315	*030° T*	*10 kts*
1315 – 1345	*340° T*	*16 kts*
1345 – 1430	*270° T*	*10 kts*

Determine the ship's position at 1430, if a current of 040°T at 3 knots is known to be setting throughout.

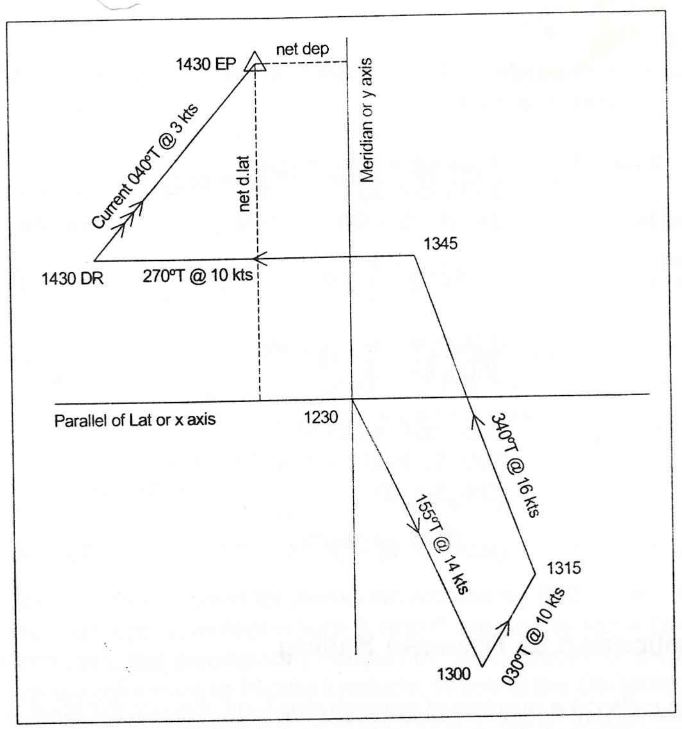


Figure 3.11 - Days Work (for use with example 3.8)

Time	Course	Speed	Dist	d.lat		dep	
				N	S	E	W
1230 – 1300	155° T	14 kts	7′		6′.3	3′.0	
1300 – 1315	030° T	10 Kts	2′.5	2′.2		1′.3	
1315 - 1345	340° T	16 kts	8′	7′.5			2′.7
1345 - 1430	270° T	10 kts	7′.5	0	0		7′.5
Current – 2 hrs	040° T	3 kts	6′	4′.6		3′.9	
Total				14′.3	6′.3	8′.2	10′.2
				Net d.lat = 8′.0 N		Net dep = 2′.0 W	

arrived lat	=	22° 30′ N ~ 00° 8′.0 N	=	22° 38′ N
mean lat	=	½ (22° 30′ + 22° 38′)	=	22° 34′ N
d.long	=	0° 2′.2 W		
arrived long	=	061° 40′ E ~ 0° 2′.2 W	=	061° 37′.8 E
Position at 1430	=	**22° 38′ N 061° 37′.8 E**		

A traverse table was used to solve this example, but the use of a calculator would improve accuracy. If required, you can add extra columns, such as leeway for example.

3.4 Mercator Sailing

The determination of the position that is reached after sailing along a rhumb line over a long distance that changes the latitude and longitude simultaneously, that is, in directions other than north-south or east-west, has to allow for curvature of the earth.

A method known as Mercator Sailing uses the difference of meridional parts (DMP) (instead of d.lat/d.long) and departure and provides greater accuracy.

Meridional parts can be found in nautical tables. Use this formula for the calculation (for the sphere):

Meridional parts $= 7915.7045 \log_{10} (\tan (45° + \text{Latitude}° / 2))$

The formulae for calculating Mercator course and distance are:

tan course = d.long / DMP

distance = d.lat x sec course (using a calculator, which can register the course to at least six decimal places) or

distance = d.lat / cos course

distance = dep x cosec course (using tables, especially when the course is 60° to 90°, dep should be from corrected mean latitude)

The distance is given in geographical miles.

Example 3.9

Determine the Mercator course and distance between 20° 24′ S 057° 26′ E and 34° 10′ S 112° 28′ E.

	Lat		MP	Long
Departure position:	20° 24′ S		1242.56	057° 26′ E
Arrived position:	34° 10′ S		2170.41	112° 28′ E
d.lat	13° 46′ S (826′)	DMP	927.85	d.long 055° 02′ E (3302′)

tan course	= d.long / DMP = 3302 / 927.85 = 3.558765
course angle	= 74°.30482997
course (to 0°.5)	= S 74°.5 E = 105°.5 T
distance	= d.lat / cos course = 826 / cos 74°.30482997
	= **3053´.4** or **3053´ (to nearest mile)**

Example 3.10

If a ship departs from position 46° 14´ N 125° 36´ W on a course of 237° T and covers 7076´, find the position reached.

course	= 237° T	= S 57° W	
d.lat	= distance x cos course	=	7076 x cos 57°
	= 3853´.9	= 64° 13´.9 S	
arrived lat	= 46° 14´ N ~ 64° 13´.9 S	=	17° 59´.9 S

departure lat	46° 14´.0 N	MP	3118.83
arrived lat	17° 59´.9 S	MP	1090.885
		DMP	4209.715

d.long	= tan course x DMP =		tan 57° x 4209.715
	= 6482´.4	=	108° 02´.4 W

departure long	=	125° 36´.0 W
d.long	=	108° 02´.4 W
	=	233° 38´.4 W
		- 360°
arrived long	=	**126° 21´.6 E**

(Subtraction of 360° has only been carried out because the result was above 180°)

3.5 Great Circle Sailing

A Great Circle is a circle on the surface of a sphere, the plane of which passes through the centre of the sphere. The Great Circle divides the sphere into two.

A Great Circle is the most direct route between two places on the Earth's surface. The shorter arc of the Great Circle between the two places is the shortest distance between these places. It is identified as arc AB in Figure 3.12. On the surface of the sphere this arc/circle through A and B has the greatest radius and hence the least curvature.

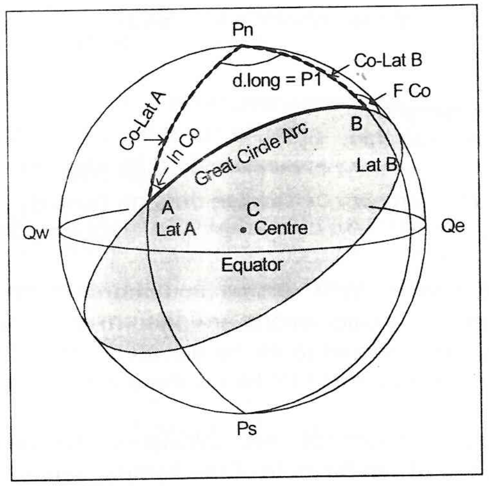


Figure 3.12 - Great Circle

Great Circles are most useful where the latitudes are high and the d.long is significant. The saving in distance may not be significant in low latitudes, with a smaller d.long, or when crossing the equator. But there are other reasons for using Great Circle for routeing ships. These include the avoidance of adverse currents or winds or for taking advantage of favourable winds or currents.

Calculations involving Great Circles are solutions of a spherical triangle with Pole, A and B as its three corners. Spherical triangles have a number of properties, including:

- All sides are less than 180°
- All angles are less than 180°
- The sum of the three angles is more than 180°, but less than 540°
- The largest angle is opposite to the longest side
- The smallest angle is opposite the shortest side.

The sum of any two sides is always greater than the length of the third side.
In all the Great Circle calculations, the Earth is assumed to be a perfect sphere.

In the formulae employed in this section:

- Where two letters are used a side is indicated
- Where a single letter is used, it indicates an angle.

The three angles and sides of the spherical triangle are:

P_1	d.long.
A	Initial Course angle.
B	Final Course angle.
PA	Co-lat A (It is an arc of meridian through point A).
PB	Co-lat B (It is an arc of meridian through point B).
AB	Distance (It is an arc of a Great Circle through points A and B).

The direction of d.long, East or West, should be determined carefully as it is a component of the course. The calculations are performed relative to one of the poles, North or South. This pole is referred to as the elevated pole. If both the latitudes are in the same hemisphere, the pole of that hemisphere is selected as the elevated pole.

If the latitudes are in different hemispheres, calculations can be performed from any pole. But it is better to work from the pole of the hemisphere that has the starting position in it, as naming the initial course would be convenient.

Figure 3.13 illustrates the elevated poles and working of Co-latitudes, PA and PB.

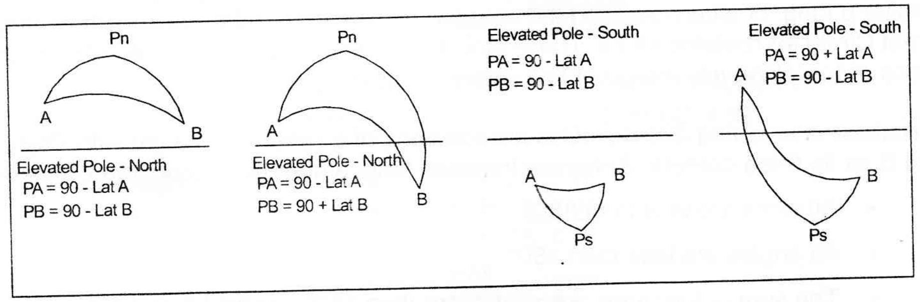


Figure 3.13 - Elevated Poles

3.5.1 Distance

The cosine method can be employed for distance calculation when using a scientific calculator.

$$\cos AB = \sin PA \sin PB \cos P_1 + \cos PA \cos PB$$

The above formula can be adapted using latitudes directly, avoiding the need for applying co-latitudes, as follows:

$$\cos AB = \cos lat\,A \cos lat\,B \cos P_1 \pm \sin lat\,A \sin lat\,B$$

If latitudes are in the same hemisphere, ADD (use +), and if the latitudes are in different hemispheres, SUBTRACT (use -).

While working with a calculator, it is recommended that all the decimal places are used in calculations and the final result either saved in memory or recorded accurately (as it may be needed for later calculations).

Generally, five (5) decimal places give an accurate answer, but a problem may arise when shifting the figures from calculator to the paper and vice versa. If the calculator comes up with a minus sign (-) during the calculations, disregard the minus sign

Using the Haversine formula:

$$hav\,AB = hav\,P_1 \sin PA \sin PB + hav\,(PA \sim PB)$$

In all cases, the arc AB is calculated in degrees and minutes. Multiply the result by 60 to obtain the distance in nautical miles. The distance as an answer should be reported to the nearest mile, but the full value of AB should be used for subsequent calculations, in the same way as for the course calculations.

3.5.2 Courses

Course – Initial:

$$\cos A = \frac{\cos PB - \cos PA \cos AB}{\sin PA \sin AB}$$

Course – Final:

$$\cos B = \frac{\cos PA - \cos PB \cos AB}{\sin PB \sin AB}$$

The course angle in a spherical triangle is an interior angle between the meridian and the Great Circle track. Depending upon the method of working, it is related to the pole from which co-lat is applied in a cosine formula.

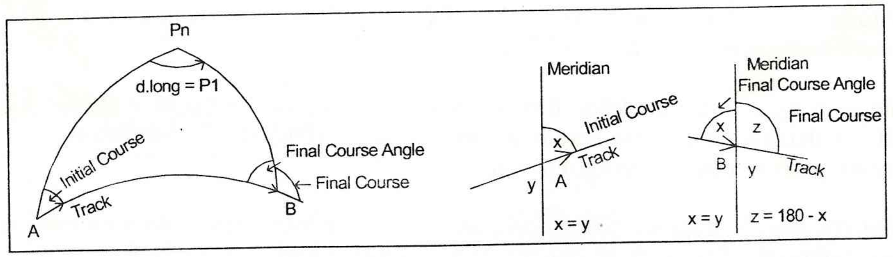


Figure 3.14 - Courses and Angles

The navigator needs the knowledge and skills to convert the interior angles to Initial and Final Courses. Basic geometry can be useful:

Where two straight lines intersect, opposite angles are equal (x = y in Figure 3.14) and the sum of adjacent angles is 180° (x + z = 180°, or z = 180° - x).

If position A is in the Northern hemisphere, with the North pole as the elevated pole, and an initial course angle is 45°, the courses would be 045°T (N45°E) for an East d.long or 315°T (N45°W) for a West d.long. If the same angle happens to be 120°T, the courses would be 120°T (S60°E) for an East d.long or 240°T (S60°W) for a West d.long.

If the final course angle is 45° with a North elevated pole, the final course would be 135°T (S45°E) for an East d.long or 225°T (S45°W) for a West d.long. The sketches in figure 3.15 illustrate different scenarios. When drawing sketches, the meridian of vertex should be drawn as a perpendicular, with other positions relative to it.

Use the A B C method to determine Courses:

Initial Course:	Final Course:
A = tan lat A ÷ tan P1	A = tan lat B ÷ tan P1
B = tan lat B ÷ sin P1	B = tan lat A ÷ sin P1
C = A ± B	C = A ± B
Course =1÷ (C cos lat A)	Course =1÷ (C cos lat B)

(Lat A and B, Same Names Sum, Different Names Difference)

With this method, the course names can be based on the signs of C and d.long. In all cases, courses should be reported to nearest half degree. For subsequent calculations (such as the vertex calculation), use the full value.

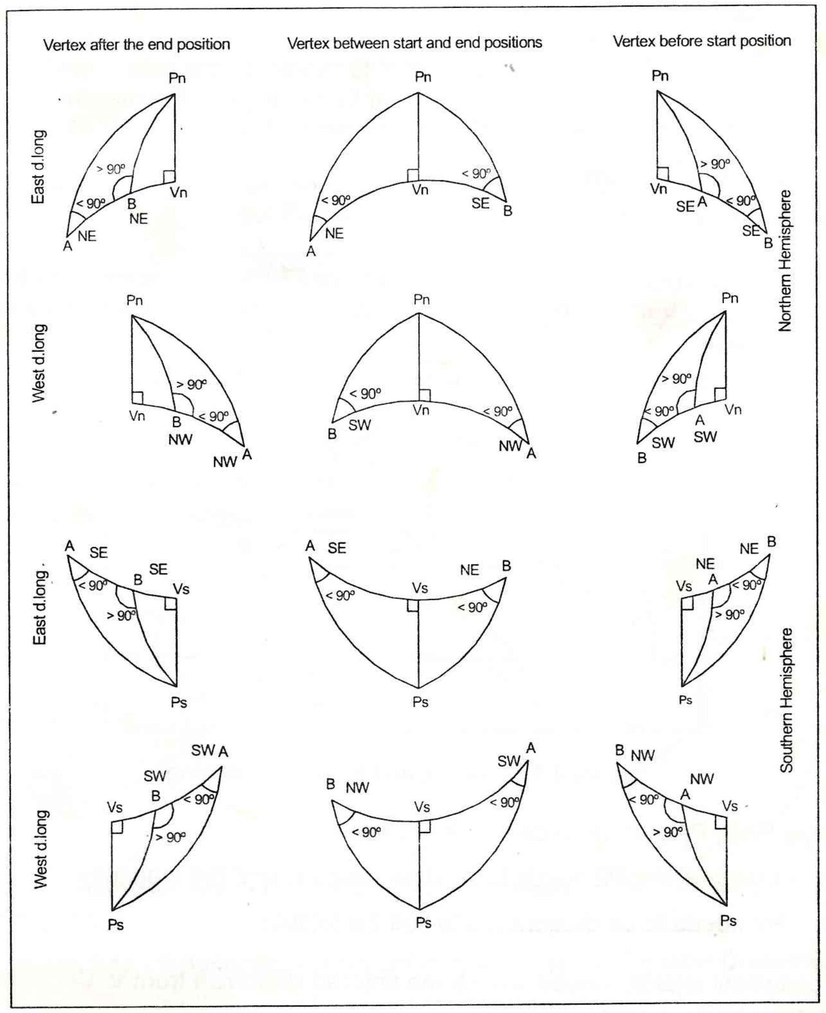


Figure 3.15 - Naming of Great Circle Courses

3.5.3 Napier's Rules and Trigonometric Identities

sin of Middle Parts = Product of tan of Adjacent Parts
sin of Middle Parts = Product of cos of Opposite Parts

sin θ	=	cos (90° - θ)	[sin = sine]
cos θ	=	sin (90° - θ)	[cos = cosine]
tan θ	=	cot (90° - θ)	[tan = tangent]
cot θ	=	tan (90° - θ)	[cot = cotangent]
tan θ	=	1 ÷ cot θ	
tan θ	=	1 ÷ tan (90° - θ)	

Effort has been made to work all examples with sine, cosine and tangent only.

3.5.4 Vertex

Vertex is the point along the Great Circle that is nearest to the pole in the hemisphere, that is, the point where the Great Circle reaches the maximum latitude. Each Great Circle, other than the equator, has two vertices:

- V_N in the northern hemisphere
- V_S in the southern hemisphere.

At the vertex, the course angle is 90°, i.e. 090°T or 270°T, dependent upon the direction of d.long. Vertex is noted as latitude and longitude. Both vertices are 180° apart in longitude.

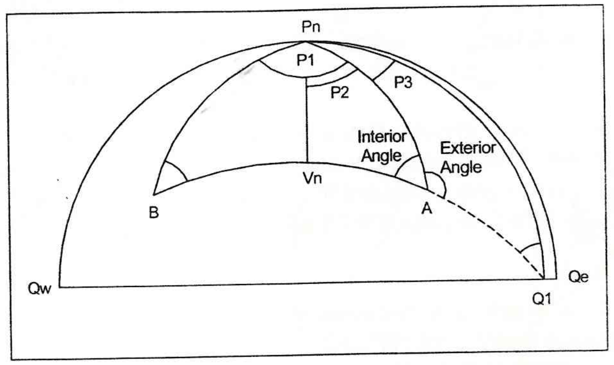


Figure 3.16 - Vertex and Equator Crossing

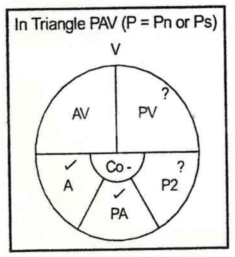
In triangle PAV, PA and initial course A are known.

- d.long APV = P2 needs to be determined to find the longitude
- PV needs to be determined to find the latitude.

In the cartwheel sketch, values have been entered clockwise from V. Co – stands for complement (90° - angle).

It is important to use PA and A for both calculations, d.long and latitude of vertex, and not any other quantity that has been determined during the vertex calculation. Any error in the working would be carried into the result.

Using Napier's Rule: sin mid part = product of cos of opposite parts



sin PV = cos (co - PA) x cos (co - A)
sin PV = cos lat A x sin A
cos lat V = cos lat A x sin A

cos lat V	=	cos lat A	x	sin A

Using Napier's Rule: sin mid part = product of tan of adjacent parts

sin (co – PA) = tan (co – P2) x tan (co - A)
cos PA = cot P2 x cot A

$$\tan P2 = \frac{1}{\sin \text{lat } A \times \tan A}$$

$$\boxed{\tan P2 = \frac{1}{\sin \text{lat } A \times \tan A}}$$

If a vertex is to be worked relative to position B, the latitude B and the final course should be used in the above formulae.

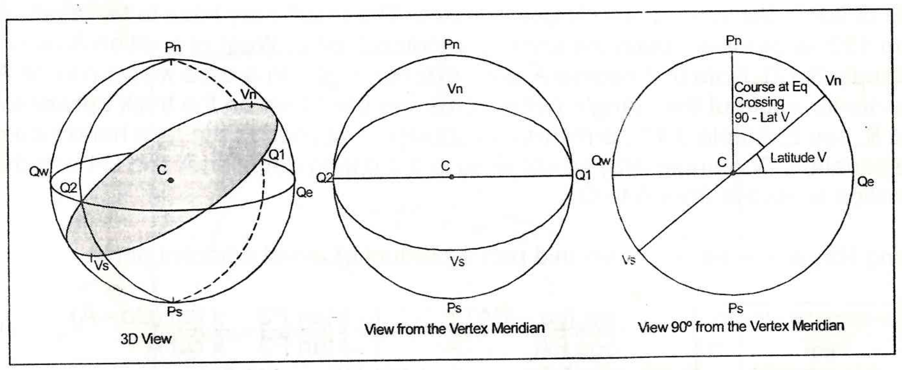


Figure 3.17 - Relationship of Great Circle Vertices and Equator Crossing

Having calculated one vertex, the other can be simply determined by reversing the sign of latitude and applying a d.long of 180° to the meridian of the first vertex (and not changing sign of longitude, unless one longitude is 090°).

3.5.5 Crossing the Equator

Each Great Circle (other than equator) crosses the equator at two points. These points are 180° apart in longitude and are at 90° in longitude from either vertex.

If the vertex is known, this point is at a d.long of 90° from the vertex longitude. Take care to apply the d.long in the correct direction east or west of the vertex meridian.