FUNCTION 1: NAVIGATION AT THE MANAGEMENT LEVEL

- **COURSE OUTLINE**

KNOWLEDGE, UNDERSTANDING AND PROFICIENCY	TOTAL HOURS FOR EACH TOPIC	TOTAL HOURS FOR EACH SUBJECT AREA OF REQUIRES PERFORMANCE
COMPETENCE:		
1.1 **PLAN A VOYAGE AND CONDUCT NAVIGATION**		
1.1.1 VOYAGE PLANNING AND NAVIGATION FOR ALL CONDITIONS	24	
1. Voyage planning for all conditions by acceptable methods of plotting ocean tracks	12	
2. Navigation and monitoring of the voyage	2	38
3. Logbooks and voyage records		
1.1.2 ROUTEING IN ACCORDANCE WITH THE GENERAL PRINCIPLES FOR SHIP'S ROUNTEING		
1. Routeing	12	12
1.1.3 REPORTING IN ACCORDANCE WITH THE GENERAL PRINCIPLES FOR SHIP REPORTING SYSTEMS AND WITH VTS PROCEDURES		
1. Ship reporting system	1	1
1.2 **DETERMINE POSITION AND THE ACCURACY OF RESULTANT POSITION FIX BY ANY MEANS**		
1.2.1 POSITION DETERMINATION IN ALL CONDITIONS		
1. Celestial Navigation	10	
2. Terrestrial observations, including the ability to use appropriate charts, notices to mariners and other publications to assess the accuracy of the resulting fix	16	
3. Modern electronic navigation aids with specific knowledge of their operating principles, limitation, sources of error, detection of misrepresentation of information and methods of correction to obtain accurate position fixing	20	46
1.3 **DETERMINE AND ALLOW FOR COMPASS ERRORS**		
1.3.1 PRINCIPLES OF THE MAGNETIC COMPASSES		
1. Parts of the magnetic compass and their function	3	
2. Errors of the magnetic compass and their correction.	27	30
1.3.2 PRINCIPLES AND ERRORS OF GYROCOMPASSES		
1. Principles of gyrocompasses	3	
2. Gyrocompass errors and corrections	7	10
1.3.3 SYSTEMS UNDER THE CONTROL OF THE MASTER GYRO AND THE OPERATION AND CAR OF THE MAIN TYPES OF GYRO COMPASS		
1. Systems under the control of master gyro and the of the operation and care of the main types of gyrocompass	2	2
1.4 **COORDINATE SEARCH AND RESCUE OPERATIONS**		

**** See IMO Model Course 1.08 and STCW reg. 1/12		
1.5 **ESTABLISH WATCHKEEPING ARRANGEMENTS AND PROCEDURES**		
1.5.1 THE INTERNATIONAL REGULATIONS FOR PREVENTING COLLISIONS AT SEA		
1. Thorough knowledge of content, application and intent of the international Regulations for Preventing Collisions at sea, 1972, as amended	30	30
1.5.2 PRINCIPLES TO BE OBSERVED IN KEEPING A NAVIGATIONAL WATCH		
1. Through knowledge of the control, application and intent of the principles to be observed in keeping a navigation watch at management level	12	12
1.5.3 Bridge WATCHKEEPING EQUIPMENT AND SYSTEM		
1. Knowledge of voyage data recorders (VDR) and bridge navigation wathckeeping alarm system (BNWAS)	6	6
1.6 **MAINTAIN SAFE NAVIGATION THROUGH THE USE OF INFORMATION FROM NAVIGATION EQUIPMENT AND SYSTEMS TO ASSIST COMMAND DECISION MAKING**		
****See IMO model course 1.08, 1.22, 1.27, 1.34 and STCW reg. I/12		60
1.7 **MAINTAIN SAFE NAVIGATION THROUGH THE USE OF ECDIS AND ASSOCIATED NAVIGATION SYSTEMS TO ASSIST COMMAND DECISION MAKING**		
****See IMO model courses 1.27 in association with 1.08 and 1.22		40
1.8 **FORECAST WEATHER AND OCEANOGRAPHIC CONDITIONS**		
1.8.1 SYNOPTIC CHARTS AND WEATHER FORECASTING		
1. Synoptic and prognostic charts and forecasts from any source	6	
2. Range of information available through fax transmission, internet and email	3	
3. Weather forecasting	15	24
1.8.2 CHARACTERISTICS OF VARIOUS WEATHER SYSTEMS		
1. Tropical revolving storms (TRS)	8	
2. Main types of floating ice, their origins and movements	2	
3. Guiding principles relating to the safety of navigation in the vicinity of ice	2	
4. Conditions leading to ice accretion on ship's superstructures, dangers and remedies available	2	14
1.8.3 OCEAN CURRENT SYSTEM		
1. Surface water circulation of the ocean and principle adjoining seas	3	
2. The principle of voyage planning with respect to weather conditions and wave height	2	
3. Formation of sea waves and swell waves	2	7
1.8.4 CALCULATION OF TIDAL CONDITIONS		
1. Ability to calculate tidal conditions	6	6

1.8.5 APPROPRIATE NAUTICAL PUBLICATIONS ON TIDES AND CURRENTS		
1. Nautical publications on tides and currents and information which can be obtained via internet and email	3	3
1.9 **RESPOND TO NAVIGATION EMERGENCIES**		
1.9.1 PRECAUTIONS WHEN BEACHING A SHIP		
1. Precautions when beaching a ship	2	2
1.9.2 ACTION TO BE TAKEN IF GROUNDING IS IMMINENT AND AFTER GROUNDING		
1. Action to be taken if grounding is imminent and after grounding	2	2
1.9.3 REFLOATING A GROUNDED SHIP WITH AND WITHOUT ASSISTANCE		
1. Refloating a grounded ship with and without assistance	1	1
1.9.4 ACTION TO BE TAKEN IF COLLISION IS IMMINENT AND FOLLOWING A COLLISION OR IMPAIRMENT OF THE WATERTIGHT INTEGRITY OF THE HULL BY ANY CAUSE		
1. Action to be taken if collision is imminent and following a collision or impairment of the watertight integrity of the hull by any cause	2	2
1.9.5 ASSESSMENT OF DAMAGE CONTROL		
1. Assessment of damage control	1	1
1.9.6 EMERGENCY STEERING		
1. Emergency steering	1	1
1.9.7 EMERGENCY TOWING ARRANGEMENT AND TOWING PROCEDURES		
1. Emergency towing arrangements and towing procedure	2	2
1.10 MANOEUVRE AND HANDLE A SHIP IN ALL CONDITIONS (Also refer to IMO model course 1.22, Ship simulator and bridge teamwork and STCW reg. I/12)		
1.10.1 MANOEUVERING AND HANDLING A SHIP IN ALL CONDITIONS		
1. Approaching pilot stations and embarking or disembarking pilots, with due regard to weather, tide, head reach and stopping distances	4	
2. Handling ship in rivers, estuaries and restricted waters, having regards to the effects of current, wind and restricted water on helm response	10	
3. Application of constant rate of turn techniques	3	
4. Manoeuvring in shallow water including the reduction in under-keel clearance caused by squat, rolling and pitching	2	
5. Interaction between passing ships and between own ship and nearby banks (canal effect)	2	
6. Berthing and unberthing under various conditions of wind, tide and current with and without tugs.	20	
7. Ship and tug interaction	3	
8. Use of propulsion and manoeuvring systems including different types of rudder	4	

9. Types of anchor; choice of anchorage; anchoring with one or two anchors in limited anchorage and factors involved in determining the length of anchor cable to be used	6	
10. Procedures for anchoring in deep water and in shallow water	1	
11. Dragging anchor; clearing fouled anchors	1	
12. Dry-docking, both with and without damage	4	
13. Management and handling ships in heavy weather including assisting a ship or aircraft in distress; towing operations; means of keeping an unmanageable ship out of a sea trough, lessening lee drift and use of oil	6	
14. Precautions in manoeuvring to launch rescue boats and survival craft in bad weather	2	
15. Methods of taking on board survivors from rescue boats and survival craft	1	
16. Ability to determine the manoeuvring and propulsion characteristics of common types of ships, with special reference to stopping distances and turning circles at various draughts and speeds	3	
17. Importance of navigating at reduced speed to avoid damage caused due ti own ship's bow and stern waves	1	
18. Practical measures to be taken when navigating in or near ice or in conditions of ice accumulation on board	4	
19. Use of, and maneuvering in and near traffic separation schemes and in vessel traffic services (VTS) areas	4	81
1.11 **GENERAL KNOWLEDGE OF REMOTE CONTROLS OF PROPULSION PLANT AND ENGINEERING SYSTEMS AND SERVICES**		
1.11.1 OPERATING PRINCIPLES OF MARINE POWER PLANTS	25	25
1.11.2 SHIP'S AUXILIARY MACHINERY	25	25
1.11.3 GENERAL KNOWLEDGE OF MARINE ENGINEERING SYSTEMS		
1. Marine engineering terms and fuel consumption	4	
2. Arrangements necessary for appropriate and effective engineering watches to be maintained for the purpose of safety under normal circumstances and UMS operations	2	
3. Arrangements necessary to ensure a safe engineering watch is maintained when carrying dangerous cargo	2	8
TOTAL FOR FUNCTION 1: Navigation at the Management Level		**451 hours**

Teaching staff and administrations should note that the hours for lectures and exercises are suggestions only as regards sequence and length of time allocate each objective. These factors may be adapted by lecturers to suit individual groups of trainees depending on their experiences, ability, equipment and staff available for teaching.

1.1. PLAN A VOYAGE AND CONDUCT NAVIGATION

Every management of Shipowning Company should have a safety management policy. It should provide practical guidance concerning safe navigation and include:

- a dear statement that safety of life and safety of the ship take precedence over all other considerations;
- allocation of bridge watchkeeping duties and responsibilities for navigational procedures;
- procedures for voyage planning and execution;
- chart and nautical publication correction procedures;
- procedures to ensure that ah essential navigation equipment and main and auxiliary machinery are available and fully operational;
- advice concerning emergency responses;
- ship position reporting procedures;
- accident and near miss reporting procedures;
- recording of voyage events;

The intended voyage should be planned prior to departure using appropriate and available corrected charts and publications. The master should check that the tracks aid down are safe, and the chief engineer should verify that the ship has sufficient fuel, water and lubricants for the intended voyage.

In addition, the duty of the master to exercise professional judgement in the light of changing circumstances remains a basic requirement for safe navigation.

Responsibility for passage planning

In most it is customary for the master to delegate the initial responsibility for preparing the passage plan to the officer responsible for navigational equipment and publications.

In small ships the master may plan the voyage himself.

While responsibility for the plan in pilotage waters rests with the ship, the pilot on boarding, or before if practicable, should advise the master of any local circumstances so that the plan can be updated.

1.1.1. VOYAGE PLANNING AND NAVIGATION FOR ALL CONDITIONS

1. **Voyage planning for all conditions by acceptable methods of plotting ocean tracks**

Plan appraisal

Before planning can commence, the charts, publications and other information appropriate for the voyage will need to be gathered together and studied. A passage appraisal checklist is included in this Guide as bridge checklist.

Charts and publications

Only official nautical charts and publications should be used for passage planning, and they should be fully corrected to the latest available notices to mariners and radio navigation warnings. Any missing charts and publications needed for the intended voyage should be identified from the chart catalogue and obtained before the ship sails.

For coastal and pilotage planning and for plotting each course alteration point (or waypoint) large scale charts should be used. For ocean passage planning and open water legs smaller scale charts should be used.

The route plan

The route plan should incorporate the following details:

- planned track showing the true course of each leg;
- leg distances;
- any speed changes required en route;
- wheel over positions for each course alteration, where appropriate;
- turn radius for each course alteration, where appropriate;
- maximum allowable off-track margins for each leg.

At any time during the voyage, the ship may need to leave the planned route temporarily at short notice. Marking on the chart relatively shallow waters and minimum clearing distances in critical sea areas is but one technique which will assist the OOW when having to decide quickly to what extent to deviate without jeopardising safety and the marine environment. However, in using this technique, care should be taken not to obscure chart features. On paper charts, only pencil should be used.

The route plan should also take into account the need to monitor the ship's position along the route, identify contingency actions at waypoints, and allow for collision avoidance in line with the COLREGS.

The main details of the route plan should be recorded using sketches, if appropriate, so that the plan can be readily referred to the main conning position.

1.1.2. ROUTEING IN ACCORDANCE WITH THE GENERAL PRINCIPLES FOR SHIP'S ROUNTEING

1. Routeing

Ship's routeing measures have been introduced in a number of coastal waters to:

- reduce the risk of collision between ships in areas of high traffic densities;
- keep shipping away from environmentally sensitive sea areas;
- reduce the risk of grounding in shallow waters.

The use of ships' routeing measures should form part of the passage plan.

Ships' routeing measures can be adopted internationally by IMO. Such schemes are recommended for use by, and may be made mandatory for all ships, certain categories of ships or ships carrying certain cargoes. Mandatory ships' routeing schemes should always be used unless the ship has compelling safety reasons for not allowing them.

IMO routeing schemes will be shown on charts with a note of any pertinent provisions as to their use. Fuller details may be described in Sailing Directions.

The IMO publications Ships' Routeing and Amendments to Ships' Routeing contain full descriptions of each scheme and any rules applying, but this publication is produced primarily for the benefit of administrations. It is not kept up to date as regularly as nautical publications, which should always be consulted for the latest information.

Elements used in routing systems include:

- traffic separation scheme - a routeing measure aimed at the separation of opposing streams of traffic by establishing traffic lanes;
- traffic lane - areas within defined limits in which one-way traffic flows are established;
- separation zone or line — a means to separate traffic lanes in which ships are proceeding in opposite or nearly opposite directions in order to separate traffic lanes from adjacent sea areas or to separate different traffic lanes;
- roundabout - a separation point or circular zone and a circular traffic lane within defined limits;
- inshore traffic zone - a designated sea area between the landward boundary of a traffic separation scheme and an adjacent coast;
- recommended route - a route of undefined width, for the convenience of ships in transit, which is often marked by centreline buoys;
- deep water route - a route which has been accurately surveyed for clearance of sea bottom and submerged articles;
- archipelagic sea lane - sea lanes designated for the continuous and expeditious passage of ships through archipelagic waters;
- precautionary area - an area where ships must navigate with particular caution and within which the direction of flow of traffic may be recommended;
- area to be avoided - an area in which either navigation is particularly hazardous or it is exceptionally important to avoid casualties and which should be avoided by ah ships, or by certain classes of ships.

1.1.3. REPORTING IN ACCORDANCE WITH THE GENERAL PRINCIPLES FOR SHIP REPORTING SYSTEMS AND WITH VTS PROCEDURES

Ship reporting systems

The Ship Reporting Systems (SRS) contribute to the safety of sailing. The purpose and aim of such SRS is to keep a vigilant eye on the sea traffic. In cases of rendering help, the systems enable to give pieces of information about navigational hazards, medical advice, directing the closest ship towards the vessel in peril, and defining the area of searching.

The ship report is a precondition for giving help. The ship report may be voluntary or obligatory, which depends on the legal stipulations of the state. Ships submit their reports in harmony with pre-determined forms, in regular periods of time, or in some other agreed manner.

The communication among SRS is carried out by means of the Global Maritime Distress Safety System (GMDSS). Reports are usually sent to a coastal radio station. The coastal radio station; then, passes them on to the head office. On the basis of the reports received, the head office follows the sailing of the ships.

By following the sea traffic, the SRS also contributes to the reduction of the time period counting from the moment of the last report and the beginning of search in cases when distress message has not been received.

Depending on the reports time periods, in cases of justified suspicion of a vessel in peril, it may not be possible to define the search area of the appropriate size, which happens mainly in cases of agreed reporting (area entrance or exit). Therefore, it appears to be necessary to reduce the span of time between two reports. But, this is not deemed a good solution due to the fact that on board ships there are comparatively small crews and a lot of work to do.

This is the reason why the Global Ship Reporting System (GSRS) should be developed and adopted. By using the existing equipment onboard and the Internet, the system is expected to transmit essential data in order to follow the position of the sea traffic. By applying modern technological solutions, the application of the system on the global level is anticipated.

Ship reporting systems are used to provide, gather, or exchange information through radio reports. The information is used to provide data for many purposes including, but not limited to: navigation safety, maritime security and domain awareness, environmental protection, vessel traffic services, search and rescue, weather forecasting and prevention of marine pollution

Ship reporting systems contribute to safety of life at sea, safety and efficiency of navigation and/or protection of the marine environment.

1.2. DETERMINE POSITION AND THE ACCURACY OF RESULTANT POSITION FIX BY ANY MEANS

1.2.1. POSITION DETERMINATION IN ALL CONDITIONS

Celestial Navigation

Celestial navigation, also known as astronavigation, is the ancient art and science of position fixing that enables a navigator to transition through a space without having to rely on estimated calculations, or dead reckoning, to know his or her position. Celestial navigation uses "sights," or angular measurements taken between a celestial body (the sun, the moon, a planet or a star) and the visible horizon. The sun is most commonly used, but navigators can also use the moon, a planet or one of 57 navigational stars whose coordinates are tabulated in the Nautical Almanac and Air Almanacs.

Celestial navigation is the use of angular measurements (sights) between celestial bodies and the visible horizon to locate one's position on the globe, on land as well as at sea. At a given time, any celestial body is located directly over one point on the Earth's surface. The latitude and longitude of that point is known as the celestial body's geographic position (GP), the location of which can be determined from tables in the Nautical or Air Almanac for that year.

The measured angle between the celestial body and the visible horizon is directly related to the distance between the celestial body's GP and the observer's position. After some computations, referred to as "sight reduction," this measurement is used to plot a line of position (LOP) on a navigational chart or plotting work sheet, the observer's position being somewhere on that line. (The LOP is actually a short segment of a very large circle on the earth which surrounds the GP of the observed celestial body. An observer located anywhere on the circumference of this circle on the earth, measuring the angle of the same celestial body above the horizon at that instant of time, would observe that body to be at the same angle above the horizon.) Sights on two celestial bodies give two such lines on the chart, intersecting at the observer's position (actually, the two circles would result in two points of intersection arising from sights on two stars described above, but one can be discarded since it will be far from the estimated position—see the figure at "example" below). Most navigators will use sights of three to five stars, if they're available, since that will result in only one common intersection and minimize the chance for error. That premise is the basis for the most commonly used method of celestial navigation, and is referred to as the "Altitude-Intercept Method."

There are several other methods of celestial navigation which will also provide position finding using sextant observations, such as the "Noon Sight", and the more archaic Lunar Distance method. Joshua Slocum used the Lunar Distance method during the first ever recorded single-handed circumnavigation of the world. Unlike the Altitude-Intercept Method, the noon sight and lunar distance methods do not require accurate knowledge of time. The altitude-intercept method of celestial navigation requires that the observer know exact Greenwich Mean Time (GMT) at the moment of his observation of the celestial body, to the second—since every four seconds that the time source (commonly a chronometer or in aircraft, an accurate "hack watch") is in error, the position will be off by approximately one nautical mile.

Modern electronic navigational aids

ELECTRONIC NAVIGATION SYSTEMS

Since the earliest days of navigation, seafarers have sought to keep track of their direction and position. The earliest forms of the magnetic compass date back to the 12th century while the crude "dead reckoning" system involved measuring the course and distance sailed from a known position.

By the end of the 15th century navigators were using the quadrant and astrolabe to find latitudinal position from the position of the sun, moon or stars and the horizon, while the chronometer, invented in the 18th century, enabled navigators to find their longitudinal position.

The introduction of radio and wireless technology in the late 19th century permitted the development of more sophisticated navigation systems. Wireless time signals, which were first broadcast from Paris in 1910, enabled more accurate determination of longitude, while the Italians Ettore Bellini and

Captain Tosi in 1906 developed a direction finding system used to determine the direction from which wireless signals were transmitted.

After the end of World War Two, the development of radar led to the possibility of ships being able to fix their position, when within 48 to 60 miles of the shore, by making reference to coastal features or responder beacons (Racons) installed on the shore. Further out to sea, hyperbolic radio systems soon enabled accurate position fixing with a range of at least 250 miles.

These early radio navigation systems - including Decca Navigator and Loran A - involved a ship's radio receiver measuring transmissions from groups of radio transmitters transmitting signals simultaneously or in a controlled sequence. By measuring the phase difference between one pair of transmissions a position line can be established, a second measurement from another pair of stations gives a second line and the intersection of the two lines gives the navigating position.

By the 1970s, Loran C and Differential Omega radio navigation systems were also becoming operational in major areas of the world's oceans and they were combined with early computer technology to provide electronic print outs of the ship's position. The Soviet Tchaika system also became operational.

Meanwhile, the world's first satellites had been launched and their potential for accurate position finding was being actively researched.

IMO and navigation systems

The importance of using navigation systems in maritime safety and preventing marine pollution, for example as an aid to avoiding hazards, was recognized by IMO in the late 1960s, and in 1968 it adopted resolution A.156(ES.IV) on Recommendation on the Carriage of Electronic Position-Fixing Equipment.

That resolution recommended that ships carrying oil or other noxious or hazardous cargoes in bulk should carry "an efficient electronic position-fixing device".

Performance Standards for Shipborne Receivers for use with Differential Omega (resolution A.479(XII) were adopted in 1981, while in 1983 the Assembly adopted resolution A.529(13) on Accuracy Standards for Navigation.

Resolution A.529(13) is aimed at providing "guidance to Administrations on the standards of navigation accuracy for assessing position-fixing systems, in particular radio-navigation systems, including satellite systems". It notes that "the navigator needs to be able to determine his position at all times".

Accuracy of navigation systems in areas such as harbour entrances and approaches depends on local circumstances, but in other waters, the resolution established that navigation systems should provide accuracy within the order of 4% of the distance from danger with a maximum of 4 nautical miles (for a ship proceeding at not more than 30 knots).

Also in 1983, IMO began a study into a world-wide radio-navigation system, in view of the need for such a system to provide ships with navigational positionfixing throughout the world - but recognizing that itwas not considered feasible for IMO to fund a world-wide radio-navigation system.

The objective of the study was to provide a basis by which Regulation 12 (covering shipborne navigational equipment) of SOLAS Chapter V might be amended to include a requirement for ships to carry equipment to receive transmissions from a radio navigation system throughout their intended voyage.

SOLAS Chapter V Regulation 12 includes a requirement for ships on international voyages over 1,600 gross tonnage to be fitted with radio direction-finding apparatus. This requirement dates back to the 1948 SOLAS Convention, while in 1988 IMO adopted an amendment which allowed ships the possibility to carry instead radionavigation equipment suitable for use throughout the intended voyage.

World-wide radio navigation system

In 1985, IMO initiated a study into a world-wide satellite position-fixing system for the safety of navigation and a report, Study of a World-Wide Radio navigation System, was adopted by the IMO Assembly in 1989 (resolution A.666(16).

The report gave a detailed summary of the different terrestrial-based radio navigation systems then in operation (Differential Omega, Loran-C, Chayka), and also the satellite systems which were being developed - Global Positioning System (GPS) Standard Positioning Service (SPS), which was being developed by the United States air force; and GLONASS (Global Navigation Satellite System), being developed by the then Soviet military (now managed for the Government of the Russian Federation by the Russian Space Agency.

The 1989 report said that it was not considered feasible for IMO to fund a world-wide radionavigation system, so existing and planned systems provided and operated by Governments or organizations were studied to ascertain whether they could be recognized or accepted by IMO.

When a radio-navigation system is accepted by IMO, it means the system is regarded as capable of providing adequate position information and that the carriage of receiving equipment satisfies the relevant SOLAS requirements.

The report notes that shipborne receiving equipment should conform to the general requirements for navigational equipment in resolution A.574(14) (later updated by A.694(17) and that detailed requirements for receivers for GPS, differential GPS, GLONASS, differential GLONASS, Loran-C, Chayka, Omega combined with differential Omega and Decca Navigator systems were available to manufacturers to enable them to construct the equipment.

The report set operational requirements for world-wide radionavigation systems: they should be general in nature and be capable of being met by a number of systems. All systems should be capable of being used by an unlimited number of ships. Accuracy should at least comply with the standards set out in resolution A.529(13) Accuracy of Standards for Navigation.

1995 update

The report was updated in 1995 by resolution A.815(19), World-Wide Radionavigation system, which takes into account the requirements for general navigation of ships engaged on international voyages anywhere in the world, as well as the requirements of the Global Maritime Distress and Safety System (GMDSS) for the provision of position information.

The revised report also addresses the development of high speed craft, such as fast ferries, noting that ships operating at speeds above 30 knots may need more stringent requirements.

The report states that provision of a radionavigation system is the responsibility of governments or organizations concerned and that these should inform IMO that the system is operational and available for use by merchant shipping while keeping IMO informed in good time of any changes that could affect the performance of shipborne receiving equipment.

Updated performance standards for Decca Navigator and Loran-C and Chayka receivers and performance standards for shipborne global positioning system (GPS) receiver equipment were also adopted in 1995. By then, GPS was fully operational, while GLONASS became fully operational in 1996. The future for terrestrial-based radio-navigation systems - in view of the development of the satellite-based systems - is unclear.

OMEGA was also phased out in 1997 while DECCA will be phased-out in many countries by the year 2000. The United States-controlled LORAN-C networks are under consideration for phasing out by the year 2000. However, the Russian Federation-controlled CHAYKA networks will not be considered for phasing out until at least the year 2010. Civil-controlled LORAN-C and LORANC/ CHAYKA networks are being set up in the Far East, North-West Europe and other parts of the world with plans for extension in some areas.

Meanwhile, there are several initiatives to improve the accuracy and/or integrity of GPS and GLONASS by augmentation. The use of different differential correction signals for local augmentation of accuracy and integrity and RAIM (Receiver Autonomous Integrity Monitoring) are examples of such initiative. In addition integrated receivers are being developed, combining signals from GPS, GLONASS, LORAN-C and/or CHAYKA. Wide area augmentation systems are also being developed using differential correction signals from geostationary satellites, in particular Inmarsat III satellites, for instance by the United States and Europe.

However, the main concern is that while GPS and GLONASS are expected to be fully operational until at least the year 2010, their availability beyond that is not guaranteed.

As a result, IMO (and other users, such as civil aviation) has recognised the need for a future system to improve, replace or supplement GPS and GLONASS, which have shortcomings on integrity, availability, control and system life expectancy. As a result, IMO in 1997 adopted resolution A.860(20) on Maritime policy for a future global navigation satellite system (GNSS).

OMEGA

A very low frequency (VLF) hyperbolic radionavigation system based on phase comparison techniques, which ceased operations in September 1997.

Omega evolved from a low frequency system known as Radux first proposed in 1947 and was further developed in the 1950s, was the first world-wide radionavigation system offering global coverage. It operated from eight Omega stations in Norway, Liberia, Hawaii, North Dakota, La Reunion, Argentina, Australia and Japan.

Differential Omega refers to the provision of increased accuracy in a local area,

such as a harbour, through the use of local transmitters of the Omega signal.

CHAYKA

A radionavigation system, similar to LORAN-C, operated by the Russian

Federation. Accuracy is 50 to 200 metres.

DECCA

A low frequency (LF) hyperbolic radionavigation system based on harmonically related continuous wave transmissions.

The basic principles of the Decca Navigator were invented in the United States in 1937 and the system was used for guiding the leading minesweepers and landing craft in the Allied invasion of Normandy during World War Two.

In 1945, the Decca Navigator Co, Ltd was formed and the first commercial chain of stations established in south-east England in 1946.

The system expanded and by 1989 had 42 fully operational chains around the world, including 42 master stations and 119 slave transmitters. Chains normally comprise one master station and three slave transmitters. Stations radiate four harmonically related frequencies in the band 70 kHz to 130kHz. Coastal accuracy is 50 metres by day and 200 metres by night.

LORAN-C

A low frequency (LF) hyperbolic radionavigation system based on measurements of the differences of times of arrival of signals using pulse and phase comparison techniques.

The Loran system was initially proposed by the United States in 1940 and the first full-scale trials, of Standard Loran, or Loran-A, took place in 1942. By 1943 coverage extended over much of western and northern Atlantic and by 1945 had extended to cover north and central Pacific, Bay of Bengal, and northern Australia. It was the standard Allied long-range navigation system for ships and aircraft. Coverage in the Japanese and East China Sea Areas was extended in the 1950s and in 1965 stations were established in Portugal and the Azores.

Loran-C was a modified version of Loran-A, developed to provide longer range and greater accuracy. Loran-C first came into operation in 1957.

By 1989, there were 16 Loran-C chains comprising 67 stations, transmitting on

100 kHz.

Typical coastal accuracy is 50 to 200 metres.

Satellite Navigation Systems

Satellite navigation and positioning has, during the later years, gone from something most people had not even heard anything about to something used in a large number of applications. Primarily it is the American Global Positioning System (GPS) (see e.g. Hoffman-Wellenhof et al. [1994] and Parkinson and Spilker (eds.) [1996]) that is used but there also exists another system in the shadow of GPS, namely the Russian Global Navigation Satellite System or

GLONASS. GLONASS has been around since the early eighties, however information about it has been very scarce in western countries until the last five years or so. The reason for this has probably much to do with the reluctance of the former Soviet Union to reveal any information about military resources and since GLONASS was developed as a military guidance and navigation system information has been very scarce.

The interest for GLONASS has increased due to larger flow of information about the system, which made it possible to manufacture receivers capable of not only tracking GPS satellites but also GLONASS satellites. This made it possible to start exploring the possibilities of applications relying on a larger number of satellites visible than provided by GPS only as well as the challenge of trying to tie measurements together stemming from two different reference systems.

The studies undertaken and presented in this thesis have been made in order to investigate the impact and usability of GLONASS, both in its own respect and in combined use together with GPS. Further, the experience that can be drawn from GLONASS usage today can be very useful in the future when more satellite navigation systems will be developed. Today Europe has plans for its own navigation system, Galileo, and in order to utilize this from the very beginning it is important to have gained experience earlier from combined use of different satellite navigation systems, a perfect role for GLONASS in conjunction with GPS.

Current Status of NAVSTAR GPS.

The launch of the 24th Block II 28 satellite in March 1994 completed the GPS constellation. The NAVSTAR system currently consists of 25 satellites, including one Block I satellite. Initial Operational Capability (IOC) was formally declared

December 8, 1993, in a joint announcement by the DoD and the Department of

Transportation (DoT). The IOC notification means that the NAVSTAR GPS is capable of sustaining the Standard Positioning Service (SPS), the 100-meter positioning accuracy available to civilian users of the system on a continuous, worldwide basis. Unlike IOC for other DoD systems, IOC for GPS has purely civil connotations.

In 1995, the U.S. Air Force Space Command formally declared that GPS met the requirements for Full Operational Capability (FOC),32 meaning that the constellation of 24 operational (Block II/IIA) satellites now in orbit has successfully completed testing for military functionality. While the FOC declaration is significant to DoD because it defines a system as being able to provide full and supportable military capability, it does not have any significant impact on civil users.

An additional 21 satellites called Block IIRs are being developed by Martin Marietta (formerly General Electric Astro Space division) as replacements for the current GPS satellites. The Block IIR satellites will provide enhanced performance over the previous generation of GPS satellites, including the capability to autonomously navigate (AUTONAV) themselves and generate their own navigation message data. This means that if the control segment cannot contact the Block IIR satellites, the AUTONAV capabilities will enable these satellites to maintain full system accuracy for at least 180 days. The Block IIR satellites will be available for launch as necessary beginning in late 1996.

A follow-on set of replenishment satellites, known as Block IIFs, is planned to replace the Block IIR satellites at the end of their useful life. The Air Force intends to buy 33 Block IIF satellites to sustain the quality of the GPS signal as a worldwide utility for the foreseeable future. These satellites will have to meet even higher levels of performance than previous generations of GPS satellites, including a longer life cycle of 6.5 to 10 years. The IIF satellite will be launched on an Evolved Expandable Launch Vehicle (EELV). The Air Force issued a draft request for proposals (RFP) on June 20, 1995, and plans to award a con-tract for the development and procurement of the Block IIF satellites in spring 1996.

<u>Satellite positioning</u>

The technique used in satellite positioning today, be it in GPS, GLONASS or any other system to obtain a position solution is based on a concept called time of arrival ranging. The idea behind time of arrival ranging is to have precise atomic clocks onboard the satellites, transmitting a precise timestamp signal. This signal gets another timestamp when it arrives in the receiver and the two timestamps are compared to get an estimated travel time for the signal. If the transmitting and receiving timestamps are synchronized it is possible to measure the signal’s travelling time and use that for calculating a distance, or range measurement, to the satellite.

From this it is easy to see that high-accuracy timing is crucial for the success of this method or the range measurements would not be accurate and positioning would be more or less impossible to do. In order to be as accurate as possible and to avoid clock biases to as large extent as possible, the system is driven by precise atomic clocks aboard the satellites. A ground-based control network and a Master Control Station monitor these onboard clocks.

Furthermore each satellite broadcasts a navigation message which, among other things, contains almanac information - information about where the satellites are at any given time epoch. This is a necessity, otherwise the user would only know the distance between the receiver and an unknown point, giving no information about the user’s position.

<u>GPS</u>

Background

In 1978, the first prototype satellite for use in the come-to-be global navigational satellite system GPS was launched. Since then GPS has developed to the well known and highly utilized system of today. However, for ordinary civilian users the accuracy is intentionally degraded down to 100 m by means of

Selective Availability (SA), which consists of a degradation in the accuracy of the broadcast orbit information a dithering of the signal and. This dithering will affect both the carrier phase and the code data.

Status

The Global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations.

GPS uses these "man-made stars" as reference points to calculate positions accurate to a matter of meters. In fact, with advanced forms of GPS you can make measurements to better than a centimeter!

In a sense it's like giving every square meter on the planet a unique address.

GPS receivers have been miniaturized to just a few integrated circuits and so are becoming very economical. And that makes the technology accessible to virtually everyone.

These days GPS is finding its way into cars, boats, planes, construction equipment, movie making gear, farm machinery, even laptop computers.

Soon GPS will become almost as basic as the telephone. Indeed, at Trimble, we think it just may become a universal utility.

The latest GPS replenishment launch took place in 1997 and the current number of orbiting operational satellites is 27, an increase from the originally planned constellation using 24 satellites divided in six different, equally distributed, orbital planes.

How it Works

The operation of the GPS and GLONASS systems is basically the same and can be resumed in five steps.

1. The basis of GPS is "triangulation" from satellites.
2. To "triangulate," a GPS receiver measures distance using the travel timeof radio signals.
3. To measure travel time, GPS needs very accurate timing which itachieves with some tricks.
4. Along with distance, you need to know exactly where the satellites are inspace. High orbits and careful monitoring are the secret.
5. Finally you must correct for any delays the signal experiences as it travels through the atmosphere.

Problems at the satellite

Even though the satellites are very sophisticated they do account for some tiny errors in the system.

The atomic clocks they use are very, very precise but they're not perfect.

Minute discrepancies can occur, and these translate into travel time measurement errors.

And even though the satellites positions are constantly monitored, they can't be watched every second. So slight position or "ephemeris" errors can sneak in between monitoring times.

Basic geometry itself can magnify these other errors with a principle called

"Geometric Dilution of Precision" or GDOP.

It sounds complicated but the principle is quite simple.

There are usually more satellites available than a receiver needs to fix a position, so the receiver picks a few and ignores the rest.

If it picks satellites that are close together in the sky the intersecting circles that define a position will cross at very shallow angles. That increases the gray area or error margin around a position.

If it picks satellites that are widely separated the circles intersect at almost right angles and that minimizes the error region.

Good receivers determine which satellites will give the lowest GDOP.

In this section you will see how a simple concept can increase the accuracy of

GPS to almost unbelievable limits.

And you will see:

- Why we need Differential GPS
- How Differential GPS works
- Where to get Differential Corrections
- Other ways to work with Differential GPS
- Advanced Concepts

Basic GPS is the most accurate radio-based navigation system ever developed.

And for many applications it's plenty accurate. But it's human nature to want

MORE!

So some crafty engineers came up with "Differential GPS," a way to correct the various inaccuracies in the GPS system, pushing its accuracy even farther.

Differential GPS or "DGPS" can yield measurements good to a couple of meters in moving applications and even better in stationary situations.

That improved accuracy has a profound effect on the importance of GPS as a resource. With it, GPS becomes more than just a system for navigating boats and planes around the world. It becomes a universal measurement system capable of positioning things on a very precise scale.

Differential GPS involves the cooperation of two receivers, one that's stationary and another that's roving around making position measurements.

The stationary receiver is the key. It ties all the satellite measurements into a solid local reference.

Here's how it works:

The problem

Remember that GPS receivers use timing signals from at least four satellites to establish a position. Each of those timing signals is going to have some error or delay depending on what sort of perils have befallen it on its trip down to us.

(For a complete discussion of all the errors review the "Correcting Errors" section of the tutorial.)

Since each of the timing signals that go into a position calculation has some error, that calculation is going to be a compounding of those errors.

Where to get differtential signals

In the early days of GPS, reference stations were established by private companies who had big projects demanding high accuracy - groups like surveyors or oil drilling operations. And that is still a very common approach.

You buy a reference receiver and set up a communication link with your roving receivers.

But now there are enough public agencies transmitting corrections that you might be able to get them for free.

The United States Coast Guard and other international agencies are establishing reference stations all over the place, especially around popular harbors and waterways.

These stations often transmit on the radio beacons that are already in place for radio direction finding (usually in the 300kHz range).

Anyone in the area can receive these corrections and radically improve the accuracy of their GPS measurements. Most ships already have radios capable of tuning the direction finding beacons, so adding DGPS will be quite easy.

Many new GPS receivers are being designed to accept corrections, and some are even equipped with built-in radio receivers.

Future global navigation satellite system

Maritime policy for a future global navigation satellite system (GNSS) sets out

IMO policy in terms of the maritime requirements for a future civil and internationally-controlled Global Navigation Satellite System (GNSS), to provide ships with navigational position-fixing throughout the world for general navigation, including navigation in harbour entrances and approaches and other waters in which navigation is restricted.

The resolution notes that development of a future GNSS is presently only in a design stage and these requirements have been limited only to basic user requirements, without specifying the organizational structure, system architecture or parameters. These maritime requirements, as well as the

Organization's recognition procedures, may need to be revised as a result of any subsequent developments.

The resolution sets out the general, operational and institutional requirements for a future GNSS in terms of maritime users and envisages a review of the requirements in 1999 (21st Assembly); consideration of the proposed future GNSS in 2001 (22nd Assembly) and completion of the implementation of the proposed GNSS in 2008.

1.3. DETERMINE AND ALLOW FOR COMPASS ERRORS

1.3.1. PRINCIPLES OF THE MAGNETIC COMPASSES

Parts of the magnetic compass and their function

There are many types of compasses ranging from tiny thumb compasses to complex high-tech gadgets. For most hikers and outdoors guys like us, an orienteering compass works just great and that is what we'll discuss here.

Not all compasses include each of these parts and some compasses include even more.	
Baseplate	hard, flat surface on which the rest of the compass is mounted. It has a rulers on its edges for measuring distances on maps. It's edge is straight and useful for laying lines on a map
Scales	each edge of a compass may have different rulers for use with different map scales
Direction-of-Travel Arrow	marked on the base plate. You point this the way you will be traveling
Magnifier	for seeing small map features better
Index Pointer	butt end of the direction-of-travel arrow. It ends right at the edge of the dial and is where you take degree readings
Dial	ring around the housing that has degree markings engraved. You hold the dial and rotate it to rotate the entire housing
Declination Marks	use to orient the compass in an area with known declination
Orienting Arrow	marked on the floor of the housing. It rotates with the housing when the dial is turned. You use it to orient a compass to a map
Orienting Lines	series of parallel lines marked on the floor of the housing and on the base plate
Needle	magnetized piece of metal that has one end painted red to indicate North. It sits on a fine point that is nearly frictionless so it rotates freely when the compass is held fairly level and steady
Housing	main part of the compass. It is a round plastic container filled with liquid and has the compass needle inside
Bubble	a bubble of air in the housing liquid is useful for making sure you are holding the compass fairly level
Mirror	lets you see the compass face and distant objects at the same time. Useful for emergency signaling
Sight	improves aiming your compass at distant objects

How a Compass Works

There is a huge magnetic field around the earth. It is huge, but it is not very strong. The magnetized needle in a compass is aligned with this magnetic field. As the image below shows, the composition of the earth acts as a huge bar magnet sitting upside down in the middle of the planet. Since its South end is at the north pole and its North end is at the south pole, the North end of a compass needle is pulled north.

Compass Corrections

Definitions

True North: This refers to the geographical North Pole. This is a physical pole since the axis of the earth passes through the same. All charts are aligned to this pole and the co-ordinate system refers to this as the North Pole.

Magnetic North: This is the south-seeking pole of the earth when considered as a giant magnet. All magnetic compasses point to this pole as North. The physical and the magnetic north pole do not coincide. The magnetic pole shifts over time as the earth cools down and also due to other various reasons. The physical pole remains stationary.

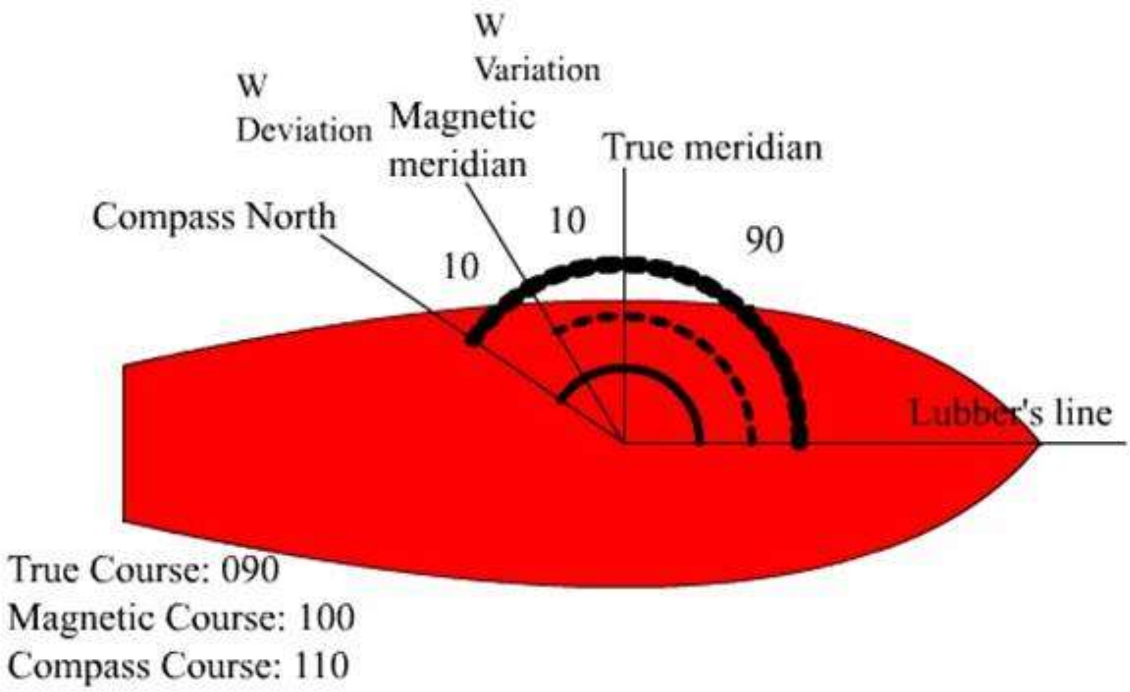
Compass North: This takes into account both variation and deviation experienced by the compass while pointing the direction of North. It is not possible to have two ships compass point at the same direction as North.

Magnetic Course:

The angle between the magnetic meridian and the direction of the ship's head. It defines the direction of the ship's head relative to "Magnetic North". The difference between the two is the Variation.

True Course: After allowing for Deviation and Variation to the Magnetic Course/bearing.

Compass Course: The angle between the compass needle and the direction of the ship's head. It defines the direction of the ship's head relative to "Compass North". The compass course is indicated by the position of the 'lubber's line' relative to the compass card. Both deviation and variation are involved in this correction.

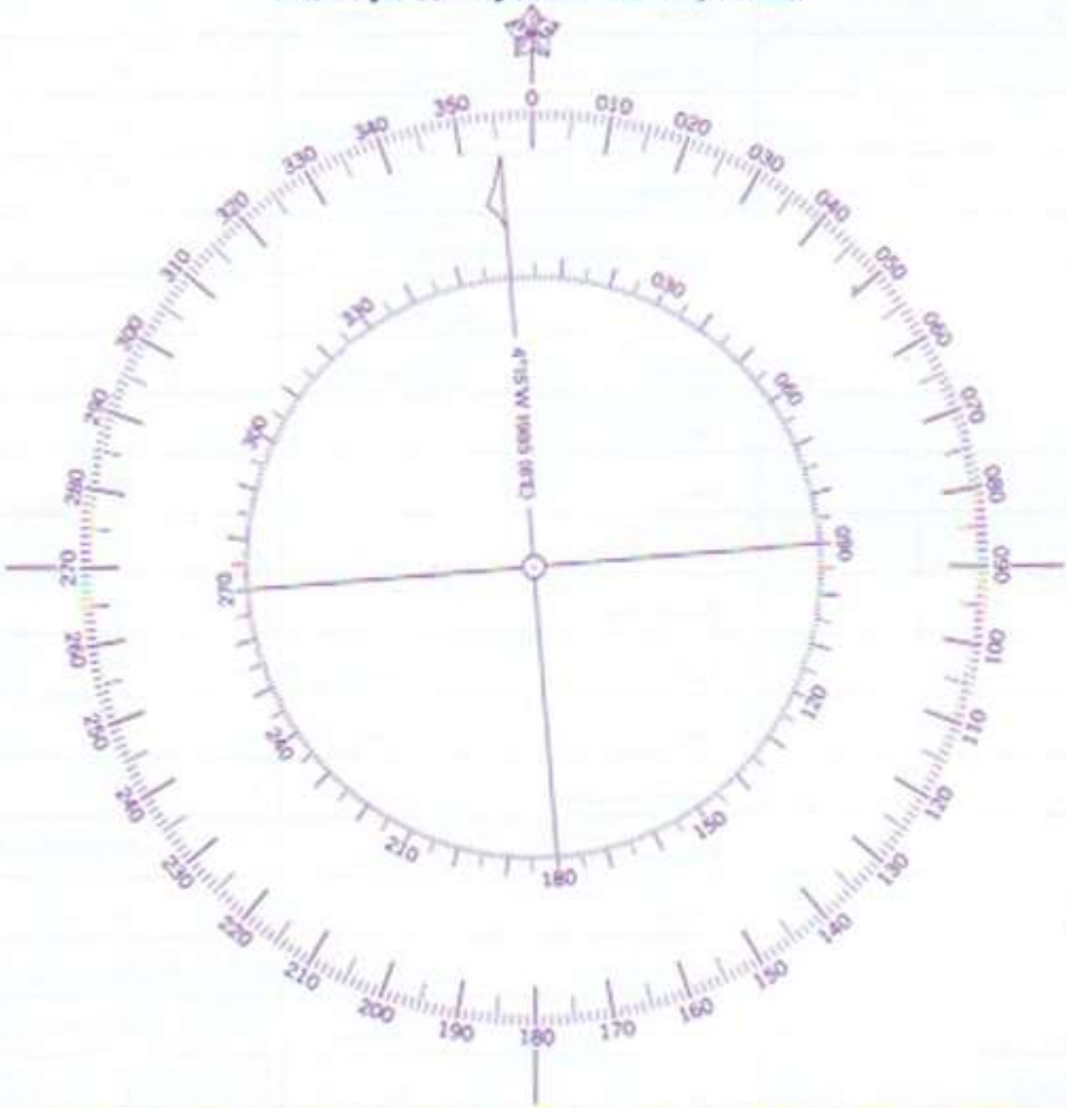


Finding deviation and variation from tables and charts

Variation may be found from variation charts as well as from that printed on the compass rose on any navigational chart.

Compass rose, normal pattern (smaller patterns of compass rose may be used)

Magnetic Variation (example): 4° 15' W 1985 (8' E) *on magnetic north arrow means Magnetic Variation* 4° 15' W *in* 1985, *annual change* 8' E *(i.e. magnetic variation decreasing 8' annually).*



Isogonic lines

Magnetic Variation Curves are for 1985
The Magnetic Variation is shown in degrees, followed by the letter W or E, as appropriate, at certain positions on the curves. The annual change is expressed in minutes with the letter W or E and is given in brackets, immediately following the variation.

Calculating true course from compass course

Given: Compass Course - 110° and on this course the deviation is 3°E, the chart shows a Variation of 9°W, to find the True Course.

We may combine the two errors - 9°W and 3°E, this becomes a combined error of 6°W. Or we may say that the compass error is 6°W.

Now using the quote:

'Error West Compass Best – Error East Compass Least'

We see that the Error is West so the compass would be the best or the greater than the True.

So, the True course would be less than the compass course by 6°. The True course therefore would be - 104°

If we do this step by step then:

Compass Course - 110°

Deviation - 3°E

Magnetic Course - 113° (Error East Compass Least, so True in this case Magnetic is more so add)

Variation - 9°W

True Course - 104° (Error West Compass Best, so True is less, so subtract)

Calculating compass course from true course

Given: True Course - 110° and on this course the deviation is 3°E, the chart shows a Variation of 9°W, to find the Compass Course.

We may combine the two errors - 9°W and 3°E, this becomes a combined error of 6°W. Or we may say that the compass error is 6°W.

Now using the quote:

'Error West Compass Best – Error East Compass Least'

We see that the Error is West so the compass would be the best or the greater than the True.

So, the Compass course would be greater than the True course by 6°. The Compass course therefore would be - 116°

If we do this step by step then:

True Course - 110°

Variation - 9°W

Magnetic Course - 119° (Error West Compass Best, so Compass in this case Magnetic is more so add)

Deviation - 3°E

Compass Course - 116° (Error East Compass Least, so Compass is less, so subtract)

Using a transit bearing to find error

Transit bearings are usually taken within Pilotage waters or in very near coastal waters. Two prominent marks are selected – generally a lighthouse and another beacon or a building (should be marked on the chart). A line is drawn between the two and extended to cut the own vessel course line at a future time.

It thus becomes obvious that the transit line (the extended line) should cut the course line.

Once this is done the transit line is read off from the compass rose and the same is written on the chart next to the line.

An estimated time is also written down of approaching this point where the transit line would be cutting the course line.

A few minutes prior to the time the two objects are sighted through the azimuth mirror and at the time of actual transit the bearing is noted. This is then compared with that which was read off the compass rose. This gives the error of the compass.

While entering port the pilot generally looks up at the leading lights which are aligned at a certain bearing and confidently tells the Master that the compass has an error or not and of the error amount.

Applying compass error to the ship's head and compass bearings to convert to true

Ships course Correction:

Given: Compass Course - 120° and on this course the deviation is 4°E, the chart shows a Variation of 9°W, to find the True Course.

We may combine the two errors - 9°W and 4°E, this becomes a combined error of 5°W. Or we may say that the compass error is 5°W.

Now using the quote:

'Error West Compass Best – Error East Compass Least'

We see that the Error is West so the compass would be the best or the greater than the True.

So, the True course would be less than the compass course by 5°. The True course therefore would be - 115°

If we do this step by step then:

Compass Course - 120°

Deviation - 4°E

Magnetic Course - 124° (Error East Compass Least, so True in this case Magnetic is more so add)

Variation - 9°W

True Course - 115° (Error West Compass Best, so True is less, so subtract)

Observed Bearing Correction:

Given: Compass Course - 110° and on this course the deviation is 3°E, the chart shows a Variation of 9°W, Bearing of a light - 145°, to find the True Bearing.

We may combine the two errors - 9°W and 3°E, this becomes a combined error of 6°W. Or we may say that the compass error is 6°W.

Now using the quote:

'Error West Compass Best – Error East Compass Least'

We see that the Error is West so the compass bearing would be the best or the greater than the True bearing.

So, the True bearing would be less than the compass bearing by 6°. The True bearing therefore would be - 139°

If we do this step by step then:

Compass bearing - 145°

Deviation - 3°E

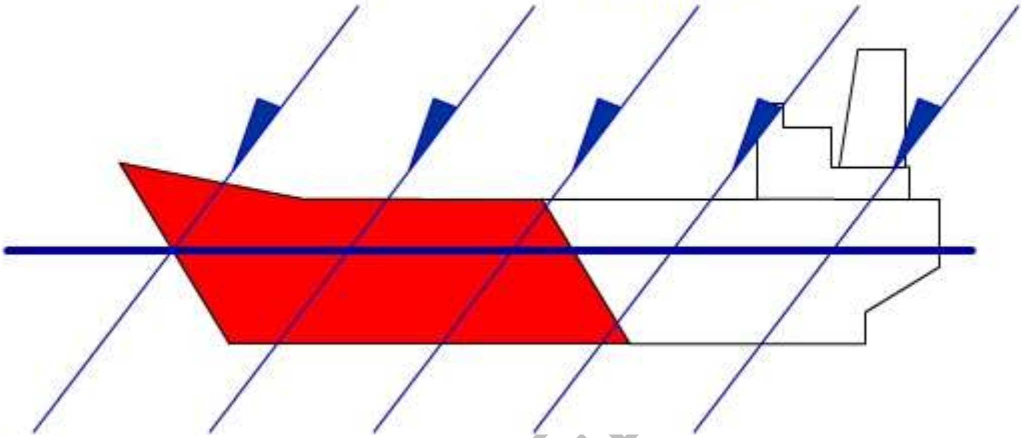
Magnetic bearing - 148° (Error East Compass Least, so True in this case Magnetic is more so add)

Variation - 9°W

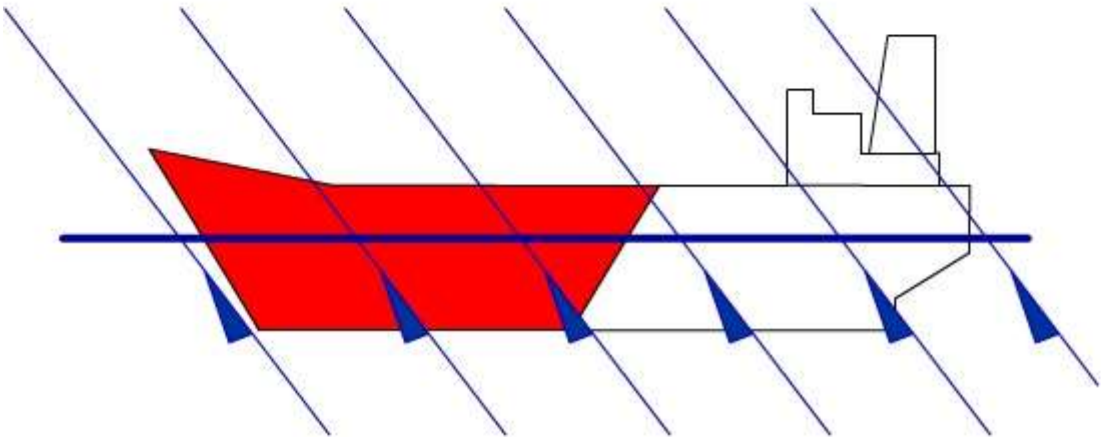
True bearing - 139° (Error West Compass Best, so True is less, so subtract)

REMEMBER THE DEVIATION IS OF THE COMPASS IS ON A PARTICULAR SHIPS HEADING – (THE MAGNETIC LINES OF THE EARTH CUT THE SHIP DIFFERENTLY ON DIFERENT HEADINGS) – AS SUCH DO NOT LOOK UP THE DEVIATION ON THE BASIS OF THE BEARING BUT LOOK UP FOR THE SHIPS HEADING.

Ship on a Northerly heading in the Northern Hemisphere



Ship on a Northerly heading in the Southern Hemisphere



1.3.2. PRINCIPLES AND ERRORS OF GYROCOMPASSES

A gyroscope consists of a spinning wheel or rotor contained within gimbals which permit movement about three mutually perpendicular axes, known as the horizontal axis, the vertical axis, and the spin axis. When spun rapidly, assuming that friction is not considered, the gyroscope develops gyroscopic inertia, tending to remain spinning in the same plane indefinitely. The amount of gyroscopic inertia depends on the angular velocity, mass, and radius of the wheel or rotor.

When a force is applied to change alignment of the spin axis of a gyroscope, the resultant motion is perpendicular to the direction of the force. This tendency is known as precession. A force applied to the center of gravity of the gyroscope will move the entire system in the direction of the force. Only a force that tends to change the axis of rotation produces precession.

If a gyroscope is placed at the equator with its spin axis pointing east-west, as the earth turns on its axis, gyroscopic inertia will tend to keep the plane of rotation constant. To the observer, it is the gyroscope which is seen to rotate, not the earth. This effect is called the horizontal earth rate, and is maximum at the equator and zero at the poles. At points between, it is equal to the cosine of the latitude.

If the gyro is placed at a geographic pole with its spin axis horizontal, it will appear to rotate about its vertical axis. This is the vertical earth rate. At all points between the equator and the poles, the gyro appears to turn partly about its horizontal and partly about its vertical axis, being affected by both horizontal and vertical earth rates. In order to visualize these effects, remember that the gyro, at whatever latitude it is placed, is remaining aligned in space while the earth moves beneath it.

Gyrocompass Operation

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The gyrocompass has several advantages over the magnetic compass:

- It seeks true or geographic meridian instead of magnetic meridian.
- It can be used near the earth's magnetic poles, where the magnetic compass is useless.
- It is not affected by surrounding material.
- Its signal can be fed into inertial navigation systems, automatic steering systems, and fire control systems.

Being a complicated electronic instrument, the gyrocompass has some disadvantages

- It requires a constant source of electrical power and is sensitive to power fluctuations.
- It requires periodic maintenance by qualified technicians.

Gyrocompass errors and corrections

The total of the all the combined errors of the gyrocompass is called gyro error and is expressed in degrees E or W, just like variation and deviation. But gyro error, unlike magnetic compass error, and being independent of Earth's magnetic field, will be constant in one direction; that is, an error of one degree east will apply to all bearings all around the compass.

- If the gyrocompass bearing is higher than the actual bearing, the error is west

- If the gyrocompass bearing is lower than the actual bearing, the error is east

The errors to which a gyrocompass is subject are speed error, latitude error, ballistic deflection error, ballistic damping error, quadrantal error, and gimballing error.

Additional errors may be introduced by a malfunction or incorrect alignment with the centerline of the vessel.

Speed error is caused by the fact that a gyrocompass only moves directly east or west when it is stationary (on the rotating earth) or placed on a vessel moving exactly east or west. Any movement to the north or south will cause the compass to trace a path which is actually a function of the speed of advance and the amount of northerly or southerly heading. This causes the compass to tend to settle a bit off true north. This error is westerly if the vessel's course is northerly, and easterly if the course is southerly. Its magnitude depends on the vessel's speed, course, and latitude. This error can be corrected internally by means of a cosine cam mounted on the underside of the azimuth gear, which removes most of the error. Any remaining error is minor in amount and can be disregarded.

Tangent latitude error is a property only of gyros with mercury ballistics, and is easterly in north latitudes and westerly in south latitudes. This error is also corrected internally, by offsetting the lubber's line or with a small movable weight attached to the casing.

Ballistic deflection error occurs when there is a marked change in the north-south component of the speed.

East-west accelerations have no effect. A change of course or speed also results in speed error in the opposite direction, and the two tend to cancel each other if the compass is properly designed. This aspect of design involves slightly offsetting the ballistics according to the operating latitude, upon which the correction is dependent. As latitude changes, the error becomes apparent, but can be minimized by adjusting the offset.

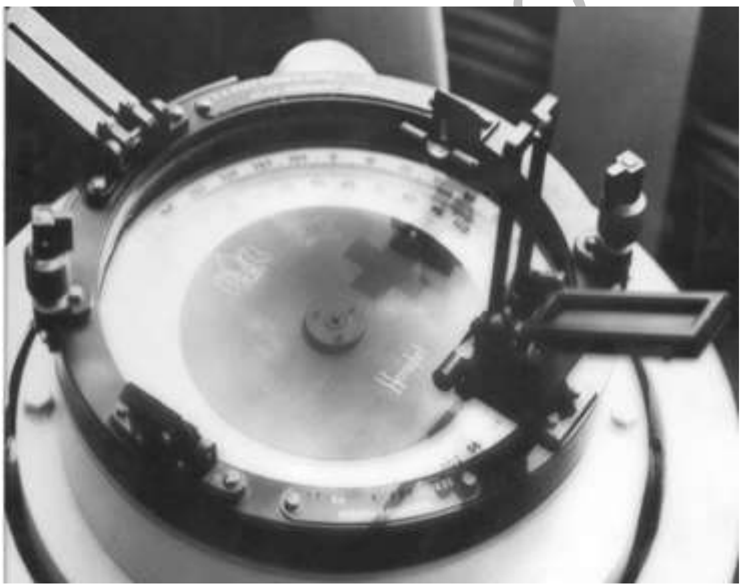
Ballistic damping error is a temporary oscillation introduced by changes in course or speed. During a change in course or speed, the mercury in the ballistic is subjected to centrifugal and acceleration/deceleration forces. This causes a torquing of the spin axis and subsequent error in the compass reading. Slow changes do not introduce enough error to be a problem, but rapid changes will. This error is counteracted by changing the position of the ballistics so that the true vertical axis is centered, thus not subject to error, but only when certain rates of turn or acceleration are exceeded.

Quadrantal error has two causes. The first occurs if the center of gravity of the gyro is not exactly centered in the phantom. This causes the gyro to tend to swing along its heavy axis as the vessel rolls in the sea. It is minimized by adding weight so that the mass is the same in all directions from the center. Without a long axis of weight, there is no tendency to swing in one particular direction. The second source of quadrantal error is more difficult to eliminate. As a vessel rolls in the sea, the apparent vertical axis is displaced, first to one side and then the other. The vertical axis of the gyro tends to align itself with the apparent vertical. On northerly or southerly courses, and on easterly or westerly courses, the compass processes equally to both sides and the resulting error is zero. On intercardinal courses, the N-S and E-W precessions are additive, and a persistent error is introduced, which changes direction in different quadrants. This error is corrected by use of a second gyroscope called a floating ballistic, which stabilizes the mercury ballistic as the vessel rolls, eliminating the error. Another method is to use two gyros for the directive element, which tend to process in opposite directions, neutralizing the error.

Gimballing error is caused by taking readings from the compass card when it is tilted from the horizontal plane. It applies to the compass itself and to all repeaters. To minimize this error, the outer ring of the gimbal of each repeater should be installed in alignment with the fore-and-aft line of the vessel. Of course, the lubber's line must be exactly centered as well.

Methods of determining gyro error:

- Celestial Methods (to be discussed later)
- Observing a visual range
- Observing bearing to an object while at a known location
- Heading while pierside
- Trial and error adjustment of three or more simultaneous LOPs
- Compare to gyrocompass of known error



1.4. COORDINATE SEARCH AND RESCUE OPERATIONS

Requirements for Co-ordination
The method by which this co-ordination is achieved may vary, depending on the detailed organization in each area. When a SAR incident occurs, an SMC will normally be designated. Usually operating from an RCC or RSC, the SMC will obtain SAR facilities, plan SAR operations, and provide overall co-ordination. The SMC will also designate an OSC to provide co-ordination at the scene to carry out plans to locate and rescue survivors. If no SMC has been designated or communications between the SMC and OSC are lost, the OSC may need to perform some additional functions normally handled by an SMC. It may be necessary to designate a vessel OSC for surface activities and an aircraft

coordinator (ACO) for aircraft activities if vessel-aircraft communications on-scene is not practical.

Note: In practice, the terms RCC and SMC are often used interchangeably due to their close association.

When a vessel or aircraft becomes aware of a SAR incident directly, it should alert the appropriate RCC or RSC as follows:

- the RCC or RSC responsible for the SRR where the incident occurred;
- the nearest RCC or RSC;
- any RCC or RSC which can be reached; or
- any communications facility (CRS, ATS unit, etc.).

The first facility to arrive in the vicinity of the SAR incident should assume OSC duties and, if necessary, SMC duties, until an SMC has been designated, and retain OSC duties until the SMC has designated an OSC.
For the maritime environment, shipmasters typically perform the OSC function due to ship endurance on-scene unless more capable SRUs are available.

Co-ordination by Land-Based Authorities

SAR operations are normally guided by specially trained and equipped land-based personnel.
This task is usually carried out by RCC personnel for associated SRRS. Some SRRs are further divided into search and rescue sub-regions (SRSS) with associated RSCS.
Land-based communication facilities include:

- land earth stations (LESS)
- local user terminals (LUTS)
- CRSs
- ATS units.

LESs may also be referred to as aeronautical ground earth stations (GESS) or maritime coast earth stations (CESs).

On-Scene Co-ordination

The types of facilities involved in the response and the region of the SAR incident affect on-scene co-ordination.
Available facilities may include: n designated SRUs civil aircraft and vessels, military and naval or other facilities with SAR capability.
In remote regions, SAR aircraft may not always be available to participate.
In most oceanic regions, ships will normally be available, depending on shipping density.
Ships may receive information from land-based SAR authorities or by monitoring distress traffic.
No advice received from these authorities can set aside the duties of any master as set forth in regulation V/10 of SOLAS 1974 (see appendix A).

Designation of On-Scene Co-ordinator (OSC)
When two or more SAR facilities conduct operations together, the SMC should designate an OSC.

If this is not practicable, facilities involved should designate, by mutual agreement, an OSC.

This should be done as early as practicable and preferably before arrival within the search area.

Until an OSC has been designated, the first facility arriving at the scene should assume the duties of an OSC.

When deciding how much responsibility to delegate to the OSC, the SMC normally considers the communications and personnel capabilities of the facilities involved.

- the poorer the communications, the more authority the OSC will need to initiate actions.

OSC Duties

Co-ordinate operations of all SAR facilities on-scene.

Receive the search action plan or rescue plan from the SMC or plan the search or rescue operation, if no plan is otherwise available. (See Planning and Conducting the Search in this section.)

Modify the search action or rescue action plan as the situation onscene dictates, keeping the SMC advised (do in consultation with the SMC when practicable).

Co-ordinate on-scene communications.

Monitor the performance of other participating facilities.

Ensure operations are conducted safely, paying particular attention to maintaining safe separations among all facilities, both surface and air.

Make periodic situation reports (SITREPS) to the SMC. The standard SITREP format may be found in appendix D. SITREPs should include but not be limited to:

- weather and sea conditions
- the results of search to date
- any actions taken
- any future plans or recommendations.

Maintain a detailed record of the operation:

- on-scene arrival and departure times of SAR facilities, other vessels and aircraft engaged in the operation

- areas searched
- track spacing used
- sightings and leads reported
- actions taken
- results obtained.

Advise the SMC to release facilities no longer required.

Report the number and names of survivors to the SMC.

Provide the SMC with the names and designations of facilities with survivors aboard.

Report which survivors are in each facility.

Request additional SMC assistance when necessary (for example, medical evacuation of seriously injured survivors).

Designation of Aircraft Co-ordinator (ACO)

When multiple aircraft conduct SAR operations, the SMC may designate an ACO in addition to an OSC.

If this in not practicable, the OSC may designate an ACO.

Generally, the ACO is responsible to the SMC and co-ordinates closely with the OSC.

Typically, the SMC or the OSC, as the case may be, would remain in overall charge.

When deciding how much responsibility to delegate to the ACO, the SMC considers the mix of radios, radar, and trained personnel capabilities of the facilities involved.

The ACO may be a fixed-wing aircraft, a helicopter, a ship, a fixed structure such as an oil rig, or an appropriate land unit.

Flight safety of SAR aircraft is a primary concern of the ACO.

ACO Duties

Maintain flight safety:

- maintain safe separation of aircraft
- ensure common pressure setting used
- advise the SMC of on-scene weather implications
- determine aircraft entry and departure points and altitudes
- filter radio messages to and from SAR aircraft
- ensure frequencies are used in accordance with SMC directives
- co-ordinate with adjacent area control centers (ACCS) and airfields.

Prioritize and allocate tasks:

- ensure air facilities are aware of the SMC/OSC overall plan
- monitor and report search area coverage
- with appropriate SMC/OSC authority, identify emerging tasks and direct SAR aircraft to meet them.

Co-ordinate the coverage of search areas:

- respond to changing factors on-scene and supervise effectiveness of searches
- co-ordinate aircraft refueling
- advise SMC/OSC on maintaining continuity.

Make periodic consolidated reports (SITREPS) of SAR aircraft to the SMC and the

OSC, as appropriate. The standard SITREP format may be found in appendix D of the IAMSAR Manual Volume 3.

Work closely with the OSC:

- assist in execution of SMC directives
- maintain communications
- advise on how the ACO can assist.

SAR Operation Risks

Safe and effective SAR operations depend on coordinated teamwork and sound risk assessment.

Saving distressed persons, and the safety of assisting personnel, should both be of concern to the OSC.

The leaders (captain, pilot-in-command, or OSC) must ensure that personnel perform properly as a team with a common mission.

- Mishaps often follow a chain of errors that can start with mistakes made during SAR planning and lead to poor decisions during operations.
- Team safety is supported by:
  - ✓ proficiency in keeping everyone informed
  - ✓ matching resource capabilities to tasks
  - ✓ detecting and avoiding errors early
  - ✓ following standard procedures
  - ✓ adjusting to non-standard activities.

Search and rescue action plans provided by the SMC are only guidance for the OSC and SAR facilities on-scene.

- the OSC may adjust the plans, based on the situation, and inform the SMC (do in consultation with the SMC when practicable)
- SAR facilities should keep the OSC advised of any difficulties or hazards encountered.

The risks inherent in any SAR response must be considered against the chances for success and the safety of SAR personnel.

Some practical concerns for assessing the situation include:

- is the distressed craft in immediate danger of causing harm or placing the rescue facility in jeopardy?
- can the rescue facility handle the weather conditions?
- has the distressed craft given enough information to prepare the assisting vessel to aid in the rescue?
- can the assisting facility realistically be of assistance?
- if recovery of a large number of survivors is a factor:
  - ✓ can the rescue facility accommodate them in regards to food, shelter, clothing, living space?
  - ✓ will the craft performing the rescue be stable with the survivors on-board?
- if helicopter operations are a factor: - is the vessel's construction suitable for a vessel-aircraft joint operation?
  - ✓ does the rescue facility have enough crewmembers available to assist?

Communications

On-Scene Communications

The OSC should ensure that reliable communications are maintained on-scene.

Normally, the SMC will select SAR-dedicated frequencies for use onscene, inform the OSC or SAR facilities, and establish communications with adjacent RCCs and parent agencies of SAR facilities as appropriate.

- the OSC should maintain communications with all SAR facilities and the SMC
- a primary and secondary frequency should be assigned for onscene communications.

SAR facilities should report to the OSC on an assigned frequency.

- if a frequency shift is carried out, instructions should be provided about what to do if intended communications cannot be reestablished on the new frequency
- all SAR facilities should carry a copy of the international Code of

Signals (INTERCO), which contains communications information internationally recognized by aircraft, vessels, and survivors.

OSC Communications with RCC or RSC

Situation Reports

The OSC uses SITREPs to keep the SMC informed of on-scene mission progress and conditions, and addresses SITREPs to the SMC unless otherwise directed.

Search facilities use SITREPs to keep the OSC informed.

- the SMC uses SITREPs to keep superiors, other RCCs and RSCS, and any other interested agencies informed
- where pollution or threat of pollution exists from the vessel or aircraft casualty, the agency tasked with environmental protection should be an information addressee on all SITREPs
- provide earliest notice of an emergency (short form)
- pass urgent essential details when requesting assistance (short form)
- pass amplifying or updating information during SAR operations (full form).

Initial SITREPs should be transmitted as soon as details of an incident become clear enough to indicate SAR involvement.

- SITREPs should not be delayed unnecessarily for confirmation of all details
- further SITREPs should be issued as soon as other relevant information is obtained
- information already passed should not be repeated
- during prolonged operations, "no change" SITREPs should be issued at intervals of about three hours to reassure recipients that nothing has been missed
- when the incident is concluded, a "final" SITREP should be issued as confirmation.

A standard SITREP format is shown in appendix D of the IAMSAR Manual Volume 3.

- each SITREP concerning the same incident should be numbered sequentially.

SITREPs prepared on-scene usually provide the following information:

Identification

- usually in the subject line
- the SITREP number
- identification of the distressed craft
- a one- or two-word description of the emergency
- numbered sequentially throughout the case
- when an OSC is relieved on-scene, the new OSC continues the SITREP numbering sequence

Situation

- a description of the case
- the conditions that affect the case
- any amplifying information that will clarify the problem
- after the first SITREP, only changes to the original reported situation need be included

Action taken

- a report of all action taken since the last report, including results of such action
- when an unsuccessful search has been conducted, the report includes:
  - ✓ the areas searched
  - ✓ hours searched
  - ✓ factors that may have decreased search effectiveness; such as weather or equipment difficulties

Future plans

- description of actions planned for future execution
- recommendations
- request for additional assistance

Status of case

- this is normally used only on the final SITREP to indicate that the case is closed or that search is suspended pending further developments.

RCC and RSC Communications
Maritime Radio Telex
RCCs and RSCs may use radio telex for shore-to-ship distress traffic.

Radio telex is sometimes called radio teletype (RTT) or narrow-band direct printing

(NBDP).

Telex messages may be sent via satellite or terrestrial radio.

Radio telex services should be indicated in the International Telecommunication Union (ITU) List of Coast 5tations.

Shore-to-ship telex messages are on predetermined frequencies, and mostly at predetermined times.

- the frequencies for radio telex are:
  - ✓ 490 kHz,
  - ✓ 518 and 4209.5 kHz (international NAVTEX)
  - ✓ 2174.5 kHz.

Maritime Safety Information

NAVTEX is used to promulgate navigation and safety warnings to vessels, and may be used by SAR personnel for SAR-related broadcasts.

The World Wide Navigational Warning System (WVVNWS) is for long-range NAVAREA warnings and coastal NAVTEX warnings.

- It provides for globally coordinated transmissions with NAVAREA Coordinators for each NAVAREA.
- Warnings which SAR personnel may send over WWNWS include:
  - ✓ distress alerts
  - ✓ information about overdue or missing aircraft or vessels.
- Collectively, these types of alerts, combined with navigation and meteorological warnings, are called maritime safety information (MSI).

Inmarsat is also used to broadcast MS[via SafetyNET.

SafetyNET provides an automatic, global method of broadcasting SAR messages to vessels in both fixed and variable geographic areas. A similar service of lnmarsat called FleetNET can be used to send 5hore-to-ship messages to predetermined groups of vessels.

RCCs normally relay distress alerts over both NAVTEX and SafetyNET.

Normally, SAR broadcasts over SafetyNET are sent to all vessels within a desired radius of a specified position.

It may be faster to first see whether an appropriate ship can be identified via a ship reporting system, and contacted, before doing a SAR broadcast.

Radio Telegraph (WT)

Radio telegraph is a Morse Code service provided in the MF and HF maritime bands.

For distress alerting, it is used on the frequencies 500 kHz and 8364 kHz.

After 1 February 1999, SOLAS vessels are not required to continue use of the service.

This service overcomes language barriers, but it depends upon trained radio operators.

WT transmissions other than distress calls are supposed to be kept to one minute or less.

Ship-to-shore WT working frequencies are 425, 454, 458, 468, 480, and 512 kHz.

During their hours of service, ships are supposed to watch on 500 kHz for three minutes twice per hour beginning at h + 15 and h + 45 by an operator using headphones or a loudspeaker.

During these periods of silence, only distress, urgency, and safety signals are permitted.

Phonetic Alphabet and Figure Code

The phonetic alphabet and figure code is sometimes necessary to use when speaking or spelling out call signs, names, search area designations, abbreviations, etc.

For a complete listing of the phonetic alphabet, figure code, and Morse signals, obtain a copy of the International Code of Signals.

Radio Communication Frequencies for Distress Purposes

The frequencies in the following tables are available for safety purposes, distress communications, and SAR operations.

Alerting, SAR operations, maritime safety, distress and safety, and survival craft frequencies

Function	System	Frequency
Alerting	406 MHz EPIRB	406–406.1 MHz (earth-to-space)
	Inmarsat-E EPIRB	1644.3–1644.5 MHz (earth-to-space)
	Inmarsat SES	1544–1545 MHz (space-to-earth) 1626.5–1646.5 MHz (earth-to-space) 1645.6–1645.8 MHz (earth-to-space)
	VHF DSC (Channel 70)	156.525 MHz[1]
	MF/HF DSC[2]	2187.5 kHz[3] 4207.5 kHz 6312 kHz 8414.5 kHz 12577 kHz 16804.5 kHz
	VHF AM	121.5 MHz
	VHF FM (Channel 16)	156.8 MHz
On-scene communications	VHF Channel 16 MF Radiotelephony MF NBDP	156.8 MHz 2182 kHz 2174.5 kHz
Communications involving aircraft	On-scene, including SAR radiotelephony	156.8 MHz[4] 121.5 MHz[5] 123.1 MHz 156.3 MHz 2182 kHz 3023 kHz 4125 kHz 5680 kHz[6]
Homing signals	406 MHz EPIRB	121.5 MHz
	9 GHz radar transponders	9200–9500 MHz
Maritime safety information (MSI)	NAVTEX Warnings	518 kHz[7]
	NBDP	490 kHz[8] 4209.5 kHz[9] 4210 kHz 6314 kHz 8416.5 kHz 12579 kHz 16806.5 kHz 19680.5 kHz 22376 kHz 26100.5 kHz
	Satellite SafetyNET	1530–1545 MHz (space-to-earth)
Safety of navigation	VHF Channel 13	156.650 MHz

Alerting, SAR operations, maritime safety, distress and safety, and survival craft frequencies *(continued)*

Function	System	Frequency
Distress and safety traffic	Satellite	1530–1544 MHz (space-to-earth) & 1626.5–1646.5 MHz (earth-to-space)
	Radiotelephony	2182 kHz 4125 kHz 6215 kHz 8291 kHz 12290 kHz 16420 kHz 156.8 MHz
	NBDP	2174.5 kHz 4177.5 kHz 6268 kHz 8376.5 kHz 12520 kHz 16695 kHz
Survival craft	VHF Radiotelephony	156.8 MHz & one other frequency in the 156–174 MHz band
	9 GHz radar transponders	9200–9500 MHz

1. Frequency 1 56.525 MHz is used for ship-to-ship alerting and, if within sea area Al, for ship-to-shore alerting.
2. For ships equipped with MF/HF DSC equipment, there is a watch requirement on 2187.5 kHz, 8414.5 kHz, and one other frequency.
3. Frequency 2187.5 kHz is used for ship-to-ship alerting and, if within sea areas A2, for ship-to-shore alerting.

4. Frequencies 1 56.3 and 1 56.8 MHz may also be used by aircraft for safety purposes only.
5. Frequency 121.5 MHz may be used by ships for distress and urgency purposes.
6. The priority of use for ship-aircraft communication is 4125 kHz. Additionally, frequencies 123.1 MHz, 3023 kHz, and 5680 kHz may be used for intercommunication between mobile stations and these stations and participating land stations engaged in coordinated search and rescue operations.
7. The international NAVFEX frequency 518 kHz is the primary frequency for the transmission by coast stations of maritime safety information by NBDP. The other frequencies are used only to augment the coverage or information provided on 518 kHz.
8. Frequency 490 kHz cannot be used for MS] employing NBDP transmission until I February 1999.
9. Frequency 4209.5 kHz is not used by all States.

Frequencies for use in the GMDSS

DSC distress & safety calling	Radiotelephony distress & safety traffic	NBDP distress & safety traffic
2187.5 kHz	2182.0 kHz	2174.5 kHz
4027.5 kHz	4125.0 kHz	4177.5 kHz
6312.0 kHz	6215.0 kHz	6268.0 kHz
8414.5 kHz	8291.0 kHz	8376.5 kHz
12577.0 kHz	12290.0 kHz	12520.0 kHz
16804.5 kHz	16420.0 kHz	16695.0 kHz
156.525 MHz (VHF Channel 70)	156.8 MHz (VHF Channel 16)	
MSI NBDP Broadcasts by coast radio and earth stations		
490.0 kHz*	518.0 kHz	
4209.5 kHz†	4210.0 kHz	
6314.0 kHz	8516.5 kHz	
12579.0 kHz	16806.5 kHz	
19680.5 kHz	22376.0 kHz	26100.5 kHz
On-scene search & rescue radiotelephony		
2182.0 kHz	(R/T)	
3023.0 kHz	(Aeronautical frequency)	
4125.0 kHz	(R/T)	
5680.0 kHz	(Aeronautical frequency)	
123.1 MHz	(Aeronautical frequency)	
156.8 MHz	(VHF Channel 16)	
156.5 MHz	(VHF Channel 10)	
156.3 MHz	(VHF Channel 6)	
Locating/homing signals		
121.5 MHz	(Cospas-Sarsat satellite location & aircraft homing)	
156-174 MHz	(VHF maritime band – radiotelephony)	
406.025 MHz	(Cospas-Sarsat satellite location)	
9200 to 9500 MHz	(X-band radar transponders – SART)	

* For use after full implementation of GMDSS (1 February 1999).
† NAVTEX service (coastal maritime safety information).

Maritime

Ships transmitting a distress message on any of the above frequencies should use the appropriate alarm signals before transmitting the message until contact has been established.

Aeronautical

The aeronautical frequencies 3023 kHz and 5680 kHz may be used for communications by ships and participating CRSs engaged in coordinated SAR operations. However, since these frequencies are not continuously monitored, shore authorities may be needed to help establish communications on these frequencies.

Land

Land SAR can be conducted for many types of incidents, ranging from a downed aircraft to a hiker lost in the wilderness. Land facilities and aeronautical facilities may conduct coordinated land searches. Since each normally operates on different radio frequencies, advance co-ordination amongst local agencies may be necessary to establish effective communication.

- Aircraft typically have at least one radio, so it may be easiest for the air facility and land facility to use an aeronautical frequency.
- If the land facility does not have a portable aircraft radio, then communications may be provided by equipping an aircraft with a radio operating on ground frequencies.

Planning and conducting the search

General

For surface and aircraft facilities to search effectively, search pattern and procedures must be pre-planned so ships and aircraft can cooperate in coordinated operations with the minimum risk and delay.

Standard search patterns have been established to meet varying circunstances.

Responsibilities of OSC

The OSC should obtain a search action plan from the SMC via the RCC or RSC as soon as possible. Normally, search planning is performed using trained, personnel, advanced search planning techniques, and information about the incident or distressed craft not normally available to the OSC. However, the OSC may still need to plan a search under some circumstances. Search operations should commence as soon as facilities are available at the scene. If a search plan has not been provided by the SMC, the OSC should do the planning until an SMC assumes the search planning function. Simplified techniques are presented below.

Modify search plan based on changes in the on-scene situation, such as:

- Arrival of additional assisting facilities
- Receipt of additional information
- Changes in weather, visibility, lighting conditions, etc.

In case of language difficulties, the International Code of Signals and Standard Marine Navigational Vocabulary should be used.

On assuming the duty, the OSC should inform the appropriate CRS or ATS unit and keep it informed of developments at regular intervals.

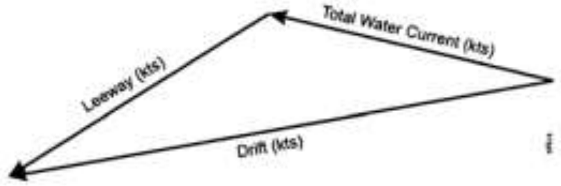
The OSC should keep the SMC informed at regular intervals and whenever the situation has changed.

Planning the search

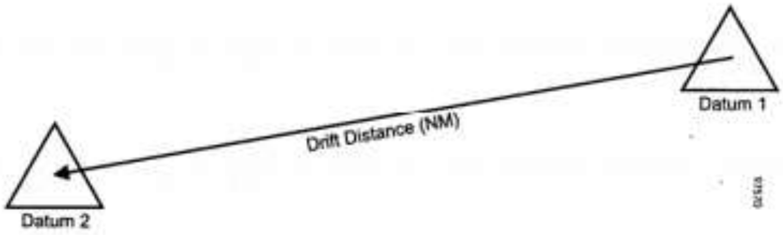
Datum

It will be necessary to establish a datum, or geographic reference for the are to be searched. The following factors should be considered:

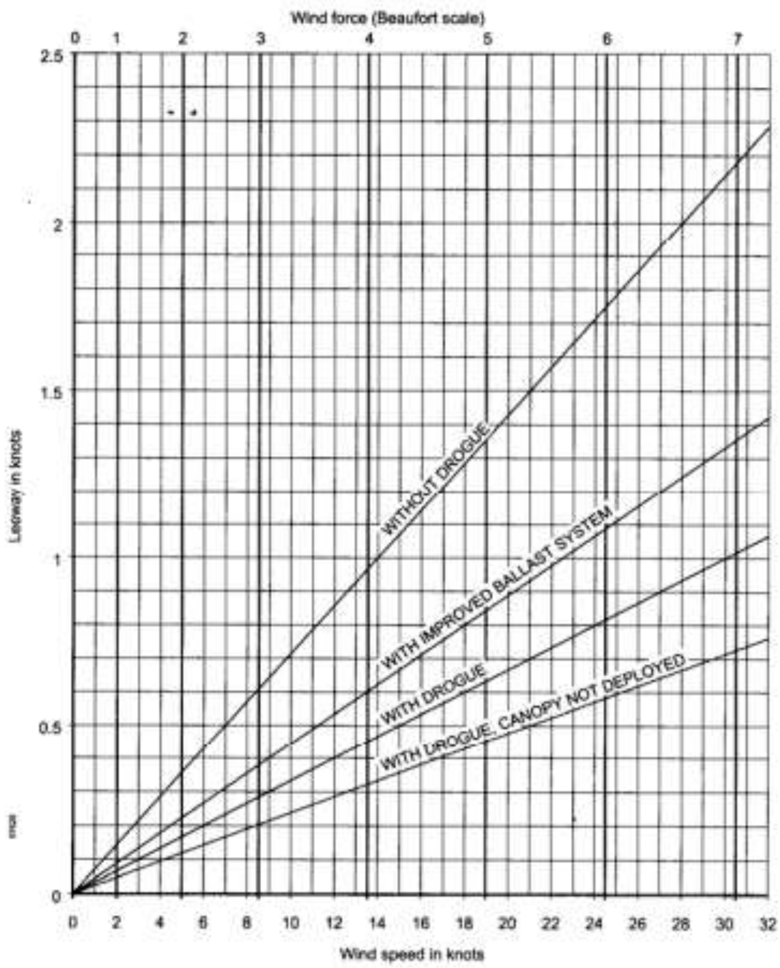
- Reported position and time of the SAR incident
- Any supplementary information such as DF bearings or sightings
- Time interval between the incident and the arrival of SAR facilities
- Estimated surface movements of the distressed craft or survival craft, depending on drift (the two figures following this discussion are used in calculating drift.) The datum position for the search is found as follows:
  - ✓ Drift has two components: leeway and total water current
  - ✓ Leeway direction is downwind
  - ✓ Leeway speed depend on wind speed
  - ✓ The observed wind speed when approaching the scene may be used for estimating leeway speed of liferafts by using the graph following this discussion (persons in the water (PIW) have no leeway while liferaft stability and speed vary with or without drogue or ballast.)
  - ✓ Total water current may be estimated by computing set and drift when approaching the scene
  - ✓ Drift direction and speed is the vector sum of leeway and total water current
- Drift distance is drift speed multiplied by the time interval between the incident time, or time of the last computer datum, and the commence search time
- Datum position is found by moving from the incident position, or last computed datum position, the drift distance in the drift direction and plotting the resulting position on a suitable chart.



Computing drift speed and direction from total water current and leeway.



Determining a new datum (drift distance = drift speed × drift time)



Visual search

Individual search patterns have been designed so that an OSC can rapidly initiate a search by one or more craft.

There will be number of variables that cannot be foreseen. Search patterns based or, visual search have been selected for simplicity and effectiveness and are discussed later in this section.

Track Spacing

Most search patterns consist of parallel tracks or sweeps covering a rectangular area.

The distance between adjacent tracks is called the track spacing.

Recommended uncorrected track spacings for merchant vessels are provided in the table following this discussion. Correction factors based on weather conditions and search object are provided in the table after the track spacing table. Multiplying the uncorrected track spacing (Su) by the appropriate weather correction factor (fw) produces the recommended track spacing (S):

$$S = Su \times fw$$

Changes in weather, number of assisting craft, etc., may occur, making it prudent to alter the track spacing.

Changes in weather, number of assisting craft, etc., may occur, making it prudent to alter the track spacing.

The SMC must ensure that all searching ships and aircraft maintain safe separations from one another and accurately follow their assigned search patterns.

Recommended track spacing (S.) for merchant vessels

	Meteorological visibility (nautical miles)				
Search object	**35**	**10**	**15**	**20**	
Person in water	0.4	0.5	0.6	0.7	0.7
4-person liferaft	2.3	3.2	4.2	4.9	5.5
6-person liferaft	2.5	3.6	5.0	6.2	6.9
15-person liferaft	2.6	4.0	5.1	6.4	7.3
25-person liferaft	2.7	4.2	5.2	6.5	7.5
Boat <5 m (I 7 ft)	1.1	1.4	1.9	2.1	2.3
Boat 7 m (23 ft)	2.0	2.9	4.3	5.2	5.8
Boat 12 m (40 ft)	2.8	4.5	7.6	9.4	11.6
Boat 24 m (79 ft)	3.2	5.6	10.7	14.7	18.1

The track spacings shown in the table above are recommended for use with all the search patterns shown in this volume except for the search pattern.

The table takes into account the type of search object and the meteorological visibility.

Other factors may also be considered, including sea conditions, time of day, position of the sun, effectiveness of observers, etc.

Sweep widths for helicopters (km (NM))

Altitude			
Search object	**150 m (500 ft)**	**300 m (1000 ft)**	**600 m (2000 ft)**
Person in water	0.2 (0.1)	0.2 (0.1)	0.2 (0.1)
4-person liferaft	5.2 (2.8)	5.4 (2.9)	5,6 (3.0)
6-person liferaft	6.5 (3.5)	6.5 (3.5)	6.7 (3.6)
15-person liferaft	8.1 (4.4)	8.3 (4.5)	8.7 (4.7)
25-person liferaft	10.4 (5.6)	10.6 (5.7)	10.9 (5.9)
Boat <5 m (I 7 ft)	4.3 (2.3)	4.6 (2.5)	5.0 (2.7)
Boat 7 m (23 ft)	10.7 (5.8)	10.9 (5.9)	11.3 (6.1)
Boat 12 m (40 ft)	21.9 (11.8)	22.0 (11.9)	22.4 (12.1)
Boat 24 m (79 ft)	34.1 (18.4)	34.3 (18.5)	34.3 (18.5)

Sweep widths for fixed-wing aircraft (km (NM))

	Altitude		
Search object	**150 m (500 ft)**	**300 m (1000 ft)**	**600 m (2000 ft)**
Person in water	0.2 (0.1)	0.2 (0.1)	0.0 (0.0)
4-person liferaft	4.1 (2.2)	4.3 (2.3)	4.3 (2.3)
6-person liferaft	5.2 (2.8)	5.2 (2.8)	5.4 (2.9)
I 5-person liferaft	6.7 (3.6)	6.9 *(3.7)*	7.2 (3.9)
25-person liferaft	8.5 (4.6)	8.7 (4.7)	9.2.(4.9)
Boat <5 m (I 7 ft)	3.3 (1.8)	3.7 (2.0)	4.1 (2.2)
Boat 7 m (23 ft)	8.9 (4.8)	9.3 (5.0)	9.4 (5.1)
Boat 12 m (40 ft)	19.3 (10.4)	19.3 (10.4)	21.5 (11.6)
Boat 24 m (79 ft)	30.9 (16.7)	30.9 (16.7)	31.1 (16.8)

\Weather correction factors (f,) for all types of search units

	Search object	
Weather	**Person in water**	**Liferaft**
Winds calm	1.0	1.0
Winds >28 km/h (15 kt) or seas >1 m (3 ft)	0.5	0.9
Winds >46 km/h (25 kt) or seas >1.5 m (5 ft)	0.25	0.6

Searching speed (V)

To carry out a parallel sweep search in a coordinated manner, all facilities should proceed at the same speed, as directed by the OSC.

This should normally be the maximum speed of the slowest ship present. In restricted visibility, the OSC will normally order a reduction in searching speed.

Search Area (A)

Compute the search radius (R), using of the following two methods:

- If the search must commence immediately, assume R=10 NM
- If time is available for computation:
  Compute the area a craft can cover in a certain amount of time (T) by the formula:

$$A = S \times V \times T$$

  - ✓ the total amount of area (At) which can be covered by several craft is the sum of the areas each craft can cover:

$$At = A1 + A2 + A3 + \text{---}$$

if all craft are searching at the same speed for the same amount of time, then:

$$At = N \times A$$

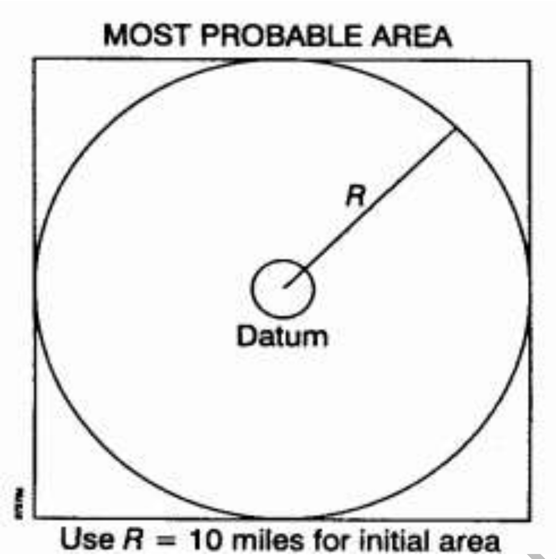
where N is the number of search craft

  - ✓ the search radius (R) of the circle is one-half the square root of the search area:

$$R = \frac{\sqrt{A_t}}{2}$$

Plot the search area:

- draw a circle centered on datum with radius R.
- Using tangents to the circle, from a square as shown below
- If several facilities will be searching at the same time, diving the square into subareas of the appropriate size and assing search facilities accordingly.

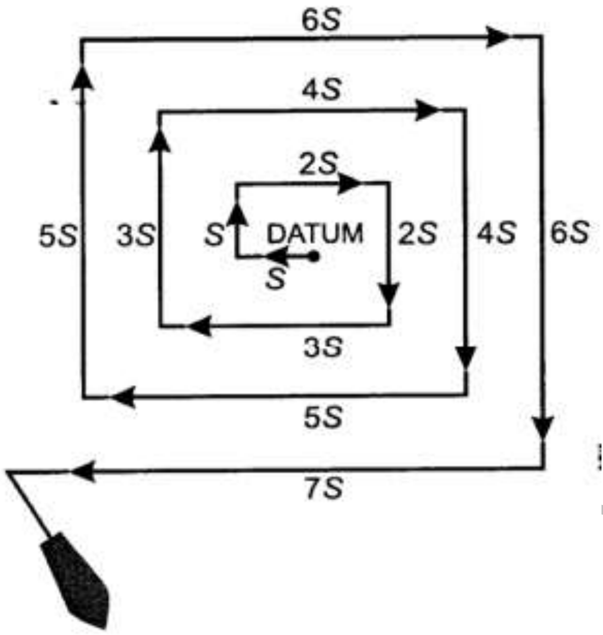


Search Pattems

Expanding Square Search (SS)

* Most effective when the location of the search object is known within relatively close limits.

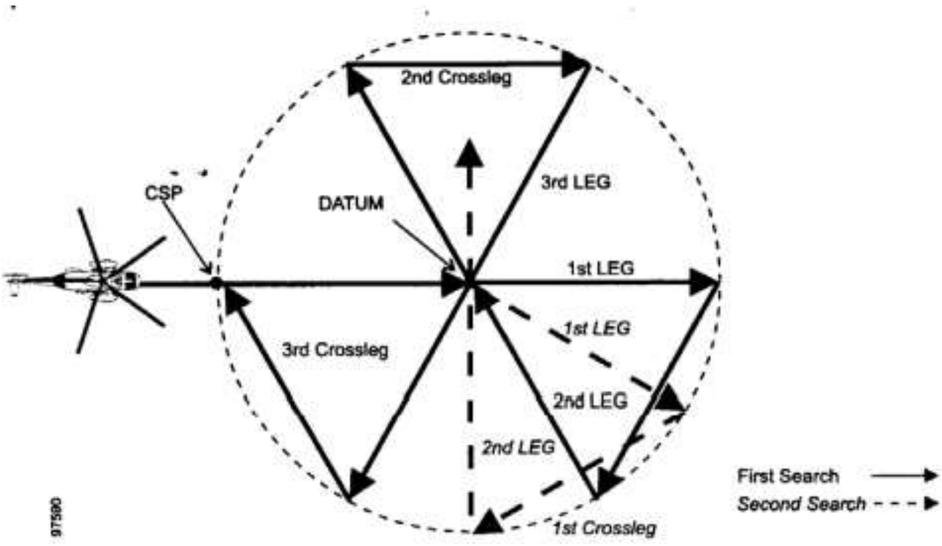
- The commence search point is always the datum position.
- Often appropriate for vessel or small boats to use when searching for persons in the water or other search objects with little or no leeway.
- Accurate navigation is required; the first leg is usually oriented directly into the with to minimize navigation errors.
- It is difficult for fixed-wing aircraft to fly legs close to datum if S is less than 2 NM.



Expanding square search (SS)

Sector Search (VS)

- Most effective when the position of the search object is accurately known and the search area is small.
- Used to search a circular area centered on a datum paint.
- Due to the small are involved, this procedure must not be used simultaneously by multiple aircraft at similar altitudes or by multiple vessels.
- An aircraft and a vessel may be used together to perform indepent sector searches of the same area.
- A suitable marker (for example, a smoke float or a radio beacon) may be dropped at the datum position and used as a reference or navigational aid marking the center of the pattern.
- For aircraft, the search pattern radius is usually between 5NM and 20 NM.
- For vessels, the search pattern radius is usually between 2 NM and 5 NM, and each turn is 120’, normally turned to starboard.

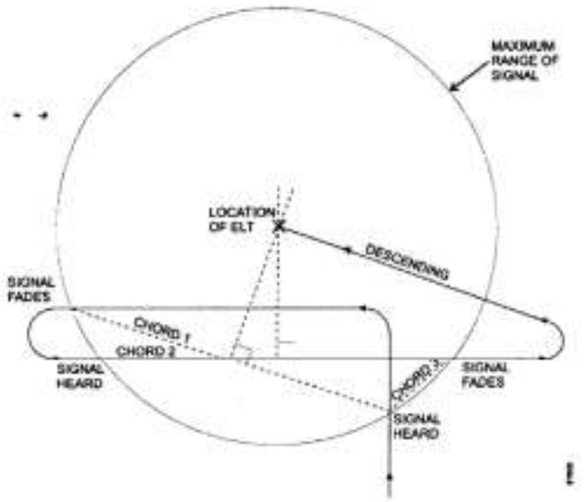


Sector pattern: single-unit (VS)

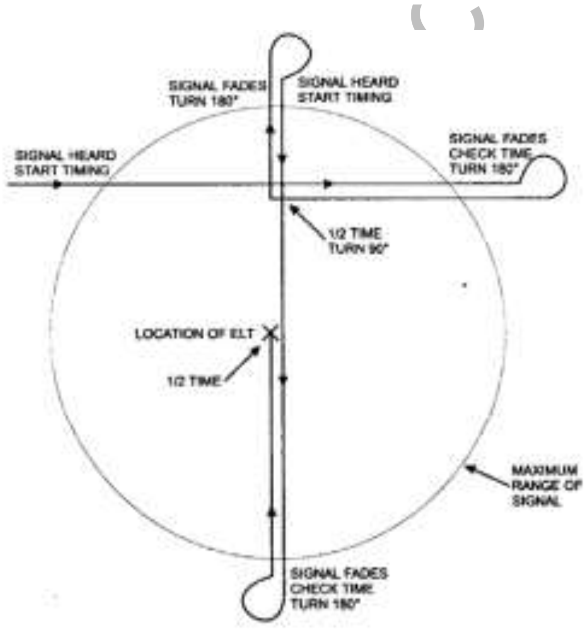
Sector search computations: time to complete one leg (*t*) in minutes and seconds

	Speed								
Radius	**3 kt**	**5 kt**	**8 kt**	**10 kt**	**15 kt**	**20 kt**	**60 kt**	**80 kt**	**90 kt**
0.5 NM	10:00	6:00	3:45	3:00	2:00	1:30	0:30	0:22.5	0:20
1.0 NM	20:00	12:00	7:30	6:00	4:00	3:00	1:00	0:45	0:40
1.5 NM	30:00	18:00	11:15	9:00	6:00	4:30	1:30	1:07.5	1:00
2.0 NM	40:00	24:00	15:00	12:00	8:00	6:00	2:00	1:30	1:20
2.5 NM	50:00	30:00	18.45	15:00	10:00	7:30	2:30	1:55.5	1:40
3.0 NM	60:00	36:00	22:30	18:00	12:00	9:00	3:00	2:18	2:00
3.5 NM		42:00	26:15	21:00	14:00	10:30	3:30	2:40.5	2:20
4.0 NM		48:00	30:00	24:00	16:00	12:00	4:00	3:03	2:40
4.5 NM		54:00	33:45	27:00	18:00	13:30	4:30	3:25.5	3:00
5.0 NM		60:00	37:30	30:00	20:00	15:00	5:00	3:48	3:20
6.0 NM			45:00	36:00	24:00	18:00	6:00	4:33	4:00
7.0 NM			52:30	42:00	28:00	21:00	7:00	5:18	4:40
8.0 NM			60:00	48:00	32:00	24:00	8:00	6:03	5:20

Note: Interpolation may be used with this table.



Map-assisted aural electronic search



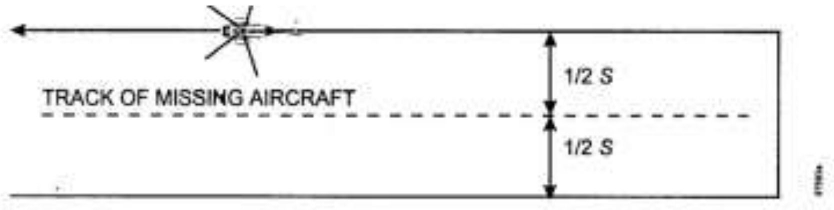
Time-assisted aural electronic search

Sweep widths for visual land search (km (NM))

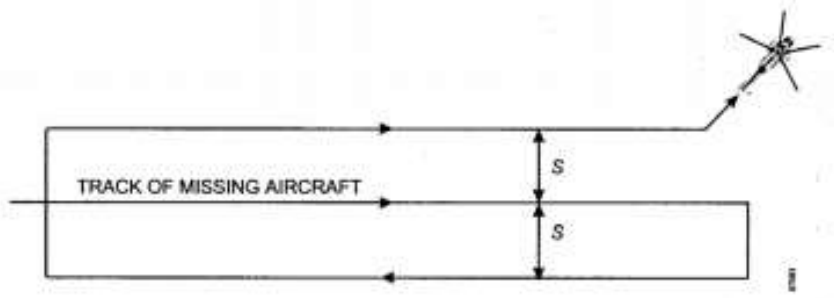
Search object	Height (m (ft))	Visibility (km (NM)) 6 (3)	9 (5)	19 (10)	28 (15)	37 (20)
Person	150 (500)	0.7 (0.4)	0.7 (0.4)	0.9 (0.5)	0.9 (0.5)	0.9 (0.5)
	300 (1000)	0.7 (0.4)	0.7 (0.4)	0.9 (0.5)	0.9 (0.5)	0.9 (0.5)
	450 (1500)	–	–	–	–	–
	600 (2000)	–	–	–	–	–
Vehicle	150 (500)	1.7 (0.9)	2.4 (1.3)	2.4 (1.3)	2.4 (1.3)	2.4 (1.3)
	300 (1000)	1.9 (1.0)	2.6 (1.4)	2.6 (1.4)	2.8 (1.5)	2.8 (1.5)
	450 (1500)	1.9 (1.0)	2.6 (1.4)	3.1 (1.7)	3.1 (1.7)	3.1 (1.7)
	600 (2000)	1.9 (1.0)	2.8 (1.5)	3.7 (2.0)	3.7 (2.0)	3.7 (2.0)
Aircraft less than 5700 kg	150 (500)	1.9 (1.0)	2.6 (1.4)	2.6 (1.4)	2.6 (1.4)	2.6 (1.4)
	300 (1000)	1.9 (1.0)	2.8 (1.5)	2.8 (1.5)	3.0 (1.6)	3.0 (1.6)
	450 (1500)	1.9 (1.0)	2.8 (1.5)	3.3 (1.8)	3.3 (1.8)	3.3 (1.8)
	600 (2000)	1.9 (1.0)	3.0 (1.6)	3.7 (2.0)	3.7 (2.0)	3.7 (2.0)
Aircraft over 5700 kg	150 (500)	2.2 (1.2)	3.7 (2.0)	4.1 (2.2)	4.1 (2.2)	4.1 (2.2)
	300 (1000)	3.3 (1.8)	5.0 (2.7)	5.6 (3.0)	5.6 (3.0)	5.6 (3.0)
	450 (1500)	3.7 (2.0)	5.2 (2.8)	5.9 (3.2)	5.9 (3.2)	5.9 (3.2)
	600 (2000)	4.1 (2.2)	5.2 (2.9)	6.5 (3.5)	6.5 (3.5)	6.5 (3.5)

Track Line Search (TS)

- Normally used when an aircraft or vessel has disappeared without a trace along a known route.
- Often used as initial search effort due to ease of planning and implementation.
- Consists of a rapid and reasonably thorough search along intended route of the distressed craft.
- Search may be along one side of the track line and return. in the opposite direction on the other side (TSR).
- Search may be along the intended track and once on each side, then search facility continues on its way and does not return (TSN).
- Aircraft are 'frequently used for TS due to their high speed.



Track line search, return (TSR)

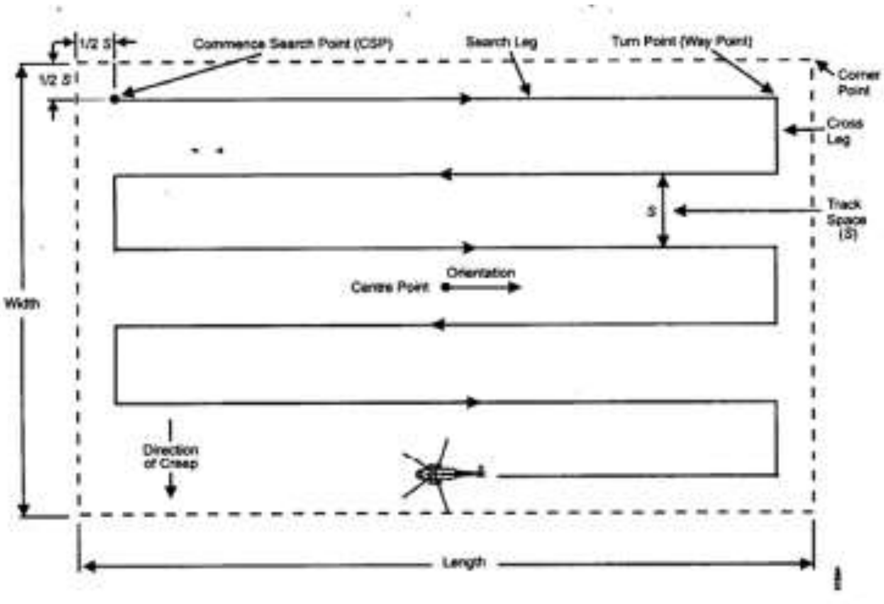


Track line search, non-return (TSN)

Aircraft search height usually 300 m to 600 m (1000 ft to 3000 ft) during daylight or 600 m to 900 m (2000 ft to 3000 ft) at night.

Parallel Sweep Search (PS)

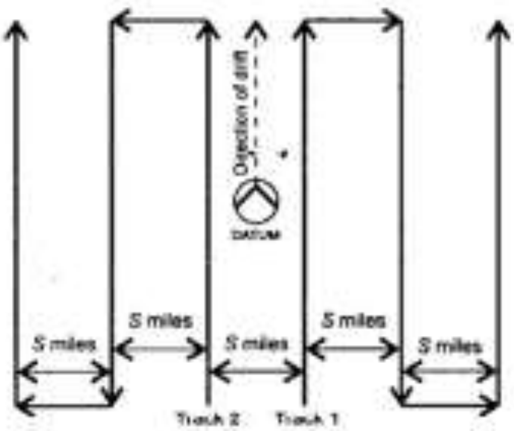
- Used to search a large area when survivor location is uncertain.
- Most effective over water or flat terrain.
- Usually used when a large search area must be divided into subareas for assignment to individual search facilities on-scene at the same time.
- The commence search point is in one corner of the sub-area, one-half track space inside the rectangle from each of the two sides forming the corner.
- Search legs are parallel to each other and to the long sides of the subarea.



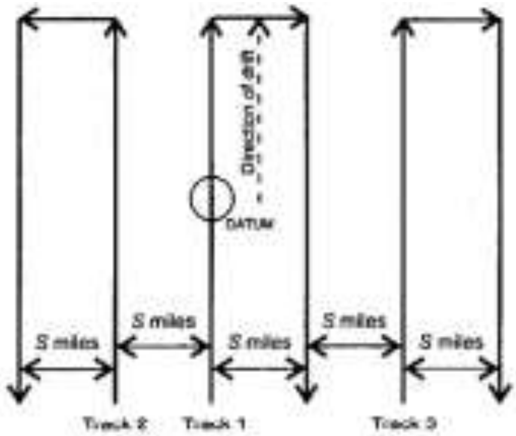
Parallel sweep search (PS)

Multiple vessels may be used as shown opposite:

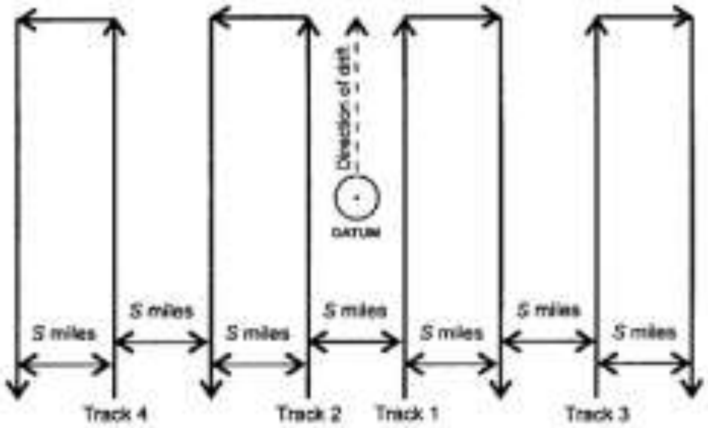
- Parallel sweep: for use by two ships.
- Parallel sweep: for use by three ships.
- Parallel sweep: for use by four ships.
- Parallel sweep: for use by five or more ships.



PATTERN 2
Parallel track search – 2 ships

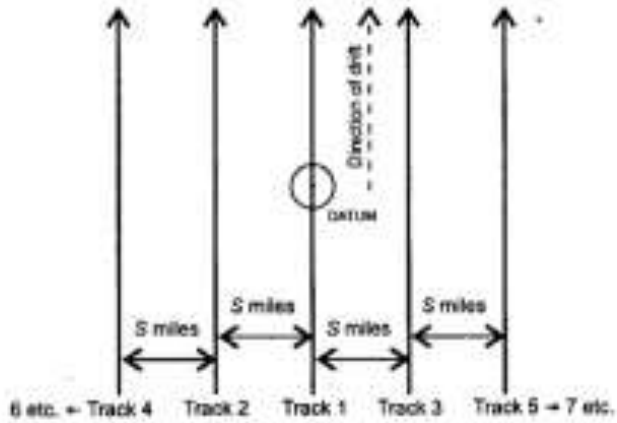


PATTERN 3
Parallel track search – 3 ships



PATTERN 4
Parallel track search – 4 ships

97656



PATTERN 5
Parallel track search – 5 or more ships

Contour Search (OS)

- Used around mountains and in valleys when sharp changes in elevation make other patterns not practical.
- Search is started from highest peak and goes from top to bottom with new search altitude for each circuit.
- Search altitude intervals may be 150 m to 300 m (500 ft to 1 000 ft).
- The aircraft may make a descending orbit away from the mountain before resuming the contour search at the lower altitude.
- The aircraft may spiral downwards around the mountain at a low but approximately constant rate of descent when there is not enough room to make a circuit opposite to the direction of search.
- If the mountain cannot be circled, successive sweeps at the same altitude intervals as listed above should be flown along its side.
- Valleys are searched in circles, moving the center of the circuit one track spacing after each completed circuit.

Co-ordinated Vessel-Aircraft Search Pattern

Normally used only if there is an OSC present to give direction to and provide - communications with the participating craft.

Creeping line search, coordinated (CSC) is often used.

The aircraft does most of the searching, while the ship steams along a course at a speed as directed by the OSC so that the aircraft can use it as a navigational checkpoint.

The aircraft, as it passes over the ship, can easily make corrections to stay on the track of its search pattern.

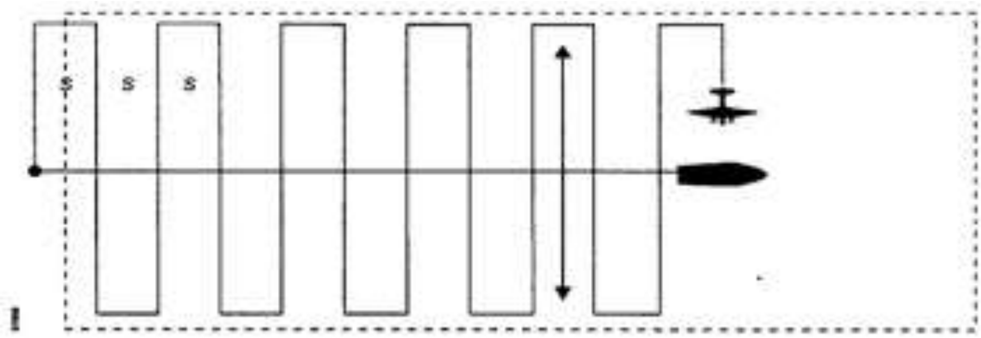
Gives a higher probability of detection than can normally be attained by an aircraft searching alone.

Ship speed varies according to the speed of the aircraft and the size of the pattern.

The relationship among the speed of the surface facility, the aircraft's speed, the track spacing and the length of the search legs is defined by the following equation:

$$V_s = (S \times V_a) / (L + S),$$

where V_s is the speed of the surface facility in knots, S is the track spacing in nautical miles, V_a is the aircraft's true air speed (TAS) in knots, and L is the length of the aircraft's search leg in nautical miles.



Creeping line search, co-ordinated (CSC)

Initiation of Search

- When a search facility arrives on-scene in advance of the 'others, it should proceed directly to datum and commence an expanding square search.
- if possible, datum may be marked by putting over a liferaft or other floating marker with a leeway similar to that of the search object, as a check on the drift.
- This can then be used as a datum marker throughout the search.
- As other facilities arrive, the OSC should select one of the search patterns, as appropriate, and allocate search sub-areas to individual facilities.
- In good visibility and with sufficient search facilities, the OSC may let the first facility continue its expanding square search while the others conduct a parallel track search through the same area.
- In restricted visibility, or if sufficient search facilities are not available, it will probably be better to have the first facility break off the expanding square search and be available for initiation of a parallel sweep search

Restricted Visibility

- A parallel sweep search in restricted visibility poses problems because of the following considerations:
    - ✓ desirability of reducing the interval between SAR facilities as much as possible consistent with safety
    - ✓ resulting loss of search area coverage
    - ✓ potential risk of collision.
- During restricted visibility, the OSC should direct a reduction of vessel speed as necessary.
- In such circumstances, any ship not fitted with radar, or whose radar has become defective, should consider dropping astern of other ships, informing the OSC of its action.

  - ✓ the ship's search should continue when it judges its position (relative to other searching ships) is safe to do so
  - ✓ if there is a reduction in visibility and ships have already started to carry out a search pattern, the OSC may decide that the safest action would be to continue the pattern in force despite the resulting loss of coverage.
- Should it be necessary for the OSC to consider initiating any of the patterns during conditions of restricted visibility, the following factors should be considered:
  - ✓ ships will be proceeding at a reduced speed and searches will take longer
  - ✓ to search the area thoroughly in such conditions must mean a reduction in track-spacing
  - ✓ reduction in track spacing would require a reduction in the interval between SAR facilities and, thus, the carrying out of more sweeps.
- The OSC may decide to accept a reduction in the area searched and should have regard to the direction and rate of estimated drift in deciding whether to accept a reduction in one or both of the length and width of the search area.
- If visibility improves, the OSC should initiate such actions as will best make good the lost coverage, which has taken place.

Radar Search

When several assisting ships are available, a radar search may be effective, especially when the position of the incident is not known reliably and SAR aircraft may not be available. No prescribed pattern has been provided for this contingency.

The OSC should normally direct ships to proceed in "loose line abreast", maintaining a track spacing between ships of the expected detection range multiplied by 1'/2.

The table below serves as a guide for detection ranges for ship radar.

	Radar scanner height	
Search object	15 m	30 m
1 0000 gt ship	13.0 NM	18.0 NM
1000 gt ship	6.0 NM	8.4 NM
200 gt ship	5.5 NM	7.7 NM
9 m boat	1.9 NM	2.7 NM

Land Search Patterns

Aircraft search over land differs from maritime searching in that it is usually more difficult to locate search objects.

Repeated aircraft searches of an area are often necessary.

Search of large areas by ground facilities alone is usually not practical but may be effective -for close examination of a small area.

Visual Ground Search

Use obvious natural or artificial landmarks such as rivers or roads to delimit search sub-areas.

Land search facilities should be equipped with large-scale topographical maps with search areas marked on them.

Land search facility patterns are normally parallel sweeps or contour searches using a line-abreast formation.

Track spacing for lost persons is normally between five and eight meters.

Search progress should be slow through wooded areas. One square kilometer of woods can be searched by 20 to 25 persons in about 1.5 hours.

The parallel sweep search:

- team leader, two flankers on end of each line, and as many searchers as the terrain will allow
- search line is first formed along the search area boundary
- if an obstacle or an item of interest is encountered, the team stops and waits for results of the investigation before the entire search line moves forward again
- boundary control of each successive sweep through an area is assigned to the pivoting flanker
- track spacing between each searcher is determined by the distance a person can effectively search while keeping adjacent searchers in visual and audible contact
- on first leg of search, one flanker will follow a natural boundary or predetermined compass course while the other flanker marks a trail at the other end to follow after the pivot is made
- if contact is lost with a searcher, the team leader must be notified and the search line stopped until complete team contact is reestablished.

The contour search:

- used when mountainous features can be circled completely n pattern is a modified parallel sweep
- search begins with one flanker at the highest level and the other flanker at the low end of the line
- when the mountain is circled once, the search line is re-formed on the lower side of the bottom flanker
- general procedures for a parallel sweep search are followed.

SAR Briefing, Debriefing, and Tasking

The SMC or OSC should provide information to SAR facilities on relevant details of the distress and all instructions prior to the conduct of SAR operations. Parent agencies may provide this information by briefing their facilities prior to deployment. Debriefings of the SAR facilities provide valuable information on effectiveness of the search and can influence planning of the next search. SAR facilities and the OSC should be aware of the type of information that the SMC is likely to request. Appendix E provides a sample SAR Briefing and Debriefing Form.

Further Action on Completion of Initial Phase

The OSC will normally consider the initial phase to have been completed when, in the absence of further information, searching ships have completed one search of the most probable area.

If at that stage nothing has been located, it will be necessary for the OSC to consider the most effective method of continuing the search.

Failure to locate the search object may be due to one or more of the following causes:

- errors in position owing to navigational inaccuracies or inaccuracy in the distress communications reporting the position. This is especially likely to apply if the position of datum was based on an estimated position using incomplete information
- an error in drift estimation
- failure to sight the search object during the search although it was in the search area. This is most likely to occur if the search object is a small craft, a survival craft,
- the craft having sunk without a trace. Other than the case of a small ship or craft in rough weather, experience has shown that there are usually some traces, even if only debris or oil patches.

Navigational Inaccuracies of Searching Ships

This is most likely to apply when navigational fixes cannot be obtained. In this situation, the OSC may:

- re-search the same area, allowing for added drift during the time elapsed since calculating last datum;
- expand the most probable area, after allowing for added drift, and search the expanded area; or
- expand the area more in one direction than another, depending on circumstance and information available.

Determine a new probable area based upon any additional information received.

Where information is received to indicate that the original datum was grossly inaccurate, determining an entirely new probable area would be advisable.

A small search object, which is easily missed in the daytime, may become visible at night if it shows lights, flares, or other pyrotechnics.

The OSC should, therefore, consider using surface craft at night to research areas covered by day.

It is good practice when searching for survivors in small craft, in survival craft, or in the water, to stop the engines occasionally at night and in restricted visibility by day to listen for cries for help.

Evidence of Distressed Craft Found

In some cases, the search may provide evidence of the distressed craft without survivors being found.

This evidence may provide information for a recalculation of datum and revision of the search area.

A low-lying, half-sunken loaded ship or aircraft may drift more slowly than a floating survival craft, even if a drogue is used.

A derelict may drift at a considerable angle off the prevailing wind direction.

When wreckage is located it usually consists of debris, possibly with an oil slick.

Should this have come from the distressed craft, survival craft will usually be found downwind from the debris.

In some cases, however, a ship may have been abandoned some time before sinking, in which case survival craft may be upwind.

- If it is known, or suspected, that survivors are in the water, the area into which they may have been forced by the buffeting of the seas should also be checked.

Maneuvering Instructions

International Regulations for Preventing Collisions at Sea continue to apply fully while carrying out searches.

Maneuvering and warning signals will be of particular importance in the circumstances.

The master of any ship taking part in a search should endeavor to carry out all directions received and have due regard for the safety of the ship and crew.

To initiate and conduct coordinated search patterns, the OSC should transmit a limited number of maneuvering instructions by the most appropriate means, and in plain language when practicable.

The text of the message for the initiation of a pattern and subsequent messages relating to its conduct or adjustment should be in standard form. The International Code of Signals may serve this purpose and a list of standard text from it follows:

Text or meaning	Code groups
Carry out search pattern_____ starting at_______ hours. Initial course________ search speed_________ knots.	FRI
Carry out radar search, ships proceeding in loose line abreast at intervals between ships of_________ miles. Initial course _______ search speed___________ knots.	FR2
Vessel indicated (call sign or identity signal) is allocated track number_________________	FR3
Vessel(s) indicated adjust interval between ships to_________ miles.	FR4
Adjust track spacing to_____________ miles.	FR5
Search speed will now be____________ knots.	FR6,
You should alter course to__________ (at time indicated).	MH
Your should steer course___________	MG
Alter course as necessary to next leg of track now (or at time indicated).	FR7

Other useful signals in the *International Code of Signals:*

Text or meaning	Code groups
I am (or vessel indicated is) in charge of coordinating search.	FR
My maximum speed is______ - (number) knots.	SJ
I have no radar.	OI
I have an echo on my radar on bearing___________ distance ________ miles.	ON
I am altering course to _________	MI
I have sighted survival craft in lat._________ long._________ (or bearing________ distance ____________ from me).	GH
I have located (or found) wreckage from the vessel/aircraft in distress (position to be indicated if necessary by lat.__________ and long._____________ or by bearing__________ from specified place and distance_____________	GL
Estimated set and drift of survival craft is________ degrees and_______ knots.	FP
I wish to communicate by VHF radiotelephony on channel indicated.	YY

Unless a time is specified in the text, individual ships should proceed as necessary to execute the purpose of the message on receipt.

Should circumstances require the OSC to direct the ships participating in a pattern to carry out a major alteration of course (anything over 90°) before proceeding to a new area, it would be desirable for the OSC to direct this in two steps.

Survival and Emergency Radio Equipment

Aeronautical and maritime survival radio equipment operates on 121.5 MHz, a frequency which can be used for alerting, homing, and on-scene communications, depending on equipment design.

Ultra-high frequency (UHF).

406 MHz is reserved solely as an alerting frequency for ELTS, EPIRBS, and PLBS.

L-band is used for Inmarsat-E EPIRBS.

The following frequencies are available for use in vessel and aircraft survival craft, and may be used by portable survival radios on land:

500 kHz (telegraphy)

2182 kHz

121.5 MHz

156.8 MHz.

Many civil aircraft worldwide, especially operating over ocean areas, carry a 121.5 MHz ELT for alerting and homing.

- SAR aircraft should be able to home on this frequency to locate survivors
- an increasing number of ELTs use 406 MHz alerting signals with 121.5 or 243.0 MHz or both for homing signals.
- 406 MHz ELTs and 406 MHz and lnmarsat-E satellite EPIRBs offer coded identities and other advantages which can reduce SAR response time by up to several hours over what would be possible with non-coded ELTS.

After January 1 999:

- SOLAS ships should have a SART to interact with 9 GHz vessel or aircraft radars for locating survival craft. (SART responses show up as a distinctive line of about 20 equally spaced blips on compatible radar displays, providing a bearing and range to the SART.)
- ships of 500 gross tons and over will no longer be required by SOLAS to carry radio apparatus for survival craft capable of transmitting and receiving on 500 kHz (telegraphy) and 2182 kHz (telephony), but these frequencies can be expected to still be used
- ships over 300 gross tons must carry at least two portable survival craft VHF transceivers
- ships over 500 gross tons must carry at least three portable survival craft VHF transceivers

- if they operate in the 156-1 74 MHz band, they will use channel 16 and at least one other channel in this band
- portable DSC equipment, if capable of operating in the indicated bands, can transmit on at least one of the following frequencies: 2187.5 kHz, 8414.5 kHz, or channel 70 VHF.

EPIRB signals indicate that a distress exists and facilitate location of survivors during SAR operations. To be effective, searching craft should be able to home on the signals intended for this purpose, or on the alerting frequency itself (which will be non-continuous if it is 406 MHz).

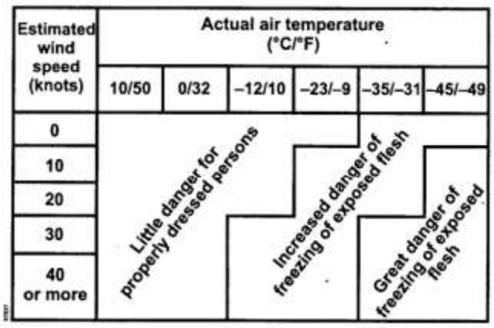
Conclusion of Search

Search Unsuccessful

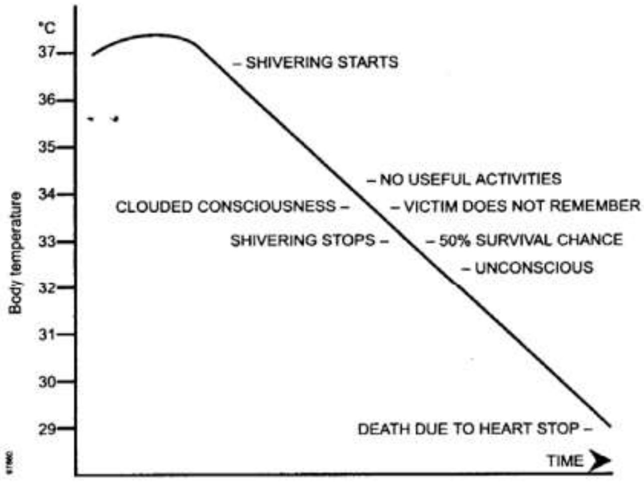
The OSC should continue the search until all reasonable hope of rescuing survivors has passed.
The OSC may need to decide whether to terminate an unsuccessful search (do in consultation with the SMC when practicable). For this determination, factors to consider include the following:

- probability that survivors, if alive, were in the search area
- probability of detection of the search object, if it were in the areas searched
- time remaining that search facilities can remain on-scene
- probability that survivors might still is alive.

The following diagrams illustrate the probability of, survival under various temperature, wind, and sea conditions:



Effect of wind on exposed persons



Symptoms in hypothermia (lowered body temperature)

Guide to survival time for persons without special protective clothing in water of various temperatures

Temperature (°C)	Expected time of survival
Less than 2	Less than /4 hour
2 to 4	Less than 1 '/2 hours
4 to 10	Less than 3 hours
10 to 15	Less than 6 hours
1 5 to 20	Less than 1 2 hours
Over 20	Indefinite (depends on fatigue)

The OSC, after consultation with other assisting craft and land-based authorities should take the following action:

Ocean Incident

- Terminate active search
- Advise assisting craft to proceed on passage and inform the landbased authority

- Send a message to all ships in the area asking them to continue to keep a look-out

1.5. ESTABLISH WATCHKEEPING ARRANGEMENTS AND PROCEDURES

1.5.1. THE INTERNATIONAL REGULATIONS FOR PREVENTING COLLISIONS AT SEA

Introduction

The 1972 Convention was designed to update and replace the Collision Regulations of 1960 which were adopted at the same time as the 1960 SOLAS Convention.

One of the most important innovations in the 1972 COLREGs was the recognition given to traffic separation schemes - Rule 10 gives guidance in determining safe speed, the risk of collision and the conduct of vessels operating in or near traffic separation schemes.

The first such traffic separation scheme was established in the Dover Strait in

1967. It was operated on a voluntary basis at first but in 1971 the IMO

Assembly adopted a resolution stating that that observance of all traffic separation schemes be made mandatory - and the COLREGs make this obligation clear.

Amendment procedureUnder the "tacit acceptance" procedure incorporated in the Convention, an amendment must first be adopted by two-thirds of those present and voting in the Maritime Safety Committee. It is then communicated to Contracting Parties and considered by the IMO Assembly. If adopted by twothirds of the States present and voting in the Assembly, it automatically enters into force on a specified date unless more than one third of the Contracting

Parties notify the Organization of their objection.In addition, a Conference for the purpose of revising the Convention or its regulations or both may be convened by IMO at the request of not less than one-third of Contracting Parties.

Technical provisions

The COLREGs include 38 rules divided into five sections: Part A - General; Part B - Steering and Sailing; Part C - Lights and Shapes; Part D - Sound and Light signals; and Part E - Exemptions. There are also four Annexes containing technical requirements concerning lights and shapes and their positioning; sound signalling appliances; additional signals for fishing vessels when operating in close proximity, and international distress signals.

Part A - General (Rules 1-3)

Rule 1 states that the rules apply to all vessels upon the high seas and all waters connected to the high seas and navigable by seagoing vessels.

Rule 2 covers the responsibility of the master, owner and crew to comply with the rules.

Rule 3 includes definitions.

Part B- Steering and Sailing (Rules 4-19)

Section 1 - Conduct of vessels in any condition of visibility (Rules 4-10)

Rule 4 says the section applies in any condition of visibility.

Rule 5 requires that "every vessel shall at all times maintain a proper look-out by sight and hearing as well as by all available means appropriate in the prevailing circumstances and conditions so as to make a full appraisal of the situation and of the risk of collision.

Rule 6 deals with safe speed. It requires that: "Every vessel shall at all times proceed at a safe speed..". The Rule describes the factors which should be taken into account in determining safe speed. Several of these refer specifically to vessels equipped with radar. The importance of using "all available means" is further stressed in **Rule 7** covering risk of collision, which warns that "assumptions shall not be made on the basis of scanty information, especially scanty radar information"

Rule 8 covers action to be taken to avoid collision.

In **Rule 9** a vessel proceeding along the course of a narrow channel or fairway is obliged to keep "as near to the outer limit of the channel or fairway which lies on her starboard side as is safe and practicable." The same Rule obliges a vessel of less than 20 metres in length or a sailing vessel not to impede the passage of a vessel "which can safely navigate only within a narrow channel or fairway."

The Rule also forbids ships to cross a narrow channel or fairway "if such crossing impedes the passage of a vessel which can safely navigate only within such channel or fairway." The meaning "not to impede" was classified by an amendment to Rule 8 in 1987. A new paragraph (f) was added, stressing that a vessel which was required not to impede the passage of another vessel should take early action to allow sufficient sea room for the safe passage of the other vessel. Such vessel was obliged to fulfil this obligation also when taking avoiding action in accordance with the steering and sailing rules when risk of collision exists.

Rule 10 of the Collision Regulations deals with the behavior of vessels in or near traffic separation schemes adopted by the Organization. By regulation 8 of Chapter V (Safety of Navigation) of SOLAS, IMO is recognized as being the only organization competent to deal with international measures concerning the routeing of ships.

The effectiveness of traffic separation schemes can be judged from a study made by the International Association of Institutes of Navigation (IAIN) in 1981.

This showed that between 1956 and 1960 there were 60 collisions in the Strait of Dover; twenty years later, following the introduction of traffic separation schemes, this total was cut to only 16.

In other areas where such schemes did not exist the number of collisions rose sharply. New traffic separation schemes are introduced regularly and existing ones are amended when necessary to respond to changed traffic conditions. To enable this to be done as quickly as possible the MSC has been authorized to adopt and amend traffic separation schemes on behalf of the Organization.

Rule 10 states that ships crossing traffic lanes are required to do so "as nearly as practicable at right angles to the general direction of traffic flow." This reduces confusion to other ships as to the crossing vessel's intentions and course and at the same time enables that vessel to cross the lane as quickly as possible.

Fishing vessels "shall not impede the passage of any vessel following a traffic lane" but are not banned from fishing. This is in line with Rule 9 which states that "a vessel engaged in fishing shall not impede the passage of any other vessel navigating within a narrow channel or fairway."In 1981 the regulations were amended. Two new paragraphs were added to Rule 10 to exempt vessels which are restricted in their ability to manoeuvre "when engaged in an operation for the safety of navigation in a traffic separation scheme" or when engaged in cable laying.

In 1987 the regulations were again amended. It was stressed that Rule 10 applies to traffic separation schemes adopted by the Organization (IMO) and does not relieve any vessel of her obligation under any other rule. It was also to clarify that if a vessel is obliged to cross traffic lanes it should do so as nearly as practicable at right angles to the general direction of the traffic flow. In 1989 Regulation 10 was further amended to clarify the vessels which may use the "inshore traffic zone."

Section II - Conduct of vessels in sight of one another (Rules 11-18)

Rule 11 says the section applies to vessels in sight of one another.

Rule 12 states action to be taken when two sailing vessels are approaching one another.

Rule 13 covers overtaking - the overtaking vessel should keep out of the way of the vessel being overtaken.

Rule 14 deals with head-on situations. Crossing situations are covered by **Rule 15** and action to be taken by the give-way vessel is laid down in **Rule 16**.

Rule 17 deals with the action of the stand-on vessel, including the provision that the stand-on vessel may "take action to avoid collision by her manoeuvre alone as soon as it becomes apparent to her that the vessel required to keep out of the way is not taking appropriate action.

Rule 18 deals with responsibilities between vessels and includes requirements for vessels which shall keep out of the way of others.

Section III - conduct of vessels in restricted visibility (Rule 19)

Rule 19 states every vessel should proceed at a safe speed adapted to prevailing circumstances and restricted visibility. A vessel detecting by radar another vessel should determine if there is risk of collision and if so take avoiding action. A vessel hearing fog signal of another vessel should reduce speed to a minimum.

Part C Lights and Shapes (Rules 20-31)

Rule 20 states rules concerning lights apply from sunset to sunrise.

Rule 21 gives definitions.

Rule 22 covers visibility of lights - indicating that lights should be visible at minimum ranges (in nautical miles) determined according to the type of vessel.

Rule 23 covers lights to be carried by power-driven vessels underway.

Rule 24 covers lights for vessels towing and pushing.

Rule 25 covers light requirements for sailing vessels underway and vessels under oars.

Rule 26 covers light requirements for fishing vessels.

Rule 27 covers light requirements for vessels not under command or restricted in their ability to manoeuvre.

Rule 28 covers light requirements for vessels constrained by their draught.

Rule 29 covers light requirements for pilot vessels.

Rule 30 covers light requirements for vessels anchored and aground.

Rule 31 covers light requirements for seaplanes

Part D - Sound and Light Signals (Rules 32-37)

Rule 32 gives definitions of whistle, short blast, and prolonged blast.

Rule 33 says vessels 12 metres or more in length should carry a whistle and a bell and vessels 100 metres or more in length should carry in addition a gong.

Rule 34 covers manoeuvring and warning signals, using whistle or lights.

Rule 35 covers sound signals to be used in restricted visibility.

Rule 36 covers signals to be used to attract attention.

Rule 37 covers distress signals.

Part E - Exemptions (Rule 38)

Rule 38 says ships which comply with the 1960 Collision Regulations and were built or already under construction when the 1972 Collision Regulations entered into force may be exempted from some requirements for light and sound signals for specified periods.

1.5.2. PRINCIPLES TO BE OBSERVED IN KEEPING A NAVIGATIONAL WATCH

Responsibilities regarding avoidance of Collision and Grounding

The officer of the watch is the eyes and the brain of a ship – in the absence of the Master who may not be available on the Bridge always – though he may be called.

This important aspect should not be forgotten by the OOW. He is the only person who would have to take a decision to avoid immediate danger and has to also take the step to call up the Master for taking over when he cannot handle the situation – this should not be looked upon as in competence rather a call well in time would be much appreciated rather than have a collision.

The OOW may not face many decision making instances everyday, and if the scenario does appear so, then the Master would be on hand to lend advise.

On normal navigation duties the OOW has to strictly follow the Rules of the Road (COLREG's) and should not deviate from the spirit.

A casual attitude would be disastrous, in case of any doubt he should call the Master.

All actions to avoid a collision and stranding should be made as stated in the Rules, well in time. So that the OOW would be able to assess his action and have adequate time to take further actions if the action is not helpful.

The OOW should at all times have the Company's Order book (for Navigation) as well as the Master's standing orders open on the Chart table.

This may be looked upon as frivolous but in case of any doubt about a situation, these lines of instructions help in making a decision.

One of the most important thing is to remember that at all times the lives of many depend on him to make the correct decision. If the OOW feels he is unwell to perform his duties he has to bring the same to the Masters notice and asked to be relieved. Some cases when all the OOW and the Master are overworked, then he has to put in a special effort to rise above the situation. Rule Six and seven should be never forgotten and should be form the back bone of all navigating decisions.

Principles applying to watch keeping generally

The following principles shall be observed to ensure that safe watches are maintained at all times.

The master of every ship is bound to ensure that watch keeping arrangements are adequate for maintaining a safe navigational watch. Under the master's general direction, the officers of the navigational watch are responsible for navigating the ship safely during their periods of duty, when they will be particularly concerned with avoiding collision and stranding.

Protection of marine environment

The master, officers and ratings shall be aware of the serious effects of operational or accidental pollution of the marine environment and shall take all possible precautions to prevent such pollution, particularly within the framework of relevant international and port regulations.

Principles to be observed in keeping a navigational watch

The officer in charge of the navigational watch is the master's representative and is primarily responsible at all times for the safe navigation of the ship and for complying with the International Regulations for Preventing Collisions at Sea, 1972.

Look-out

A proper look-out shall be maintained at all times in compliance with rule 5 of the International Regulations for Preventing Collisions at Sea, 1972 and shall serve the purpose of:

1. maintaining a continuous state of vigilance by sight and hearing as well as by all other available means, with regard to any significant change in the operating environment;
2. fully appraising the situation and the risk of collision, stranding and other dangers to navigation; and
3. detecting ships or aircraft in distress, shipwrecked persons, wrecks, debris and other hazards to safe navigation.

The look-out must be able to give full attention to the keeping of a proper look-out and no other duties shall be undertaken or assigned which could interfere with that task.

The duties of the look-out and helmsperson are separate and the helmsperson shall not be considered to be the look-out while steering, except in small ships where an unobstructed all-round view is provided at the steering position and there is no impairment of night vision or other impediment to the keeping of a proper look-out. The officer in charge of the navigational watch may be the sole look-out in daylight provided that on each such occasion:

1. the situation has been carefully assessed and it has been established without doubt that it is safe to do so;
2. full account has been taken of all relevant factors including, but not limited to:
    - ✓ state of weather,
    - ✓ visibility,
    - ✓ traffic density,
    - ✓ proximity of dangers to navigation, and
    - ✓ the attention necessary when navigating in or near traffic separation schemes; and
3. assistance is immediately available to be summoned to the bridge when any change in the situation so requires.

In determining that the composition of the navigational watch is adequate to ensure that a proper look-out can continuously be maintained, the master shall take into account all relevant factors, including those described in this section of the Code, as well as the following factors:

1. visibility, state of weather and sea;
2. traffic density, and other activities occurring in the area in which the vessel is navigating;
3. the attention necessary when navigating in or near traffic separation schemes or other routeing measures;
4. the additional workload caused by the nature of the ship's functions, immediate operating requirements and anticipated manoeuvres;
5. the fitness for duty of any crew members on call who are assigned as members of the watch;
6. knowledge of and confidence in the professional competence of the ship's officers and crew;
7. the experience of each officer of the navigational watch, and the familiarity of that officer with the ship's equipment, procedures, and manoeuvring capability;
8. activities taking place on board the ship at any particular time, including radio communication activities and the availability of assistance to be summoned immediately to the bridge when necessary;
9. the operational status of bridge instrumentation and controls, including alarm systems;
10. rudder and propeller control and ship manoeuvring characteristics;
11. the size of the ship and the field of vision available from the conning position;
12. the configuration of the bridge, to the extent such configuration might inhibit a member of the watch from detecting by sight or hearing any external development; and
13. any other relevant standard, procedure or guidance relating to watch keeping arrangements and fitness for duty which has been adopted by the Organization.

Watch arrangements

The following shall be taken into account:

1. at no time shall the bridge be left unattended;
2. weather conditions, visibility and whether there is daylight or darkness;
3. proximity of navigational hazards which may make it necessary for the officer in charge of the watch to carry out additional navigational duties;
4. use and operational condition of navigational aids such as radar or electronic position-indicating devices and any other equipment affecting the safe navigation of the ship;
5. whether the ship is fitted with automatic steering;
6. whether there are radio duties to be performed;

7. unmanned machinery space (UMS) controls, alarms and indicators provided on the bridge, procedures for their use and limitations; and
8. any unusual demands on the navigational watch that may arise as a result of special operational circumstances.

Taking over the watch

The officer in charge of the navigational watch shall not hand over the watch to the relieving officer if there is reason to believe that the latter is not capable of carrying out the watch keeping duties effectively, in which case the master shall be notified.

The relieving officer shall ensure that the members of the relieving watch are fully capable of performing their duties, particularly as regards their adjustment to night vision. Relieving officers shall not take over the watch until their vision is fully adjusted to the light conditions.

Prior to taking over the watch relieving officers shall satisfy themselves as to the ship's estimated or true position and confirm its intended track, course and speed, and UMS controls as appropriate and shall note any dangers to navigation expected to be encountered during their watch.

Relieving officers shall personally satisfy themselves regarding the:

1. standing orders and other special instructions of the master relating to navigation of the ship;
2. position, course, speed and draught of the ship;
3. prevailing and predicted tides, currents, weather, visibility and the effect of these factors upon course and speed;
4. procedures for the use of main engines to manoeuvre when the main engines are on bridge control; and
5. navigational situation, including but not limited to:
   - 5.1. the operational condition of all navigational and safety equipment being used or likely to be used during the watch,
   - 5.2. the errors of gyro and magnetic compasses,
   - 5.3. the presence and movement of ships in sight or known to be in the vicinity,
   - 5.4. the conditions and hazards likely to be encountered during the watch, and
   - 5.5. the possible effects of heel, trim, water density and squat on under keel clearance.

If at any time the officer in charge of the navigational watch is to be relieved when a manoeuvre or other action to avoid any hazard is taking place, the relief of that officer shall be deferred until such action has been completed.

Performing the navigational watch

The officer in charge of the navigational watch shall:

1. keep the watch on the bridge;
2. in no circumstances leave the bridge until properly relieved;
3. continue to be responsible for the safe navigation of the ship, despite the presence of the master on the bridge, until informed specifically that the master has assumed that responsibility and this is mutually understood; and
4. notify the master when in any doubt as to what action to take in the interest of safety.

During the watch the course steered, position and speed shall be checked at sufficiently frequent intervals, using any available navigational aids necessary, to ensure that the ship follows the planned course.

The officer in charge of the navigational watch shall have full knowledge of the location and operation of all safety and navigational equipment on board the ship and shall be aware and take account of the operating limitations of such equipment.

The officer in charge of the navigational watch shall not be assigned or undertake any duties which would interfere with the safe navigation of the ship.

Officers of the navigational watch shall make the most effective use of all navigational equipment at their disposal.

When using radar, the officer in charge of the navigational watch shall bear in mind the necessity to comply at all times with the provisions on the use of radar contained in the International Regulations for Preventing Collisions at Sea, in force.

In cases of need the officer in charge of the navigational watch shall not hesitate to use the helm, engines and sound signalling apparatus. However, timely notice of intended variations of engine speed shall be given where possible or effective use made of UMS engine controls provided on the bridge in accordance with the applicable procedures.

Officers of the navigational watch shall know the handling characteristics of their ship, including its stopping distances, and should appreciate that other ships may have different handling characteristics.

A proper record shall be kept during the watch of the movements and activities relating to the navigation of the ship.

It is of special importance that at all times the officer in charge of the navigational watch ensures that a proper look-out is maintained. In a ship with a separate chart room the officer in charge of the navigational watch may visit the chart room, when essential, for a short period for the necessary performance of navigational duties, but shall first ensure that it is safe to do so and that proper look-out is maintained.

Operational tests of shipboard navigational equipment shall be carried out at sea as frequently as practicable and as circumstances permit, in particular before hazardous conditions affecting navigation are expected. Whenever appropriate, these tests shall be recorded. Such tests shall also be carried out prior to port arrival and departure.

The officer in charge of the navigational watch shall make regular checks to ensure that:

1. the person steering the ship or the automatic pilot is steering the correct course;
2. the standard compass error is determined at least once a watch and, when possible, after any major alteration of course; the standard and gyro-compasses are frequently compared and repeaters are synchronized with their master compass;
3. the automatic pilot is tested manually at least once a watch;
4. the navigation and signal lights and other navigational equipment are functioning properly;
5. the radio equipment is functioning properly in accordance with paragraph 86 of this section; and
6. the UMS controls, alarms and indicators are functioning properly.

The officer in charge of the navigational watch shall bear in mind the necessity to comply at all times with the requirements in force of the International Convention for the Safety of Life at Sea, (SOLAS) 1974 (including latest amendments). The officer of the navigational watch shall take into account:

1. the need to station a person to steer the ship and to put the steering into manual control in good time to allow any potentially hazardous situation to be dealt with in a safe manner; and
2. that with a ship under automatic steering it is highly dangerous to allow a situation to develop to the point where the officer in charge of the navigational watch is without assistance and has to break the continuity of the look-out in order to take emergency action.

Officers of the navigational watch shall be thoroughly familiar with the use of all electronic navigational aids carried, including their capabilities and limitations, and shall use each of these aids when appropriate and shall bear in mind that the echo-sounder is a valuable navigational aid.

The officer in charge of the navigational watch shall use the radar whenever restricted visibility is encountered or expected, and at all times in congested waters having due regard to its limitations.

The officer in charge of the navigational watch shall ensure that range scales employed are changed at sufficiently frequent intervals so that echoes are detected as early as possible. It shall be borne in mind that small or poor echoes may escape detection.

Whenever radar is in use, the officer in charge of the navigational watch shall select an appropriate range scale and observe the display carefully, and shall ensure that plotting or systematic analysis is commenced in ample time.

The officer in charge of the navigational watch shall notify the master immediately:

1. if restricted visibility is encountered or expected;

2. if the traffic conditions or the movements of other ships are causing concern;
3. if difficulty is experienced in maintaining course;
4. on failure to sight land, a navigation mark or to obtain soundings by the expected time;
5. if, unexpectedly, land or a navigation mark is sighted or a change in soundings occurs;
6. on breakdown of the engines, propulsion machinery remote control, steering gear or any essential navigational equipment, alarm or indicator;
7. if the radio equipment malfunctions;
8. in heavy weather, if in any doubt about the possibility of weather damage;
9. if the ship meets any hazard to navigation, such as ice or a derelict; and
10. in any other emergency or if in any doubt.

Despite the requirement to notify the master immediately in the foregoing circumstances, the officer in charge of the navigational watch shall in addition not hesitate to take immediate action for the safety of the ship, where circumstances so require.

The officer in charge of the navigational watch shall give watchkeeping personnel all appropriate instructions and information which will ensure the keeping of a safe watch, including a proper look-out.

Watch keeping under different conditions and in different areas

Clear weather

The officer in charge of the navigational watch shall take frequent and accurate compass bearings of approaching ships as a means of early detection of risk of collision and bear in mind that such risk may sometimes exist even when an appreciable bearing change is evident, particularly when approaching a very large ship or a tow or when approaching a ship at close range. The officer in charge of the navigational watch shall also take early and positive action in compliance with the applicable International Regulations for Preventing Collisions at Sea, 1972 and subsequently check that such action is having the desired effect.

In clear weather, whenever possible, the officer in charge of the navigational watch shall carry out radar practice.

Restricted visibility

When restricted visibility is encountered or expected, the first responsibility of the officer in charge of the navigational watch is to comply with the relevant rules of the International Regulations for Preventing Collisions at Sea, 1972 with particular regard to the sounding of fog signals, proceeding at a safe speed and having the engines ready for immediate manoeuvre. In addition, the officer in charge of the navigational watch shall:

1. inform the master;
2. post a proper look-out;
3. exhibit navigation lights; and
4. operate and use the radar.

In hours of darkness

The master and the officer in charge of the navigational watch when arranging look-out duty shall have due regard to the bridge equipment and navigational aids available for use, their limitations; procedures and safeguards implemented.

Coastal and congested waters

The largest scale chart on board, suitable for the area and corrected with the latest available information, shall be used. Fixes shall be taken at frequent intervals, and shall be carried out by more than one method whenever circumstances allow.

The officer in charge of the navigational watch shall positively identify all relevant navigation marks.

Navigation with pilot on board

Despite the duties and obligations of pilots, their presence on board does not relieve the master or officer in charge of the navigational watch from their duties and obligations for the safety of the ship. The master and the pilot shall exchange information regarding navigation procedures, local conditions and the ship's characteristics. The master and/or the officer in charge of the navigational watch shall co-operate closely with the pilot and maintain an accurate check on the ship's position and movement.

If in any doubt as to the pilot's actions or intentions, the officer in charge of the navigational watch shall seek clarification from the pilot and, if doubt still exists, shall notify the master immediately and take whatever action is necessary before the master arrives.

Ship at anchor

If the master considers it necessary, a continuous navigational watch shall be maintained at anchor. While at anchor, the officer in charge of the navigational watch shall:

1. determine and plot the ship's position on the appropriate chart as soon as practicable;
2. when circumstances permit, check at sufficiently frequent intervals whether the ship is remaining securely at anchor by taking bearings of fixed navigation marks or readily identifiable shore objects;
3. ensure that proper look-out is maintained;
4. ensure that inspection rounds of the ship are made periodically;

5. observe meteorological and tidal conditions and the state of the sea;
6. notify the master and undertake all necessary measures if the ship drags anchor;
7. ensure that the state of readiness of the main engines and other machinery is in accordance with the master’s instructions;
8. if visibility deteriorates, notify the master;
9. ensure that the ship exhibits the appropriate lights and shapes and that appropriate sound signals are made in accordance with all applicable regulations; and
10. take measures to protect the environment from pollution by the ship and comply with applicable pollution regulations.

1.5.3. **Bridge watchkeeping equipment and system**

- **The Automatic Identification System (AIS)**

Is an automatic tracking system used on ships and by vessel traffic services (VTS) for identifying and locating vessels by electronically exchanging data with other nearby ships, AIS base stations, and satellites. When satellites are used to detect AIS signatures then the term Satellite-AIS (S-AIS) is used. AIS information supplements marine radar, which continues to be the primary method of collision avoidance for water transport.

An AIS-equipped system on board a ship presents the bearing and distance of nearby vessels in a radar-like display format.

A marine traffic coordinator using AIS and radar to manage vessel traffic.

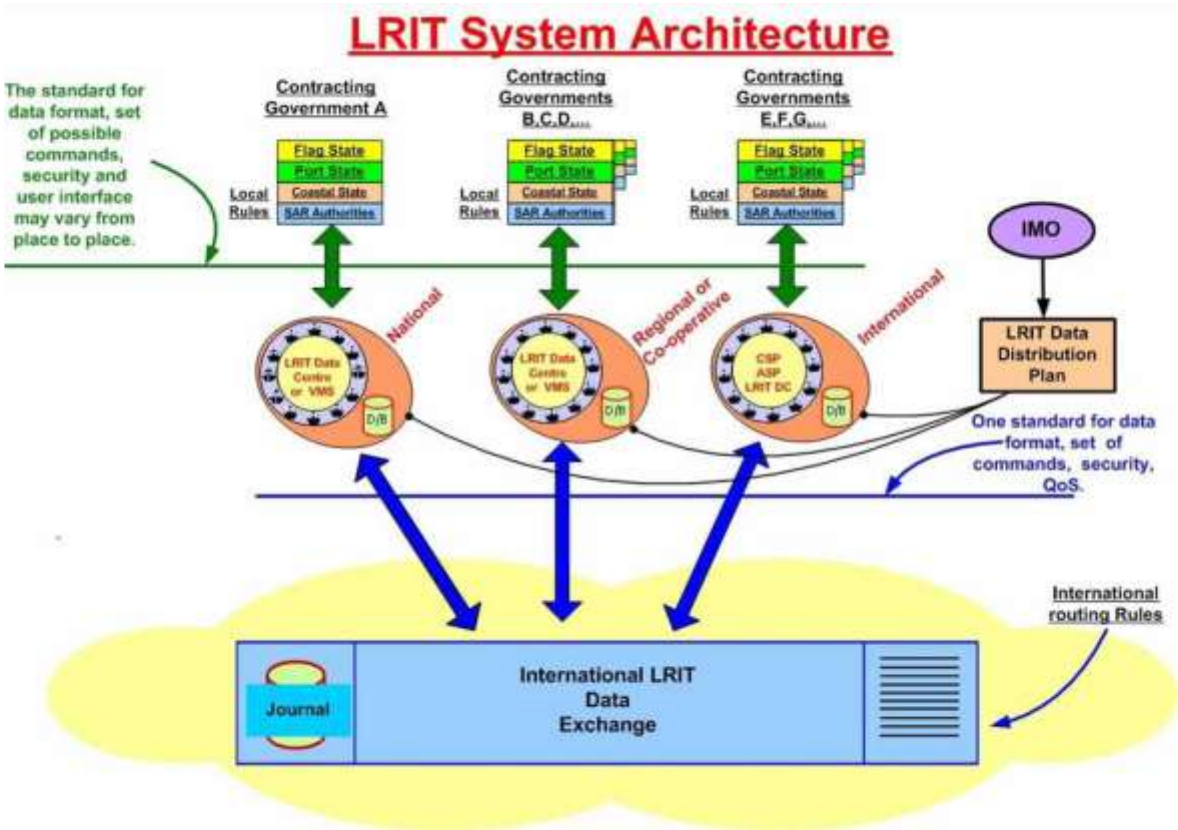
Information provided by AIS equipment, such as unique identification, position, course, and speed, can be displayed on a screen or an ECDIS. AIS is intended to assist a vessel's watch standing officers and allow maritime authorities to track and monitor vessel movements. AIS integrates a standardized VHF transceiver with a positioning system such as a GPS or LORAN-C receiver, with other electronic navigation sensors, such as a gyrocompass or rate of turn indicator. Vessels fitted with AIS transceivers and transponders can be tracked by AIS base stations located along coast lines or, when out of range of terrestrial networks, through a growing number of satellites that are fitted with special AIS receivers which are capable of deconflicting a large number of signatures.

Long Range Identification and Tracking (LRIT):

The Long-Range Identification and Tracking (LRIT) system provides for the global identification and tracking of ships.

The obligations of ships to transmit LRIT information and the rights and obligations of SOLAS Contracting Governments and of Search and rescue services to receive LRIT information are established in regulation V/19-1 of the 1974 SOLAS Convention.

The LRIT system consists of the shipborne LRIT information transmitting equipment, the Communication Service Provider(s), the Application Service Provider(s), the LRIT Data Centre(s), including any related Vessel Monitoring System(s), the LRIT Data Distribution Plan and the International LRIT Data Exchange. Certain aspects of the performance of the LRIT system are reviewed or audited by the LRIT Coordinator acting on behalf of all SOLAS Contracting Governments.



LRIT information is provided to Contracting Governments to the 1974 SOLAS Convention and Search and rescue services entitled to receive the information, upon request, through a system of National, Regional and Cooperative LRIT Data Centres using the International LRIT Data Exchange.

Each Administration should provide to the LRIT Data Centre it has selected, a list of the ships entitled to fly its flag, which are required to transmit LRIT information, together with other salient details and should update, without undue delay, such lists as and when changes occur. Ships should only transmit the LRIT information to the LRIT Data Centre selected by their Administration.

- **Voyage Data Recorders**

Voyage Data Recorders (VDRs) are systems installed on modern vessels to preserve details about the ship's status, and thus provide information to investigators in the case of an accident. While the ongoing data collection is performed by various devices, such as analog and digital sensors or dedicated computer systems, the actual recording of this information is entrusted to an industrial grade computer.

Nowadays almost any ship has a VDR. VDRs are considered the best evidence in an accident investigation. The data on these VDR systems can provide a very detailed understanding of events leading up to an accident.

VDRs are computers and store digital evidence, hence require digital forensic processing. In fact, all the standard steps (collection, prevention, survey, examination, analysis, reconstruction) apply to the analysis of VDRs.

Although some general purpose digital forensic processes which are commonly applied to standard computers can also be applied to VDRs, including hard disk imaging, the specialized, proprietary, and non-standard formats of data in these system unique challenges from a digital forensic perspective.

Regulation governing use of VDRs

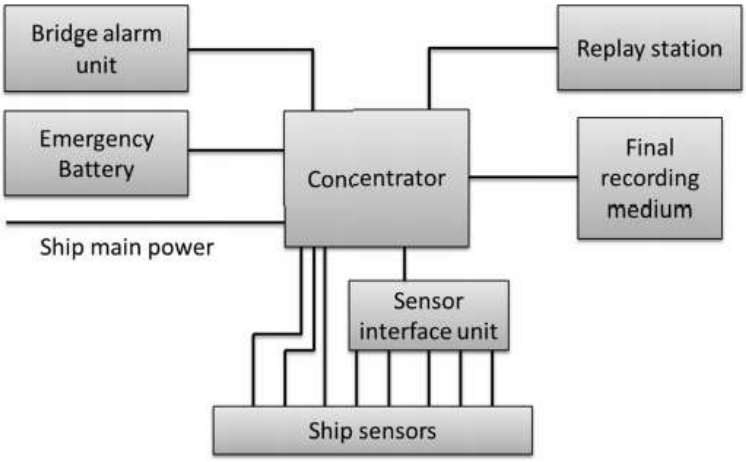
The use of VDRs on ship is subjected to the regulations contained in chapter V on "Safety of Navigation" of the "International Convention for the safety of life at sea" (SOLAS) (International Maritime Organization, 1974). This chapter has been amended in 1999 to adopt the IMO (International Maritime Organization) resolution A. 861(20) "Performance Standards for Shipborne Vogaye Data Recorders (VDRs)" (International Maritime Organization 1997). These regulations, entered into force on July 1st, 2002, specify the kinds of ship that are required to carry Voyage Data Recorders, which include passenger ships, roll on-roll off passenger ship built before july 1st, 2002 8designed to carry wheeled cargo such as automobiles and trucks and thus provide with built-in ramps), and other ships over 3000 gross tonnage built on or after july 1, 2002.

The IMO resolution also sets requirements about the operation of the VDR. For example, it states that the device should be entirely automatic in normal operation and should continuously store sequential records of preselected data items related to status, command, and control of the ship. The recording medium should be installed in a brightly colored protective capsule and fitted with a beaconing device to help its localization. A further IMO resolution, MSC. 163 (78) adopted on 17 May 2004 (International Maritime Organization, 2004), creates a new category of VDR, called "simplified VDR" or S-VDR, with lesser requirement to be fitted on older vessels.

According to the aforementioned regulation, a standard VDR is required to store at least the following data items: date and time referenced to Coordinated Universal Time (UTC), ship's position (latitude, longitude, coordinate rederence), speed, heading, bridge audio (acquired by one or more microphones placed as to record conversations and audible alarms), very High Frequency (VHF) radio communications, radar data (such as to record a faithful replica of the radar display that was on view at the time of recording), depth under keel, main alarms, rudder order and response, engine order and response, hull openings status, watertight and fire door status and, where available, acceleration and hull stresses.

VDR system

The VDR is the complete system for processing, encoding and recording the data required by the IMO regulations. The elements in this system, as seen are:



VDR system schematic

- Concentrator: usually an industrial grade computer which receives data from the sensors, processes and encodes them, and then records the stream to the final recording medium.
- Sensors: all the external devices from which the VDR receives data.
- Sensor interface unit: optional device providing additional input lines to the concentrator.
- Final recording medium (FRM): the capsule used to store the data, designed to survive an accident and thus enable the recovery of the voyage data even in the event of a catastrophic loss of the ship.
- Dedicated power source: an external battery exclusively used to power the VDR for at least 2 h in the event of loss of main and backup power source of the ship.
- Bridge alarm unit: a remote interface to manage the VDR and acknowledge system alarms and warnings.
- Replay stations: one or more optional personal computers used to download and review voyage data from the concentrator.

In case of accident and subsequent investigation, both the final recording medium and, if they survived, the concentrator and the replay stations can serve as sources of data. The final recording medium is required to store at least the last 12 h of data (older records can be over-written). Recording is required to continue 2 h after the loss of ship power, to allow archiving of data from before, during and after the accident. In case of non-catastrophic accident, various manufacturers provide a way to backup data to another medium, usually placed near the concentrator, to prevent them from being overwritten and thus allowing their use for investigations. At last, the concentrator itself usually stores a larger amount of data, so its recovery can provide data which, even if not required by the regulations, can also be useful in an investigation.

- **BNWAS**

The purpose of a BNWAS Bridge Navigational Watch Alarm System is to monitor bridge activity and detect operator disability which could lead to accidents.

The system monitors the awareness of the Officer of the Watch (OOW) and automatically alerts another qualified OOW or the Captain if for any reason the OOW becomes incapable of performing the OOW's duties.

This purpose is achieved by a series of indications and alarms to alert first the OOW and, if he is not responding, then to alert another qualified OOW or the Captain. Additionally, the BNWAS may provide the OOW with a means of calling for immediate assistance if required.

The BNWAS should be operational whenever the ship's heading or track control system is engaged, unless inhibited by the Captain.

Why install BNWAS?

Regulations from IMO’s Maritime Safety Committee (MSC) requires carriage of a BNWAS Bridge Navigational Watch Alarm System complying with IMO performance standards.

The purpose of a bridge navigational watch alarm system (BNWAS) is to monitor bridge activity and detect operator disability which could lead to marine accidents. The system monitors the awareness of the Officer of the Watch (OOW) and automatically alerts the Captain or another qualified OOW if for any reason the OOW becomes incapable of performing the OOW’s duties.

This purpose is achieved by a series of indications and alarms to alert first the OOW and, if he is not responding, then to alert the Captain or another qualified OOW. Additionally, the BNWAS may provide the OOW with a means of calling for immediate assistance if required. The BNWAS should be operational whenever the ship's heading or track control system is engaged, unless inhibited by the Captain.

Deadlines for installation of BNWAS

1 July 2011: New Ships > 150 GT and all new passenger ships.

1 July 2012: Existing passenger ships and ships over 3.000 GT

1 July 2013: Existing ships over 500 GT

1 July 2014: Existing ships over 150 GT

IMO performance standards for BNWAS

In February 2010 the new performance standard IEC62616 was adopted. IEC 62616 specifies the minimum performance requirements, technical characteristics and methods of testing, and required test results, for a bridge navigational watch alarm system (BNWAS) as required by Chapter V of the International Convention for the Safety of Life at Sea (SOLAS), as amended. It takes account of the general requirements given in IMO resolution A.694(17) and is associated with IEC 60945.

This means that from July 2011 all new ships over 150 GT has to be fitted with a type approved BNWAS complying with the new standard. Only a few systems have this new approval. Our new generation of BNWAS is called BW-800 and is Wheel mark approved and has several Type Approvals.

NEW! June 30th 2014 The IMO has issued interim guidance (contained in IMO circular MSC.1/Circ.1474) that the automatic operational mode on bridge navigational watch alarm systems BNWAS), if available, should not be used on a ship conforming to regulation SOLAS V/19.2.2.3. Which requires the BNWAS to be in operation whenever the ship is underway at sea

1.6. MAINTAIN SAFE NAVIGATION THROUGH THE USE OF INFORMATION FROM NAVIGATION EQUIPMENT AND SYSTEMS TO ASSIST COMMAND DECISION MAKING

Safe navigation is the most fundamental attribute of good seamanship. An increasingly sophisticated range of navigational aids can today complement the basic skills of navigating officers, which have accumulated over the centuries.

But sophistication brings its own dangers and a need for precautionary measures against undue reliance on technology. Experience shows that properly formulated bridge procedures and the development of bridge teamwork are critical to maintaining a safe navigational watch.

Finally, an essential part of bridge organisation is the procedures, which should set out in clear language the operational requirements and methods that should be adopted when navigating. In this section, we have attempted to codify the main practices and provide a framework upon which masters, officers and pilots can work together to achieve consistent and reliable performance.

Seafaring will never be without its dangers but the maintenance of a safe navigational watch at all times and the careful preparation of passage plans are at the heart of good operating practice. If this Guide can help in that direction it will have served its purpose.

Safe navigation is of utmost importance to. Safe navigation means that the ship is not exposed to undue danger and that at ah times the ship can be controlled within acceptable margins.

To navigate safely at all times requires effective command, control, communication and management. It demands that the situation, the level of bridge manning, the operational status of navigational systems and the ships' engines and auxiliaries are ah taken into account.

It is people that control ships, and it is therefore people, management and teamwork which are the key to reliable performance. People entrusted with the control of ships must be competent to carry out their duties.

People also make mistakes and so it is necessary to ensure that monitoring and checking prevent chains of error from developing. Mistakes cannot be predicted, and once a mistake has been detected, it is human nature to seek to fit circumstances to the original premise, thus compounding a simple error of judgement.

Passage planning is conducted to assess the safest and most economical sea route between ports. Detailed plans, particularly in coastal waters, port approaches and pilotage areas, are needed to ensure margins of safety. Once completed, the passage plan becomes the basis for navigation. Equipment can fail and the unexpected can happen, so contingency planning is also necessary.

Ergonomics and good design are essential elements of good bridge working practices. Watchkeepers at sea need to be able to keep a look-out, as well as monitor the chart and observe the radar. They should also be able to communicate using the VHF without losing situational awareness. When boarding or disembarking pilots, handling tugs or berthing, it should be possible to monitor instrumentation, particularly helm and engine indicators, from the bridge wings. Bridge notes should be provided to explain limitations of any equipment that has been badly sited, pointing out the appropriate remedies that need to be taken.

The guiding principles behind good management practices are:

- Clarity of purpose

- Delegation of authority;
- Effective organization
- Motivation

Clarity of purpose

If more than one person is involved in navigating it is essential to agree the passage plan and to communicate the way the voyage objectives are to be achieved consistently and without ambiguity. The process starts with company instructions to the ship, as encompassed by a safety management system supported by master's standing orders and reinforced by discussion and bridge orders. Existing local pilotage legislation should also be ascertained to enable the master to be guided accordingly.

Before approaching coastal and pilotage waters, a ship's passage plan should ensure that dangers are noted and safe-water limits identified. Within the broad plan, pilotage should be carried out in the knowledge that the ship can be controlled within the established safe limits and the actions of the pilot can be monitored.

In this respect early exchange of information will enable a clearer and more positive working relationship to be established in good time before the pilot boards. Where this is not practicable the ship's plan should be sufficient to enable the pilot to be embarked and a safe commencement of pilotage made without causing undue delay.

Delegation of authority

The master has the ultimate responsibility for the safety of the ship. Delegation of authority to the officer of the watch (OOW) should be undertaken in accordance with agreed procedures and reflect the ability and experience of the watchkeeper.

Similarly, when a pilot boards the master may delegate the conduct of the ship to the pilot, bearing in mind that pilotage legislation vanes from country to country and from region to region. Pilotage can range from optional voluntary pilotage that is advisory in nature, to compulsory pilotage where the responsibility for the conduct of the navigation of the ship is placed upon the pilot.

The master cannot abrogate responsibility for the safety of the ship and he remains in command at ah times. If the master delegates the conduct of the ship to the pilot, it will be because he is satisfied that the pilot has specialist knowledge, ship handling skills and communications links with the port. In doing so the master must be satisfied that the pilot's intentions are safe and reasonable. The OOW supports the pilot by monitoring the progress of the ship and checking that the pilot's instructions are correctly carried out. Where problems occur which may adversely affect the safety of the ship, the master must be advised immediately.

The process of delegation can be the cause of misunderstanding and so it is recommended that a clear and positive statement of intention be made whenever handing over and receiving conduct of the ship.

When navigating with the master on the bridge it is considered good practice, when it is ascertained that it is safe to do so, to encourage the OOW to carry out the navigation, with the master maintaining a monitoring role.

The watch system provides a continuity of rested watchkeepers, but the watch changeover can give rise to errors. Consequently routines and procedures to monitor the ship's position and to avoid the possibility of mistakes must be built into the organisation of the navigational watch.

The risks associated with navigation demand positive reporting at all times, self verification, verification at handover and regular checks of instrumentation and bridge procedures. The course that the ship is following and compass errors must be displayed and checked, together with the traffic situation, at regular intervals and at every course change and watch handover.

Effective organisation

Preparing a passage plan and carrying out the voyage necessitates that bridge resources are appropriately allocated according to the demands of the different phases of the voyage.

Depending upon the level of activity likely to be experienced, equipment availability, and the time it will take should the ship deviate from her track before entering shallow water, the master may need to ensure the availability of an adequately rested officer as back-up for the navigational watch.

Where equipment is concerned, errors can occur for a variety of reasons and poor equipment calibration may be significant. In the case of integrated systems, it is possible that the failure of one component could have unpredictable consequences for the system as a whole.

It is therefore essential that navigational information is always cross checked, and where there is doubt concerning the ship's position, it is always prudent to assume a position that is closest to danger and proceed accordingly.

Motivation

Motivation comes from within and cannot be imposed. It is however the responsibility of the master to create the conditions in which motivation is Encouraged.

A valuable asset in any organisation is teamwork and this is enhanced by recognising the strengths, limitations and competence of the people within a team, and organising the work of the bridge team to take best advantage of the attributes of each team member.

Working in isolation when carrying out critical operations carries the risk of an error going undetected. Working together and sharing information in a professional way enhances the bridge team and the master/pilot relationship.

Training in bridge resource management can further support this.

1.7. MAINTAIN SAFE NAVIGATION THROUGH THE USE OF ECDIS AND ASSOCIATED NAVIGATION SYSTEMS TO ASSIST COMMAND DECISION MAKING

An Electronic Chart Display & Information System (ECDIS) is a computer-based navigation information system that complies with International Maritime Organization (IMO) regulations and can be used as an alternative to paper nautical charts. IMO refers to similar systems not meeting the regulations as Electronic Chart Systems (ECS).

An ECDIS system displays the information from electronic navigational charts (ENC) or Digital Nautical Charts (DNC) and integrates position information from position, heading and speed through water reference systems and optionally other navigational sensors. Other sensors which could interface with an ECDIS are radar, Navtex, automatic identification systems (AIS), Sailing Directions and fathometer.

ECDIS provides continuous position and navigational safety information. The system generates audible and/or visual alarms when the vessel is in proximity to navigational hazards.

Within the ECDIS, the ENC database stores the chart information in the form of geographic objects represented by point, line and area shapes, carrying individual attributes, which make any of these objects unique. Appropriate mechanisms are built into the system to query the data, and then to use the obtained information to perform certain navigational functions (e.g. the anti-grounding surveillance).

1.8. FORECAST WEATHER AND OCEANOGRAPHIC CONDITIONS

1.8.1. SYNOPTIC CHARTS AND WEATHER FORECASTING

Weather forecasting

The biggest factor to take into account when sailing always has been and always will be, the weather. However, whilst this remains constant, our understanding of the weather, our ability to forecast it and the technology used to deliver weather information to sailing vessels, is always changing and improving.

Climatology

The information is required to ensure that the vessel in question is in compliance with local/national regulations and is capable of operating in conditions both typical and extreme.

To derive information about the climatology of a particular marine area, a statistical analysis is performed on a long time series of data on wave height, period, and direction, and wind speed and direction. Using these data, the climate of the area can be derived in terms of the statistical likelihood of encountering winds and waves of a particular size, direction or period on a monthly or seasonal basis. Also derived are the properties of the average wave expected at a particular time of year, and the maximum wave in a 50 or 100 year period. The longer the time series of observations, the more confident engineers can be of the predicted climatology.

In some cases, it is possible to split the seas and the oceans into 'climate coherent' areas which have a particular prevailing climate in terms of winds and waves, so that measurements at one location are representative of the whole area. How large these areas are depends on their geographical location, proximity to currents and coastline. However, in some areas there can be great variations in just a hundred kilometers, bringing into question the validity of the climatologically information supplied to a customer if the wave measurements were not made at the location of interest.

1.8.2. CHARACTERISTICS OF VARIOUS WEATHER SYSTEMS

Tropical revolving storms (TRS)

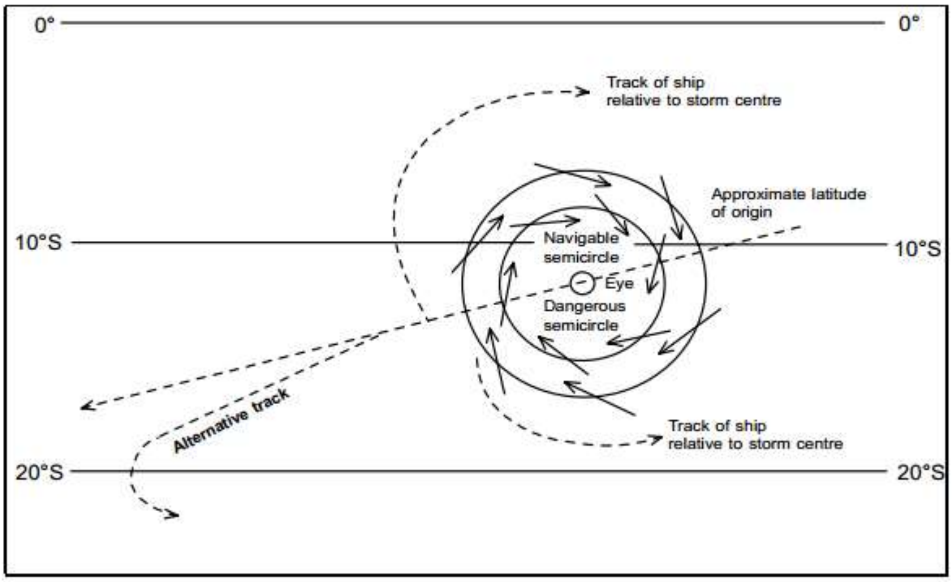
Tropical revolving storms are intense depressions that may develop in tropical latitudes between 5° South and 20° South. In the South Pacific the main season for tropical storms is from November to April, however the greatest frequency of storms is from January to March.

In the southern hemisphere the wind blows around a tropical revolving storm in a spiral flow inwards in a clockwise direction.

The general track of the storm is usually south-westerly but it may change direction and recurve to the south and thence follow a south-easterly path.

INDICATIONS OF TROPICAL STORM.

1. A long low swell is usually the first indications of the existence and approximate bearing of a tropical storm.
2. Extensive high cirrus clouds generally in the direction from which the storm is approaching.
3. A change of 3 hectopascals, or more, below the mean pressure for the area during the tropical storm season.
4. A marked change in the direction of wind and speed.
5. To find the direction of the storm, face the wind and the centre of the storm lies approximately 90° on your left hand side (Buy's Ballots Law)



AVOIDING TROPICAL STORMS		
WIND	**VESSEL IN**	**TO AVOID**
1. BACKING (Changing anti-clockwise)	DANGEROUS SEMICIRCLE	Make MAXIMUM speed with wind on PORT BOW.
2. VEERING (Changing clockwise)	NAVIGABLE SEMICIRCLE	Make MAXIMUM speed with wind on PORT QUARTER, or heave-to with wind on PORT BOW.
3. STEADY & INCREASING (Pressure falling dramatically)	PATH OF STORM	Put wind well on to the PORT QUARTER & make Navigable Semicircle at MAXIMUM speed.

Tropical Storm Table

ICE

Ice is an obstacle to any ship, even an icebreaker, and the inexperienced Navigation Officer is advised to develop a healthy respect for the latent power and strength of ice in all its forms. However, it is quite possible, and continues to be proven so, for well-found ships in capable hands to navigate successfully through ice-covered waters.

The first principle of successful ice navigation is to maintain freedom of manoeuvre. Once a ship becomes trapped, the vessel goes wherever the ice goes. Ice navigation requires great patience and can be a tiring business with or without icebreaker escort. The open water long way round a difficult ice area whose limits are known is often the fastest and safest way to port, or to the open sea when leaving a port.

Experience has proven that in ice of higher concentrations, four basic ship handling rules apply:

- keep moving - even very slowly, but try to keep moving;
- try to work with the ice movement and weaknesses but not against them;
- excessive speed almost always results in ice damage; and
- know your ship's manoeuvring characteristics.

Forms of ice

Several forms of ice may beencountered at sea. By far the most common type is that which result from the freezing at the sea surface, namely sea ice. The other forms are iceberg and river ice. River ice is sometimes encountered in harbours and off estuaries during the spring break – up, but it is then in a state of decay so generally presents only a temporary hindrance to shipping.

Types of sea ice

Sea ice is divided into two main types according to its mobility. One typo is drift ice, which is reasonably dree to move under the action of wind and current; the other is fast ice which not move.

Ice first forms near the coast and spreads seaward. A certain width of fairly level ice, depending on the depth of water, becomes fast to the coastline and is immobile. The outer edge of the fast ice is often located in the vicinity of the 25 m depth contour. A reason for this is that well-hummocked and ridged ice may ground in these depths and so form offshore anchor – points for the new season's ice to become fast. Beyond this ice lies the drift ice, formed, to a small but fundamental extent, from pieces of ice which have broken off from the fast ice. As these spread seaward they, together with any remaining old ice floe, facilitate the formation of new, and later young, ice in the open sea. This ice, as it thickens is continually broken up by wind and waves so that it consists of ice of all sizes and ages from giant floes of several years growth to the several forms of the new ice whose life may be measured in hours.

In open ice, floes turn to trim themselves to the wind. In closed ice, this tendency may be produced by pressure from another floe, but since floes continually hinder each other, and the wind may not be constant in direction, even greater forces, some rotational, result. This screwing or shearing effect resulting excessive pressure at the corners of floes, and forms a hummock of loose ice blocks. Ice undergoing such movement is said to be "screwing", and is extremely dangerous to vessels.

Formation, deformation and movement of sea ice

The freezing of fresh and salt water does not occur in the same manner. This is due to the presence of dissolved salts in sea water. The salinity of water is usually expressed in International Standard Units: sea water typically has a salinity of 35, though in some areas, especially where there is a considerable discharge of river water, the salinity is much less. In the Baltic, for example, the salinity is less than 10 throughout the year.

When considering the freezing process, the importance of salinity lies not only in its effect on the density of the water. The loss of heat from a body of water takes place principally from its surface to the air. As the surface water cools it becomes more dense and sinks, to be replaced by warmer, less dense water from below in a continuous cycle.

Fresh water reaches its maximum density at a temperature of 4ºC; thus when a body of fresh water is cooled to this temperature throughout its depth convection ceases, since further cooling results in a slight decrease in density. Once this stable condition has been reached, cooling of the surface water leads to a rapid drop in temperature and ice begin to form when the temperature falls to 0ºC.

Bergy bit, with very open ice

Requirements for Ships Operating in Ice

The propulsion plant and steering gear of any ship intending to operate in ice must be reliable and must be capable of a fast response to manoeuvring orders. The navigational and communications equipment must be equally reliable and particular attention should be paid to maintaining radar at peak performance.

Light and partly loaded ships should be ballasted as deeply as possible, but excessive trim by the stern is not recommended, as it cuts down manoeuvrability and increases the possibility of ice damage to the more vulnerable lower area of the exposed bow. Engine room suction strainers should be able to be removed easily and to be kept clear of ice and snow. Good searchlights should be available to aid in visibility during night navigation with or without icebreaker support.

Ships navigating in ice-covered waters may experience delays and, therefore, should carry sufficient fresh water, supplies and manoeuvring fuel, especially vessels which use heavy bunker fuel for main propulsion.

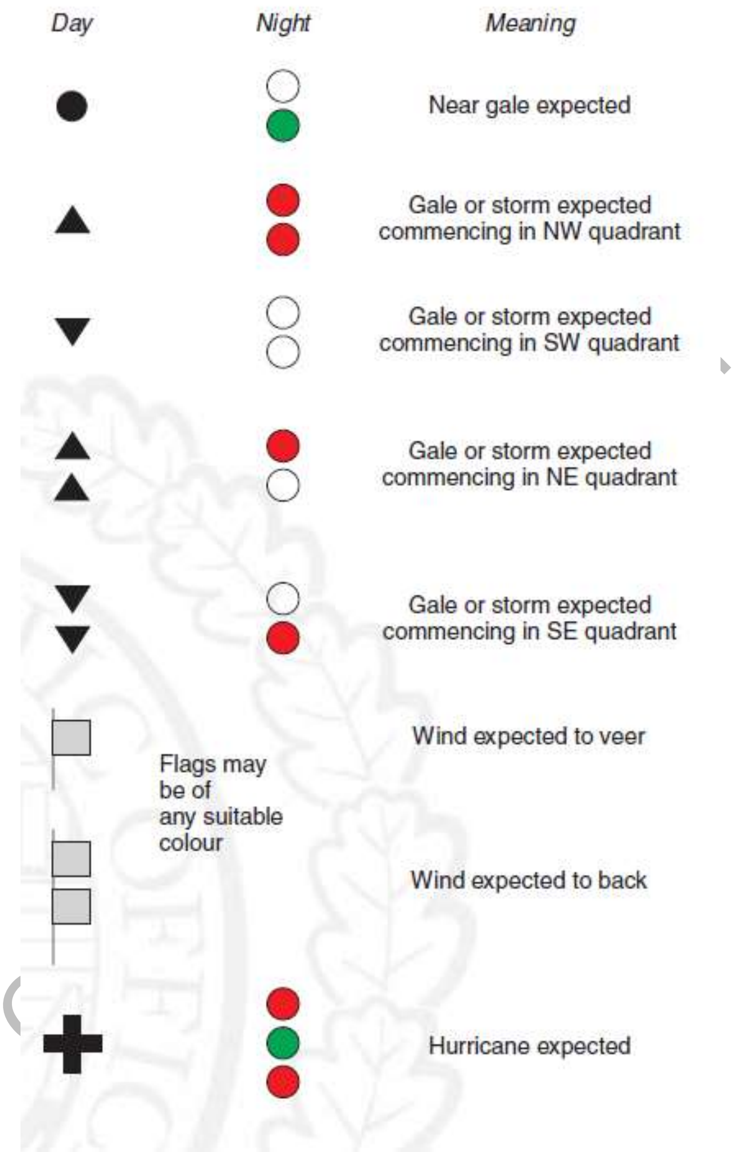
Storm warning signals

- ✓ System

Radio broadcasts of storm warnings are listed and described in Admiralty List of Radio Signals Volume 3. Visual storm warning signals, either national or local, are shown in many countries, and these signals are described in the appropriate volumes of Admiralty Sailing Directions.

The International System of Visual Storm Warning Signals, prescribed by the International Convention for the Safety of life at Sea (SOLAS) 1974, is in use in some countries, and members of the Convention establishing new systems are recommended to adopt it.

In the International System, day signals each consist of a shape or rectangular flag, of any colour, or 2 shapes or flags disposed vertically; night signals consist of lights disposed vertically.



International system of visual strom warning signals

National or local signals may be used in conjunction with these signals, provided they do not resemble the International ones.

More than one day signal may be displayed simultaneously. For example: a gale expected to commence from the SW quadrant and veering is indicated by a cone, pointing down, and a single flag, the initial direction being indicated by the cone.

A near gale expected from the SW quadrant is indicated by a ball and a cone point down. The signal "Near gale expected" may be used to indicated that a strong breeze is expected if local circumstances, such as fishing activities, call for warning of winds less strong than a near gale.

Weather routeing of ships

- ✓ Routeing

The mariner planning a transoceanic passage can select either the shortest route, or the quickest route at a given speed, or the most suitable route from the point of view of weather or any other particular requirements.

The shortest distance from the point of departure to destination, providing no obstructions lie on the track, is the great circle between the two positions. For selected ports and positions throughout the world, distance based on great circle routes are given in admiralty distance tables.

Climatic conditions, however, such as the existence of currents or the prevalence of wind, sea or swell from certain directions, may lead to the selection of a longer "climatological route" along which a higher speed can be expected that the great circle route across the N Atlantic Ocean represents the fastest route only 13 % of the time for E-bound ships and 2 % of the time for W-bound ones. Climatological routes are shown on routeing charts and are considered in Ocean Passages for the World.

- ✓ Weather routeing

The development of weather routeing has followed advanced in the collection of oceanographical and meterological data, improved forescasting techniques and international co-operation, the introduction of orbital weather satellites, and better communications including the use of facsimile recorders to display on board the least weather map, ice charts and other forecasts.

Weather routeing makes use of the actual weather (as opposed to the expected climatic conditions), and the forecast weather to select a route, and the modifying the route as necessary as the voyage proceeds, consideration can be given not only to the quickest route, known as the "optimum route", but also to the "strategic route" which will minimize storm damage to the ship and her cargo, or suit any other particular requirements. Weather routeing is at present extensively used for passages across the N and S Atlantic and Pacific Oceans.

If a ship is on a regular run fitted with a facsimile recorded, and carrier a weather forecaster with a sound knowledge of routeing methods, weather routeing can often be satisfactorily carried out on board.

Alternatively, if details of the ship are given, use can be made of one of the weather routeing services provided by certain governments or consultancy firms. The Meteorological Office, Exeter, provides a routeing service for ships world-wide; a team of highly trained and experienced forecasters and Ship Masters have extensive facilities to hand for close study of a ship's individual requirements and problems. Further details and the procedure for requesting this Ship Routeing Service and similar weather routeing service provided by certain governments or consultancy firms. The Meteorological office, Exeter, provides a routeing service for ships world-wide; a team of highly trained and experienced forecasters and ship Masters have extensive facilities to hand for close study of a ship's individual requirements and problems. Further details and the procedures for requesting this ship Routeing Service and similar weather routeing services are given in Admiralty List of Signal Volume 3.

1.8.3. **OCEAN CURRENT SYSTEM**

Ocean Currents

The movement of ocean water is one of the two principal sources of discrepancy between dead reckoned and actual positions of vessels.

Modern shipping speeds have lessened the impact of currents on a typical voyage, and since electronic navigation allows continuous adjustment of course, there is less need to estimate current set and drift before setting the course to be steered. Nevertheless, knowledge of ocean currents can be used in cruise planning to reduce transit times, and current models are an integral part of ship routing systems.

Causes of Ocean Currents

The primary generating forces are wind and differences in water density caused by variations in heat and salinity Currents generated by these forces are modified by such factors as depth of water, underwater topography including shape of the basin in which the current is running, extent and location of land, and deflection by the rotation of the Earth.

Current flow at all depth in the oceans, but in general the stronger currents occur in an upper layer which is shallow in comparison with the general depths of the oceans. Ocean current circulation takes place in three dimensions. A current at any depth in the ocean may have a vertical component, as well as horizontal ones; a surface current can only have horizontal ones; a surface current can only have horizontal components. The navigator is primarily interested in the surface currents.

The general surface current circulation of the world is shown on the World Climatic charts in Ocean Passages for the World and in the various of Admiralty Sailing Directions.

The main cause of surface currents in the open ocean is the direct action of the wind on the sea surface and a close correlation accordingly exists between their directions and those of the prevailing winds. Winds of high constancy blowing over extensive areas of ocean will naturally have a greater effect in producing a current than will variable or local winds. Thus the North-east and south-east trade winds of the two hemispheres are the main spring of the mid-latitude surface current circulation.

In the Atlantic and Pacific Oceans the two Trade Winds drive an immense body of water W over a width of some 50º of latitude, broken only by the narrow belt of the E-going

Equatorial Counter- current, which is found a few degrees N of the equator in both these oceans. A similar transport of water to the W occurs in the South Indian Ocean driven by the action of the South-east Trade wind.

The trade Winds in both hemispheres are balanced in the higher latitudes by wide belts of variable W winds. These produce corresponding belts of predominantly E-going sets in the temperature latitudes of each hemisphere.

With these E-going and W-going sets constituting the N and S limbs, there thus arise great continuous circulations of water in each of the major oceans. These cells are centred in about 30ºN and S, and extend from about the 10^{th} to at least the 50^{th} parallel in both hemispheres. The direction of the current circulation is clockwise in the N hemisphere and counter-clockwise in the S hemisphere.

There are also regions of current circulation outside the main gyres, due to various causes, but associated with them or depent upon them. As an example, part of the North Atlantix Current branches from the main system and flows N of Scotland and N along the coast of Norway. Branching again, part flows past Svalbard into the Artic Ocean and part enters the Barents Sea.

In the main monsoon regions, the N part of the Indian Ocean, the China Seas and eastern archipelago, the current reverses seasonally, flowing in accordance with the monsoon blowing at the time. The south Atlantic, South Indian and South Pacific Oceans are all open to the Southern Ocean, and the Southern Ocean Current, supplements the S part of the main circulation of each of these three oceans.

Summary – ocean current

The causes which produce currents are thus seen to be very complex, and in general more than one cause is at work in giving rise to any part of the surface current circulation. Observations of current are still not so numerous that their distribution in all parts of the ocean can be accurately defined. Still less is known of the subsurface circulation, since the oceans are vast and the work of research expeditions is very limited in time and place. The winds act upon the upper layer of water and it is known that the greatest changes in the temperature and salinity and hence the greatest pressure gradients are present in the same layer. In middle latitudes it extends from the surface to depth varying from 500 to 1000 m.

The greatest current generating forces act on this layer and therefore the strongest current are confined to it. Below it the circulation at all depths, in the open ocean, is caused by density differences, and is relatively weak. The great coastal surface currents on the W sides of the oceans flow also in the deeper layers and perhaps nearly reach the bottom.

The main surface circulation of an ocean, though it forms a closed eddy, is not self-compensating. Examination of current charts makes it obvious that the same volume of water is not being transported in all parts of the eddy. There are strong and weak parts in all such circulations. Also there is some interchange between different oceans at the surface. Thus a large part of the South Equatorial Current of the Atlantic passes into the

North Atlantic Ocean to join the North Equatorial Current, and so contributes to the flow of the Gulf Stream. There is no adequate compensation for this if surface currents only are considered. There must, therefore, be interchange between surface and surfaced water. The process of upwelling has been described; in other regions, notably in high latitude, water sinks from the surface to the bottom. Deep currents, including those along the bottom of the oceans, also play their past in the process of compensation. Thus water sinking in certain places in high latitudes in the North Atlantic flows S along bottom, and subsequently enters the South Atlantic.

Much though not necessarily all, of the day to day variability if surface current is due to wind variation. Seasonal variation of current is also largely due to seasonal wind charges. Abnormal weather patterns will produce abnormal current, and it is probable that the average current will vary somewhat from year to year.

- Waves

Almost all waves at sea are caused by wind, though some may be caused by other forces of nature such as volcanic explosions, earthquakes or even icebergs calving

All ships and boats generate a pattern of waves when they move, and the characteristics of these waves alter significantly with changes in speed, hull shape and water depth.

Recent work has seen the development of an empirical tool that can accurately predict the characteristics of the waves generated by any vessel and a method to assess their potential impact on any specific waterway. This is important during design and planning stages to ensure a vessels waves will not be damaging to the surrounding environment and maritime structures, or dangerous to other users of the waterway.

Almost all waves at sea are caused by wind, though some may be caused by other forces of nature such as volcanic explosions, earthquakes or even icebergs calving. The area where waves are formed by wind is known as the generating area, and Sea is the name given to the waves formed in it.

The height of the sea waves depends on how long the wind has been blowing, the fetch, the currents and the wind strength. The Beaufort Wind Scale gives a guide to probable wave heights in the open sea, remote form land, when the wind has been blowing for some time. The effect of sea and swell on ships, and the planning of passages to put sea and swell on ships, and the planning of passages to put sea and swell conditions to best advantage are discussed in Ocean Passages for the World.

Sea states are describe as follow:

Code		Height in metres*
0	Calm-glassy	0
1	Calm-rippled	0–0·1
2	Smooth wavelets	0·1–0·5
3	Slight	0·5–1·25
4	Moderate	1·25–2·5
5	Rough	2·5–4
6	Very rough	4–6
7	High	6–9
8	Very high	9–14
9	Phenomenal	Over 14

*The average wave height as obtained from the large well-formed waves of the wave system being observed.

Swell

Swell is the wave motion caused by a meteorological disturbance, which persists after the disturbance has died down or moved away.

Swell often travels for considerable distances out of its generating area, maintaining a constant direction as long as it keeps in deep water. As the swell travels away from its generating area, its height decrease though its length and speed remain constant, giving rise to the long low regular undulation so characteristics of swell.

The measurement of swell is no easy task. Two or even three swells from different generating areas, are often present and these may be partially obscures by the sea wave also present. Some climatic atlases give world-wide monthly distribution of swell, but for the reasons given above and the small number of observations in some oceans they should be used with caution.

Swell waves are described as follows:

Type	Metres
Length	
Short	0–100
Average	100–200
Long	over 200
Height	
Low	0–2
Moderate	2–4
Heavy	over 4

1.8.4. CALCULATION OF TIDAL CONDITIONS

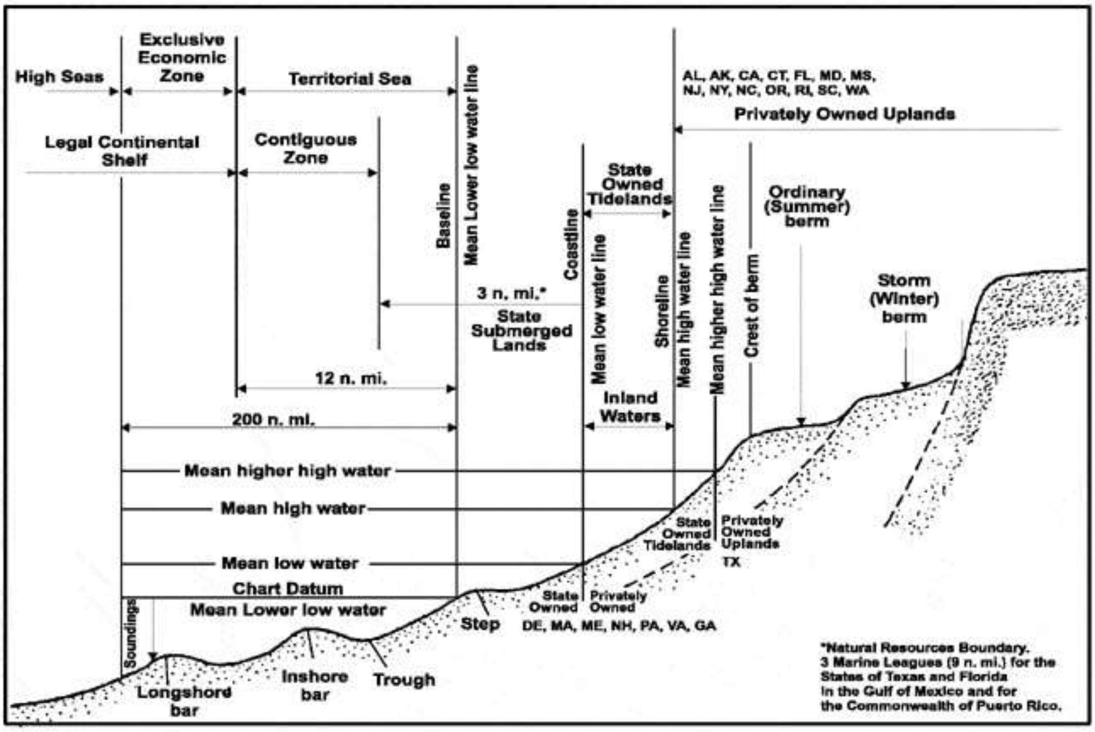
Tidal flows are important for navigation, and significant errors in position occur if they are not accommodated. Tidal heights are also important; for example many rivers and harbours have a shallow "bar" at the entrance which prevents boats with significant draft from entering at low tide.

Until the advent of automated navigation, competence in calculating tidal effects was important to naval officers. The certificate of examination for lieutenants in the Royal Navy once declared that the prospective officer was able to "shift his tides".

Tidal flow timings and velocities appear in tide charts or a tidal stream atlas. Tide charts come in sets. Each chart covers a single hour between one high water and another (they ignore the leftover 24 minutes) and show the average tidal flow for that hour. An arrow on the tidal chart indicates the direction and the average flow speed (usually in knots) for spring and neap tides. If a tide chart is not available, most nautical charts have "tidal diamonds" which relate specific points on the chart to a table giving tidal flow direction and speed.

The standard procedure to counteract tidal effects on navigation is to (1) calculate a "dead reckoning" position (or DR) from travel distance and direction, (2) mark the chart (with a vertical cross like a plus sign) and (3) draw a line from the DR in the tide's direction. The distance the tide moves the boat along this line is computed by the tidal speed, and this gives an "estimated position" or EP (traditionally marked with a dot in a triangle).

DATUMS



Nautical charts display the water's "charted depth" at specific locations with "soundings" and the use of bathymetric contour lines to depict the submerged surface's shape. These depths are relative to a "chart datum", which is typically the water level at the lowest possible astronomical tide (although other datums are commonly used, especially historically, and tides may be lower or higher for meteorological reasons) and are therefore the minimum possible water depth during the tidal cycle. "Drying heights" may also be shown on the chart, which are the heights of the exposed seabed at the lowest astronomical tide.

Tide tables list each day's high and low water heights and times. To calculate the actual water depth, add the charted depth to the published tide height. Depth for other times can be derived from tidal curves published for major ports. The rule of twelfths can suffice if an accurate curve is not available. This approximation presumes that the increase in depth in the six hours between low and high water is: first hour — 1/12, second — 2/12, third — 3/12, fourth — 3/12, fifth — 2/12, sixth — 1/12.

1.9. RESPOND TO NAVIGATION EMERGENCIES

1.9.1. PRECAUTIONS WHEN BEACHING A SHIP

One kind of emergency situation which can really test skills and ability of a ship’s captain is -Beaching of the ship.

What is Beaching of the ship?

Beaching is a process wherein during an emergency situation a ship is intentionally taken towards shallow waters and at last grounded.

The word Beaching is used for such process because the type of emergency grounding is done only in those areas where the ground is of soft mud or sand (as in a Beach) in order to avoid damage to ship's hull, propeller, rudder etc.

Why Beaching is done?

The three main reasons for which Beaching of ship is done are:

- To prevent loss of ship due to flooding when there is major damage below the water line of the ship
- To refloat the ship when satisfactory repair has been done and water tight integrity is restored
- In order to hand it over to the scrap yard

Procedure to Perform Beaching of Ship:

- Ballast the ship to its maximum capacity
- Check where the damage is more-bow side or stern side. Head with the damage side for beaching with 90 o to the tides
- Take all measure to avoid ship going parallel to the beach (throw weather anchor first)
- If approaching from astern due to stern damage, drop both the anchor at good distance so that they can assist the vessel in heaving when going water
- Sounding of all tanks must be done before and after beaching

1.9.2. ACTION TO BE TAKEN IF GROUNDING IS IMMINENT AND AFTER GROUNDING

Stranding or Grounding

Stranding is the accidental grounding of a vessel on a beach or shoreline while grounding is the accidental contact with the sea bed other than the shoreline.

Actions to take (accidental stranding or grounding):

- sound the alarm to muster the crew/passengers (7 short, 1 long)
- account for all personnel and check for injuries
- stop engines and auxiliaries if grounding is severe
- sound bilges and inspect void areas
- take bearings and plot your position - then attempt to determine reason for grounding from the charts
- survey the area around the grounding (from chart)
- determine the tide and tidal stream
- check weather predictions for the area
- sound around the vessel to determine the extent of the grounding
- check for hull damage (if severe damage has occurred, it may be best to stay grounded)

With a partial grounding:

- move passengers and crew to lighten the grounded section of the vessel, jettison any weights possible
- use astern power sparingly, pay attention to the pumping of mud/sand under the keel due to excess astern propulsion. if rocky - astern propulsion can damage the hull lay out anchors to assist in refloating or preventing vessel going further aground
- request assistance (if necessary). consider a tow
- display appropriate signal `vessel aground'.

When refloating, use anchors to kedge, if the engine's propulsion is insufficient to refloat. Move weights as necessary, have lifesaving appliances ready in case of sudden need. Commence refloating just prior to high tide. If the bottom is sand or mud a vacuum may be created between the hull and the sea-bed. To break this suction it may be necessary to "waggle the vessel's tail" by use of the weights or pulling on alternate anchors.

Once clear of the obstruction it will be necessary to again check the vessel for any damage or ingress of water. Also check propulsion and steerage systems and engine cooling systems.

Note events in vessel’s log or record book and report incident to the authorities.

If grounded on a reef at an uncertain location it may be prudent to stay grounded and adding ballast to prevent further damage to the hull due to movement of the vessel on the grounding.

1.9.3. REFLOATING A GROUNDED SHIP WITH AND WITHOUT ASSISTANCE

There are several different methods for refloating stranded ships and these imply the following actions:

- Moving the ship to water deep enough to float it at the draft corresponding to its weight.
- Deepening the water around the casualty.
- Reducing the required draft at the grounded portion by removing weight, lifting, or altering trim.

In practice, there is always a combination of these actions that is normally used. In most cases, the stranded ship is lightened until the required freeing force is less than the available tractive forces, and then pulled into deeper water. It is often necessary to remove many tons of cargo, stores, or floodwater.

Moving the Casualty

In order to move a casualty it must be taken into consideration that the force required to move that particular stranded ship over its strand is the sum of the forces required to:

- Overcome friction between the ship and seafloor.
- Move loose seafloor material that may be pushed ahead of the ship.
- Break or crush obstructions or impalements, such as rock outcroppings, coral heads, etc.
- Overcome suction on soft bottoms.

Friction is a function of ground reaction as modified by other factors, such as the coefficient of friction of the bottom, the area of the hull in contact with the bottom, and the casualty’s list and trim. Freeing force is reduced by decreasing the effects of these factors, as well as by decreasing ground reaction.

Reducing Water Depth

The reasons for trying to increase the water depth under and around a casualty are:

- To obtain sufficient water depth to refloat the vessel.
- To reduce ground reaction by increasing buoyancy.
- To free one end of a vessel to allow it to be pivoted by other methods.

Water depth inside small coves or estuaries can be increased by closing the entrance with sheet-steel piles or cofferdams. In some navigable rivers and canals, water level can be controlled to some extent by lock gates and dams – it may be possible to raise water level by increasing flow past upstream dams. On very soft soils, it may be possible to increase the ship's weight, by flooding or other means, so that she settles more deeply into the seafloor. After she has settled, the excess weight can be removed to allow her to float free. More commonly, water depth around a casualty is increased by removing ground from under it. Ground removal is accomplished by scouring or dredging soft bottoms, or by blasting hard bottoms.

Temporary Reduction

Dynamic friction is almost always less than the static friction between two objects. If freeing force can be reduced long enough for the pulling system to start the ship moving, it can usually be kept moving. Swells increase the buoyancy of the stranded ship and decrease the ground reaction as they pass. High seas or heavy swells running during a retraction decrease the pulling force required to refloat the ship. If the pulling force is enough to start the ship moving at the top of a swell when ground reaction is lowest, the coefficient of friction is lowered instantly to the dynamic level. The dynamic coefficient of friction may be low enough that freeing force stays less than pulling force after ground reaction increases again, and the ship keeps moving. When there are no natural swells, ships passing parallel to the beach at high speed create swells that act like the natural swell.

Destroyers running a long racetrack pattern as close to the refloating operation as safety permits are ideal for this purpose. Jacking reduces freeing force by changing the nature of the ground reaction, rather than reducing it.

By taking up part of the ship's weight on the jacks, the amount of weight bearing on the high friction interface between the ship's bottom and seabed is decreased. The jacks are rigged on long spuds that can pivot at their bases, allowing the casualty to be moved when the friction force is sufficiently reduced. Jacks are placed symmetrically about the estimated position of the centre of ground reaction and are secured with a retrieving line led to the deck. The jacks are raised to their maximum lift at the beginning of a pull. When the ship moves, the jacks will topple and must be reset for the next operation.

Once the stranded ship is moving, it is often possible to keep it moving against the lower dynamic coefficient of friction, even if the ground reaction increases when the jacks trip. If not, the casualty is refloated by moving it seaward in a series of short steps. For jacking to be successful, the seafloor must be hard enough, or must be reinforced, to support the jacking forces. On rock seafloors, concrete rubble-filled beds or heavy timbers topped by steel plate are adequate foundations.

On sediment seafloors, plate or timber mats are used to spread the load until the unit pressure is less than the bearing capacity of the soil. Crushed coral, stone, shell, or gravel can be laid in to increase soil bearing strength.

Similarly, the hull of the ship must be protected from the jacking forces. If these forces are not spread out along the hull, they will cause local damage at the point of application and may even rupture the hull. Steel welding or heavy steel angles welded to the hull and padded with timbers are suitable jacking pads. The load is transmitted to the ship structure by shear stress in the welds and side plating.

Explosives

Explosive measures to reduce freeing force include:

- Judicious use of small charges to deepen the water around the casualty and cut channels through hard bottoms (explosive dredging).
- Explosively cutting or pulverizing coral or rock outcroppings that are impaling the casualty or blocking its retraction.
- Using small charges along the length of the casualty to cause vibration and fluid behaviour in the seafloor under the casualty.
- Detonating moderate charges several hundred feet from the casualty to generate artificial swells to momentarily increase buoyancy.

Use of explosives requires skill and experience to avoid damaging the casualty.

1.9.4. ACTION TO BE TAKEN IF COLLISION IS IMMINENT AND FOLLOWING A COLLISION OR IMPAIRMENT OF THE WATERTIGHT INTEGRITY OF THE HULL BY ANY CAUSE

Collision

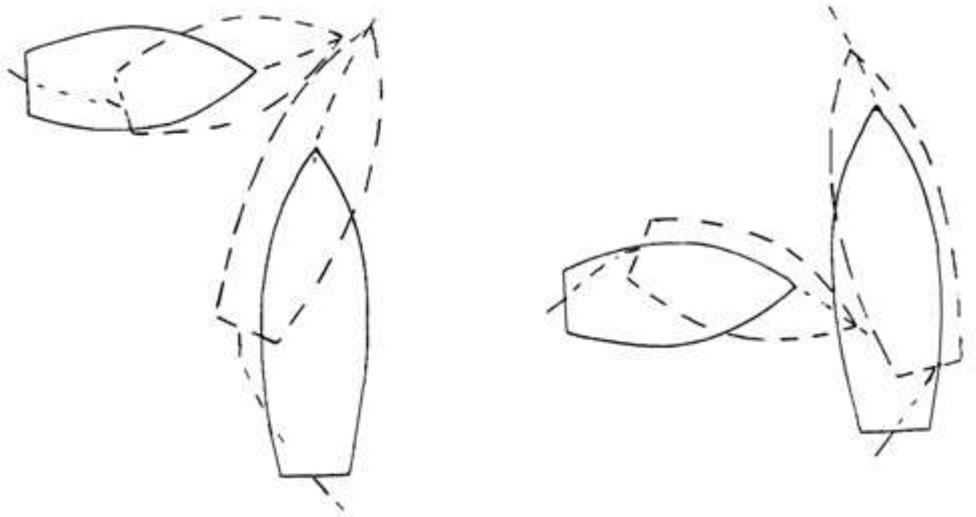
Collisions must be avoided - as rule 16 of the International Collision Regulations states - every vessel, which is directed to keep out of the way of another vessel, must take early and substantial action to stay clear.

Collision Imminent

Whatever action you take, it should be to prevent contact, however if collision is unavoidable you should reduce damage to ‘sensitive’ areas of both vessels.

Reduction of damage can be achieved by:

- Taking speed off the vessel (full astern, etc).
- Attempting to avoid by turning the vessel (a glancing blow rather than a direct contact). A bow to bow situation or bow to quarter situation will be far less damaging that the bow cutting directly into the other vessel's hull, particularly near the engine room compartment.



Actions to take after collision

- sound emergency muster alarm – (7 short, 1 long)
- stop the vessel
- transmit distress or urgency signal on the radio (if necessary)
- evacuate passengers and crew to emergency stations
- ensure all people are accounted for and check for injuries
- ensure the safety of the vessel and all on-board - Master's responsibility
- determine the extent of damage
- sound tank/s
- inspect bilges or sound if enclosed
- observe for any oil, or fuel spills in the water around the vessel.

If damage has occurred take damage control measures:

- prepare lifesaving equipment
- prepare to abandon (if situation deteriorates).

With situation controlled:

- contact the other vessel and give whatever assistance is necessary (without endangering your vessel) to ensure the safety of life of the people from both vessels

- produce documents and exchange particulars adequate to identify the vessel and details of ownership

- stay by the other vessel until no further help is needed

- notify the authorities at the earliest opportunity but within 48 hours of the incident occurring (Check your State/Territory's' Legislation as to the exact length of time for reporting and who to report to)

- log details of event in the vessel log book or record book as soon as possible after the event

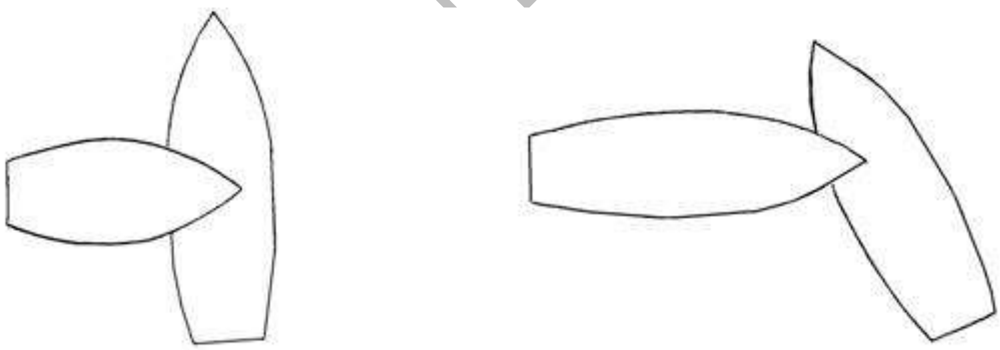
- attend to any injured person

- undertake an on-board inquiry and detail information

- if required show the appropriate signals undertake repairs

If assistance from other vessels is non-existent and the vessel looks like foundering with a coastline nearby, consider 'beaching' the vessel.

REMEMBER:- if the collision between the two vessels has resulted in the vessel piercing the other and becoming wedged, the striking vessel should refrain from going astern immediately, as this may result in one or both vessels' sinking. If abandonment of either vessel is essential, transferring to the stable vessel, while wedged, may be easier than by doing so via water.



1.9.5. ASSESSMENT OF DAMAGE CONTROL

Develop plans for damage control following a shipboard emergency

- Possible damage scenarios are identified and methods of damage control are devised by the vessel's management team as per standard operating procedures.
- Plans of action for dealing with shipboard damage, particularly that involving the integrity of the vessel's hull, are developed by the vessel's management team in accordance with regulatory requirements and company procedures.
- Planned damage control procedures for dealing with damage to the vessel and its hull are documented as per company and regulatory requirements.

- Appropriate resources are organised in readiness for possible deployment should there be damage to the vessel during an emergency.

1.9.6. EMERGENCY STEERING

Emergency Steering Gear On ships equipped with electromechanical steering gear, the old-fashioned, hand-operated steering wheel is about the only recourse if the primary mechanism fails. On some small ships, a yoke can be fitted over the rudder head, and the rudder can be turned with a block and tackle. Electrohydraulic steering gear usually is provided with a standby pumping unit for emergency use. It is composed of a pump and an electric motor. If the steering engine being employed has a casualty, the six-way pump transfer cock is adjusted to align the ram with the stand by pumping unit; the power is turned on in the standby unit; and steering is transferred over to the standby unit. Emergency steering for destroyers also uses the trick wheel. If a steering signal failure occurs between the steering wheel on the bridge and the receiving unit, the helmsman standing watch in after steering operates the trick wheel and receives steering orders on the sound-powered telephone. Should a power failure occur in steering aft, the rudder is moved by disengaging the running electric motor, and hand-pumping oil to the ram by means of a hand crank. This procedure is very slow. The rudder turns only a small amount for every revolution of the crank.

Procedure for Starting Emergency Steering System

An emergency steering system, as the name suggests, is a system which is used during the failure of the main steering system of the ship.

Procedure for Emergency steering Operation

The following points should be followed for emergency steering operation.

- The procedure and diagram for operating emergency steering should be displayed in steering gear room and bridge.
- Even in emergency situation we cannot turn the massive rudder by hand or any other means, and that’s why a hydraulic motor is given a supply from the emergency generator directly through emergency switch board (SOLAS regulation). It should also be displayed in the steering room.
- Ensure a clear communication for emergency operation via VHF or ships telephone system.
- Normally a switch is given in the power supply panel of steering gear for tele motor; switch off the supply from the panel.
- Change the mode of operation by selecting the switch for the motor which is supplied emergency power.
- There is a safety pin at the manual operation helms wheel so that during normal operation the manual operation always remains in cut-off mode. Remove that pin.

- A helms wheel is provided which controls the flow of oil to the rams with a rudder angle indicator. Wheel can be turned clockwise or anti clockwise for going port or starboard or vice versa.
- If there is a power failure, through sound power telephone receive orders from the bridge for the rudder angle. As soon as you get the orders, turn the wheel and check the rudder angle indicator.

A routine check should always be done for proper working of manual emergency system and steering gear system. An emergency steering drill should be carried out every month (prescribed duration – 3 months) in the steering gear room with proper communication with bridge to train all the ship's staff for proper operation of the system so that in emergency situation ships control can be regained as soon as possible, avoiding collision or grounding.

1.9.7. EMERGENCY TOWING ARRANGEMENT AND TOWING PROCEDURES

Emergency towing procedure

According to the provisions of Annex to IMO Res. MSC.256(84) passenger and cargo ships above 500 GT shall be provided with a ship-specific Emergency towing procedure. The procedure is to be followed aboard the ship in emergency situations. The procedure shall be based on existing arrangements and equipment onboard the ship.

This requirement is applicable to the following categories of ships:

1. all passenger ships - the due time of implementation of the requirement is not later than 1 January 2010;
2. cargo ships constructed before 1 January 2010 - the due time of implementation of the requirement is not later than 1 January 2012;
3. cargo ships constructed on 1 January 2010 or after that date.

The requirement also applies to tankers of 20,000 deadweight and above, for which the obligation of having Emergency Towing Arrangements has not been combined with the obligation of having Emergency towing procedure.

Emergency towing procedure shall be elaborated individually for each ship, taking into account the guidance in IMO - MSC.1/Circ.1255. The procedure shall include:

1. drawings of fore and aft deck showing possible emergency towing arrangements;
2. inventory of equipment on board that can be used for emergency towing with information on its safe working load (SWL);
3. means and methods of communication;
4. sample procedures to facilitate the preparation for and conducting of emergency towing operations.

Detailed information on the preparation and content of Procedure is included in IMO - MSC.1/Circ.1255.

The implementation of requirement of having Emergency towing procedure onboard:

1. new ships with keel laid on 1 January 2010 or after that date and ships still not delivered, but with keel laying before 1 January 2010:,br> Emergency towing procedures shall be submitted to PRS Head Office for verification.

As a result of positive verification the procedure will be ‘noted’ by PRS.

The strength of equipment and its supporting hull structure is subject to approval by PRS Head Office during the analysis of mooring and towing equipment documentation.

2. existing ships:

Emergency towing procedure shall be produced by the Owner or their consultant. The ability of the ship to be towed from bow or stern shall be assessed by a person knowledgeable in towing equipment and operations.

Unless the safe working load is given in the original shipyard documentation, it shall be determined by strength calculations or load tests. In this case the guidelines in IMO – MSC/Circ.1175 may be followed. When determining the value of SWL, the strength of the under deck construction supporting a given part of the equipment shall be taken into account.

PRS surveyor only states the execution of the Recommendation, after he/she has verified the Emergency towing procedure favourably. The verified procedure is neither approved nor noted by PRS afterwards.

1.10. MANOEUVRE AND HANDLE A SHIP IN ALL CONDITIONS

The STCW Convention requires trainees to be able to demonstrate practical competence in performing the manoeuvres stated under this competence in addition to any examination of their knowledge and understanding of principles. This practical competence may be developed and demonstrated in service, in which case the practical elements of actual ship handling may not be included in the training course.

Administrations and training centres need to evaluate whether is likely that their trainees will get sufficient opportunity to develop their practical ability and to demonstrate competence on board ships in service.

Where this is unlikely, the use of appropriate simulators, manned ship models or training ships will be required. The content below assumes that practical demonstrations will be part of the training course. Under each manoeuvre, trainees should undertake a number of practical exercises ranging from relatively simple to more complex.

1.10.1 MANOEUVERING AND HANDLING A SHIP IN ALL CONDITIONS

Manoeuvering and handling of a ship in all conditions, including:

(a) Maneuvers when approaching pilot vessels or stations with due regard to weather, tide, headreach and stopping distances;

(b) Handling a ship in rivers, estuaries, etc., having regard to the effects of current, wind and restricted water on the response to the helm;

(c) Maneuvering in shallow water, including the reduction in keel clearance due to the effect of squat*, rolling and pitching;

(d) Interaction between passing ships and between own ship and nearby banks (canal effect);

(e) Berthing and unberthing under various conditions of wind and tide with and without tugs;

(f) Choice of anchorage; anchoring with one or two anchors in limited anchorages and factors involved in determining the length of anchor cable to be used;

(g) Management and handling of ships in heavy weather, including assisting a ship or aircraft in distress, towing operations, means of keeping an unmanageable ship out of a sea trough, lessening drift and use of oil;

(h) Precautions in maneuvering for launching boats or life rafts in bad weather.

Approaching pilot stations and embarking or disembarking pilots, with due regard to weather, tide, head reach and stopping distances

Embarking and Disembarking

The maritime pilot organization should establish and maintain embarking and disembarking procedures for al transport services used in support of the pilotage services.

These procedures should include but not be restricted to:

- Technical and safety operational data particular to the transport service provider
- Communication requirements between the transport service provider and the vessel to be piloted

Any maritime pilot transfer arrangement, together with any suspension arrangements or attachments fitted and intended for the use of the embarking and/or disembarking of the maritime pilot, should be in compliance with local, national and international requirements.

The embarking and disembarking procedures for pilot vessels should include but not be restricted to:

- Pilot vessel technical operational restrictions, such as:
- Maximum wave and swell height - Visibility data
- Maneuvering data
- Weather restrictions
- Pilot vessel safety operational restrictions

The maritime pilot organization should establish clear instructions regarding maritime pilot transfer arrangements. These instructions should be communicated to the vessel and the vessel representative as part of the communication procedures outlined in paragraph

These instructions should include but not be restricted to the following information:

- Pilot ladder positon, side of vessel and specially required securing arrangements, if necessary
- Pilot ladder construction
- Ropes and heaving lines
- Accommodation ladder positon and side of the vessel
- Mechanical pilot hoist positon and side of the vessel
- Other equipment if necessary, in addition to IMO/SOLAS requirements

The embarking and disembarking procedures for helicopter transfers should include but not be restricted to:

- Helicopter technical operational requirements, such as:
- Operating conditions
- Weather restrictions
- Manoeuvring data
- Performance requirement

- Helicopter safety operational requirements:
- Safety briefings prior to commencing operations
- Survival training - aircrew and maritime pilots
- Emergency equipment - fire fighting and personal survival
- Required attire

- Shipboard operating requirements:
- Operating area - landing, winching and/or other areas
- Shipboard crew

- Operating instructions for maritime pilots, including:
- Embarking and disembarking
- Winching = lowering and hoisting

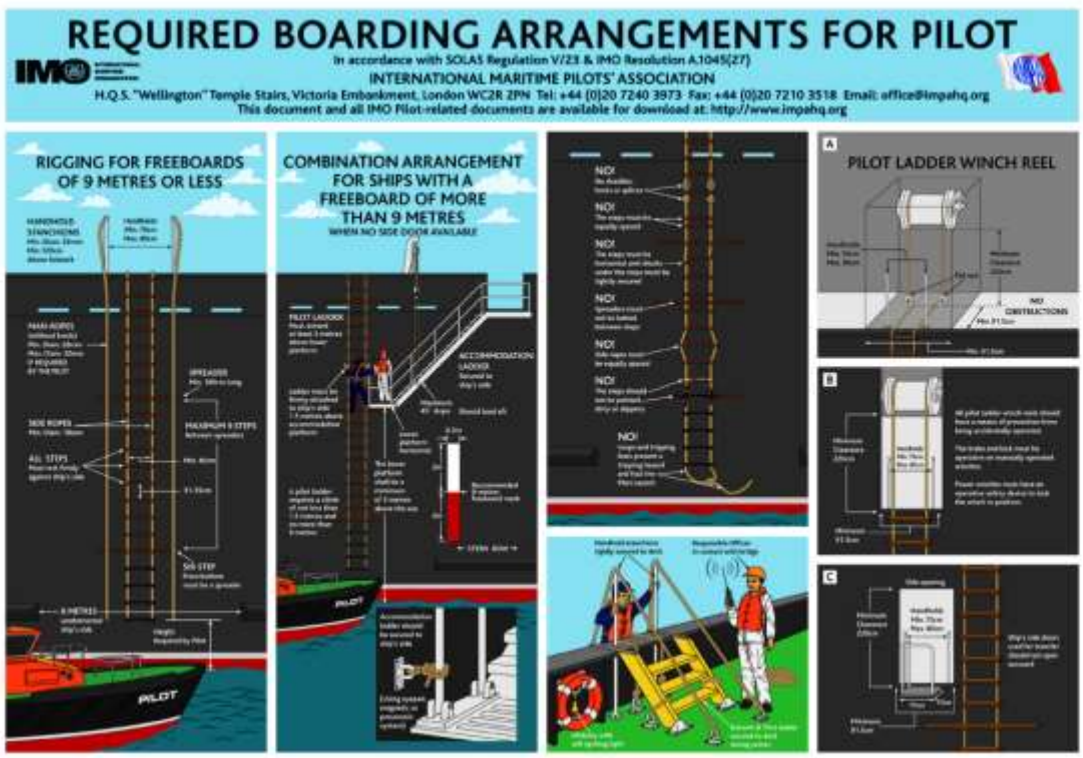
- Communication between the vessel and the helicopter
- Communication between the helicopter and the maritime pilot, including:
- Initial before approach (prior airborne)
- In flight

- After landing - rotors running turnaround
- After landing - shutting down
- Winching operations

The procedures for communication between the vessel and the helicopter aircrew should clearly define the responsibility and authority of the aircrew in relation to the vessel crew.

The master of the vessel is responsible for the overall safety of the ship. The safety of the helicopter and the aircrew remains at all times the responsibility of the helicopter pilot. In order to carry out their respective responsibilities the helicopter pilot and the master must agree on the proposed operation.

Clearance for any helicopter operations and permission for the helicopter to land on board are given entirely at the discretion of the master of the vessel. If the master of the vessel is in any doubt whether the helicopter operations may jeopardize ship safety, he/she may stop the operation at any time.



1.11. GENERAL KNOWLEDGE OF REMOTE CONTROLS OF PROPULSION PLANT AND ENGINEERING SYSTEMS AND SERVICES

1.11.1. OPERATING PRINCIPLES OF MARINE POWER PLANTS

Marine power plants

Diesel Engine Theory and Structure

- **Engine Types**

The choice of a main propulsion engine for a motorship is by no means an easy one. A few years ago a shipowner had the straight choice of a direct coupled slow-speed engine driving a fixed pitch propeller or a geared four-stroke medium-speed engine driving either a fixed or controllable pitch propeller. Today, vessels are entering service with geared and direct coupled two-stroke engines driving either fixed or controllable pitch propellers and geared four-strokes; while for certain ships, particularly those involved with offshore oil exploration and production, diesel-electric power plants are becoming increasingly popular. The choice of either direct or indirect drive of a ship is governed more by the operating profile of the ship and economic factors concerning the power plant as a whole, rather than the characteristics of a particular make or type of diesel main propulsion engine.

Marine engines are required to operate continuously, reliably and safety in unmanned engine rooms and with extended periods between planned overhauls. They may be expected to operate for considerable periods at low power without ill effects, and to be tolerant of low quality fuels while maintaining very high thermal efficiency.

Continuing development and improvement in design are necessary to meet these demands and new generations of engine models are produced to take advantage of advances in research and experience. Considerable improvements in design and performance of turbo-chargers and charge air systems in recent years have contributed substantially to increases in engine power and economy. The supply of charge air at reduced power is sufficient to maintain efficient combustion, and at full power surplus exhaust gas energy can be diverted to operate ‘power take off’ systems which will supplement the main electrical power output.

Changes in world trade may lead to the emergence of different ship types with special demands upon their power systems. Manufacturers produce a range of cylinder sizes and numbers in each model so that a wide selection of power or other parameters is available. Further sizes are developed when a particular demand becomes evident.

Practically all new merchant ships are powered by diesel engines, and some existing large steamships have been re-engined with diesel power to improve their economy and extend their useful life.

Basically, marine diesel engines can be divided into two main types: large, slowrunning direct drive engines with limited numbers of cylinders, or medium to high speed engines driving through reduction gears. Cylinder sizes do not necessarily distinguish between; slow-speed engines are available with cylinder bores down to 260 mm, while medium speed engines are produced with bores up to 620 mm.

Although there are distinct differences between both types, much of the subject matter in this unit is relevant to all engines. Where necessary their characteristics are dealt with separately.

- **Slow Speed Engines**

This category refers to engines operating at between 55 to 150 rpm. Large, slowspeed, direct drive main engines operate exclusively on the two-stroke cycles and are

3 of 58 of crosshead construction which allows complete isolation between the cylinders and crankcase. They are best able to tolerate low-quality fuels and burn these successfully to obtain the highest thermal efficiencies. Slow piston speed and fewer working parts make them very economical in lubricating oil, and give low rates of wear and remarkable reliability. Although there are now few manufacturers producing these engines, they dominate the market particularly in ocean-going ships.

A variety of size and numbers of cylinders are available, to suit all power requirements.

In addition, to the standard models they are produced in long-stroke versions with stroke/bore ratio up to 3.8:1 and at speeds down to 55 rpm, allowing the use of large, slow propellers for high efficiency in vessels such as bulk carriers and large tankers.

Slightly shorter stroke engines operating in the speed range of 100 rpm are designed for high speed container ships. Short-stroke models cater for ships with limited draft, propeller size or engine room height. Many of the basic engine components are common to all vendors.

- **Medium and High Speed Engines**

Most of these are designed to operate on the four-stroke cycle and are of trunk piston construction. They are much lighter and smaller than equivalent slow-speed engines, but require gearing or some other means to reduce the drive speed for ship's propellers. Medium speed generally means between 400 and 1,000 rpm.

Smaller engines are robust and can be highly rated. Their power/weight and power/size ratios make them particularly attractive where engine room size is limited.

They also require less strength built into the ship's supporting structure. Long-stroke versions are produced to give greater fuel economy on heavy fuels.

Medium speed engines are widely used in ferry type vessels and those of limited size.

Rapid progress has brought many different models into to production and a wide choice exists in size, speed and power. They are well adapted for re-engining existing ships, fitting well into existing engine space and giving ample power with increased economy. Flexible couplings and torsional vibration dampers are fitted at the couplings. Flexible coupling and torsional vibration dampers are fitted at couplings between engines and gearbox drives.

Plant systems may incorporate a number of similar engines of this type, giving great flexibility for part-load operating or maintenance. With controllable pitch propellers there is no need to fit the more expensive reversible engines.

Modern engines can operate successfully on all but the heaviest of fuels with surprisingly low wear rates. Smaller and lighter parts, with simpler construction, give easier maintenance. Shell bearings are in general use.

Engines may operate on either the pulse or constant pressure turbocharger system. As four-stroke engines they are self-aspirating at slow speeds. Pulse charging will incorporate pulse converters to reduce the size of exhaust manifolds and improve turbine efficiency. This system may have some advantage where rapid acceleration is required, while constant pressure gives a greater efficiency overall. Turbochargers may require water cooling with the high exhaust temperatures which may be produced.

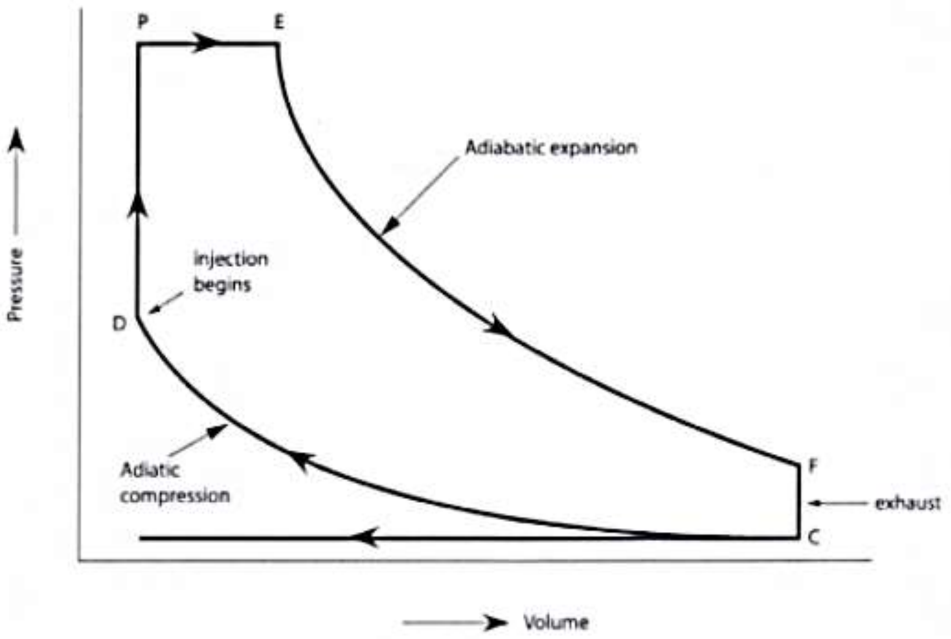
Medium and high speed engines may be constructed in either in-line or Vee configurations, and many manufacturers supply all but the largest-bore models in either form. As the name implies, Vee engines are constructed with two banks of cylinders arranged at an angle using a common crankcase and bedplate with considerable saving in size and weight. Twice as many cylinders can be accommodated in a given length, although the width of the engine is increased. Due to the increased power from a Vee engine, however, the crankshaft must be of adequate strength. A variety of methods have been utilised to connect two pistons to each throw of the shaft; most common is the side-by-side arrangement with two bottom end bearings.

The Vee formation gives economy in the common space used for the exhaust system and turbochargers. Two camshafts are used, but in multi-cylinder engines starting air valves may only be necessary on one bank of cylinders.

- **The Work Done Diagram**

In the original patent by Rodulf Diesel, the diesel engine operated on the diesel cycle in which the heat was added at constant pressure. This was achieved by the blast injection principle. Nowadays the term is universally used to describe any reciprocating engine in which the heat induced by compressing air in the cylinders ignites a finely atomised spray of fuel.

This means that the theoretical cycle on which the modern diesel engine works is better represented by the dual or mixed cycle, diagrammatically illustrated below. The area of the diagram, to a suitable scale, represents the work done on the piston during one cycle.



Starting from point C, the air is compressed adiabatically to a point D. Fuel injection begins at D, and heat is added to the cycle partly at constant volume as shown by vertical line DP, and partly at constant pressure, as shown by horizontal line PE. At the point E expansion begins. This proceeds adiabatically to point F when the heat is rejected to exhaust at constant volume as shown by vertical line FC.

The ideal efficiency of this cycle, (i.e. of the hypothetical indicator diagram) is about

55-60%: that is to say, about 40-45% of the heat supplied is lost to the exhaust. Since the compression and expansion strokes are assumed to be adiabatic, and friction is disregarded, there is no loss to coolant or surroundings.

For a four-stroke engine the exhaust and suction strokes are shown by the horizontal line at C, and this has no effect on the cycle.

- **Actual Diagrams**

While the theoretical cycle facilitates simple calculations, it does not exactly represent the true state of affairs. This is because:

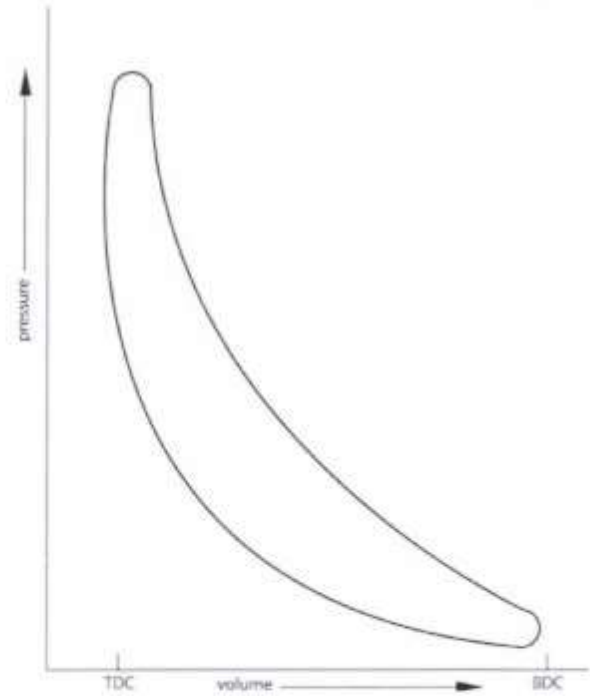
1. The manner in which, and the rate at which, heat is added to the compressed air (the heat release rate) is a complex function to the hydraulics of the fuel injection equipment and the characteristic of its operating mechanism; of the way the spray is atomised and distributed in the combustion space; of the air movement at and after top dead centre (TDS), and to a degree also of the qualities of the fuel.

2. The compression and expansion strokes are note truly adiabatic. Heat is lost to the cylinder walls to an extent which is influenced by the coolant temperature and by the design of the heat paths to the coolant.
3. The exhaust and suction strokes on a four-stroke engine (and the appropriate phases of a two-stroke cycle) do create pressure differences which the crank shaft feels as ‘pumping work’.

It is the designer’s objective to minimise all these losses without prejudicing first cost or reliability, and also to minimise the cycle loss, that is, the heat rejected to exhaust.

In practice designers have at their disposal sophisticated computer techniques which are capable of representing the actual events in the cylinder with a high degree of accuracy. But broadly speaking, the cycle efficiency is a function of the compression ratio (or more correctly the effective expansion ratio of the gas/air mixture after combustion).

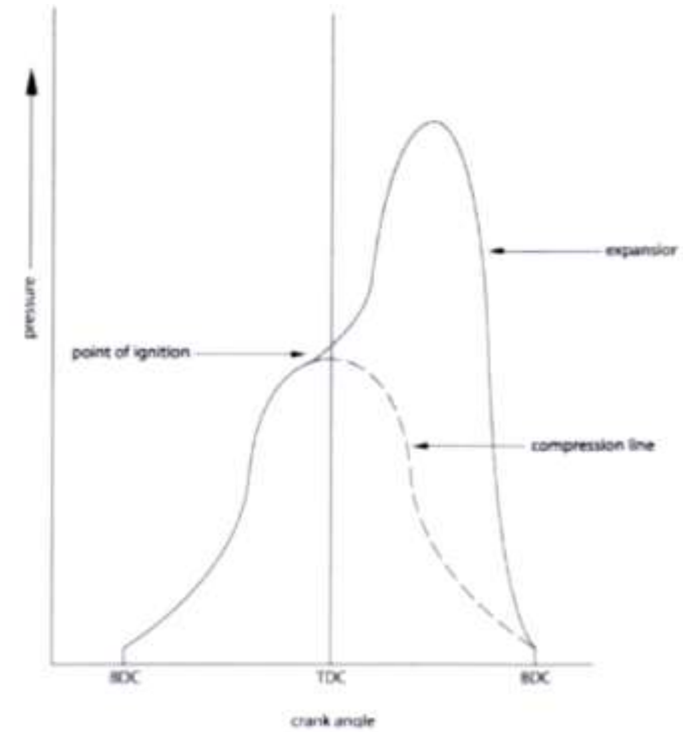
The theoretical cycle may be compared with a typical actual diesel indicator diagram such as that shown below.



Note that in higher speed engines combustion events are often represented on a crank angel, rather than a stroke basis, in order to achieve better accuracy in portraying events at the top dead centre, as shown below. The actual indicator diagram is derived from it by transposition. This form of diagram is useful too when setting injection timing. If electronic indicators are used it is possible to choose either form of diagram.

An approximation to a crank angle based diagram can be made with mechanical indicators by disconnecting the phasing and taking a card quickly, pulling it by hand: this is termed a ‘draw card’. Faults on the engine will be indicated on the draw card, e.g., Low compression pressure: Blow past and defective piston rings. Late ignition:

Fuel pump timing.



- **Engine Cycles**

The term ‘cycle’ refers to one complete sequence of operators required to produce power in an engine. This cycle of operations is continuously repeated while the engine is running. For a diesel engine it consists of four operations within the cylinder:

1. Compression of a charge of air.
2. Injection of fuel which then ignites.
3. Expansion of the hot gases formed during combustion.
4. Expulsion of the used gas to exhaust.

The cylinder is then recharged with air and the cycle is repeated.

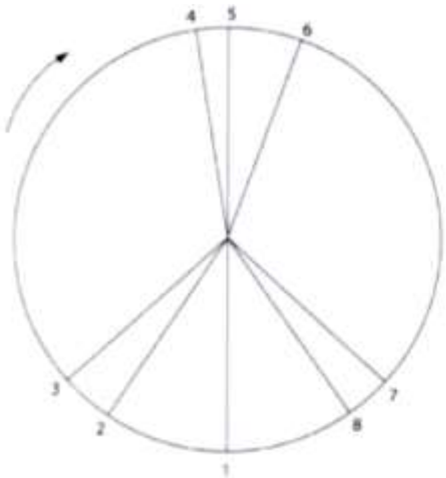
Diesel engines can be designed to complete this cycle once during each revolution and this is termed the two-stroke cycle, or alternatively to take two engine revolutions to complete – the four-stroke cycle. An engine can only operate on the cycle for which it was designed.

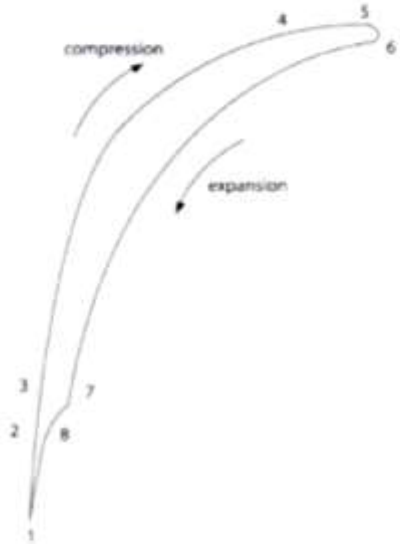
Engine stroke is measured as the full distance through which the piston moves between each end of its travel. It can be seen that it must move through two complete strokes (one up and one down) during each revolution of the engine.

Engine timing refers to the relative time or position of the crank, at which each operation during the cycle is commenced and is completed. It is measured as the angle through which the crank has been rotated from a datum position such as top or bottom centre.

- **Two-stroke cycle**

Practically all large, slow-speed, direct drive marine diesel engines operate on the two-stroke cycle. As its name implies a two-stroke cycle takes place in two consecutive strokes of the engine piston, or one revolution of the crankshaft. Thus each operation in the cycle is repeated during every revolution of the engine. The two strokes of the cycle may be termed: Compression stroke and Power or Expansion Stroke. Operations take place in a fixed order and must occur when the piston reaches a corresponding position in its stroke. These positions are show as volumes on an indicator diagram which relates them with pressure within the cylinder. It is convenient to express them in terms of angles of crank position measured from top dead centre (TDS) or bottom dead centre (BDC) and they may be shown as a circle on a timing diagram. (Numbers have been added for reference). Actual timing may differ between engines due to construction and design differences such as: ratio of connecting rod length/crank length, stroke/bore ratio, engine speed, engine rating etc.





Position 1 represents bottom of stroke (BDC). Position 5 represents top of stroke (TDC).
1-2 Completion of scavenge. Air is entering the cylinder, expelling exhaust gas and recharging it for the next combustion. Scavenge and exhaust are open.
2-3 Post-scavenge. Scavenge ports have closed and some air within the cylinder may lead to exhaust. In some engines 2 and 3 are made to coincide to eliminate leakage of air.
3-4 Compression. Exhaust has now closed and the air trapped within the cylinder is compressed by the upstroke of the piston to raise its temperature sufficiently to ignite the fuel.
4-5-6 Fuel injection takes place and combustion occurs causing a rapid rise in pressure. The period for which this continues depends upon the fuel pump setting and power to be produced.

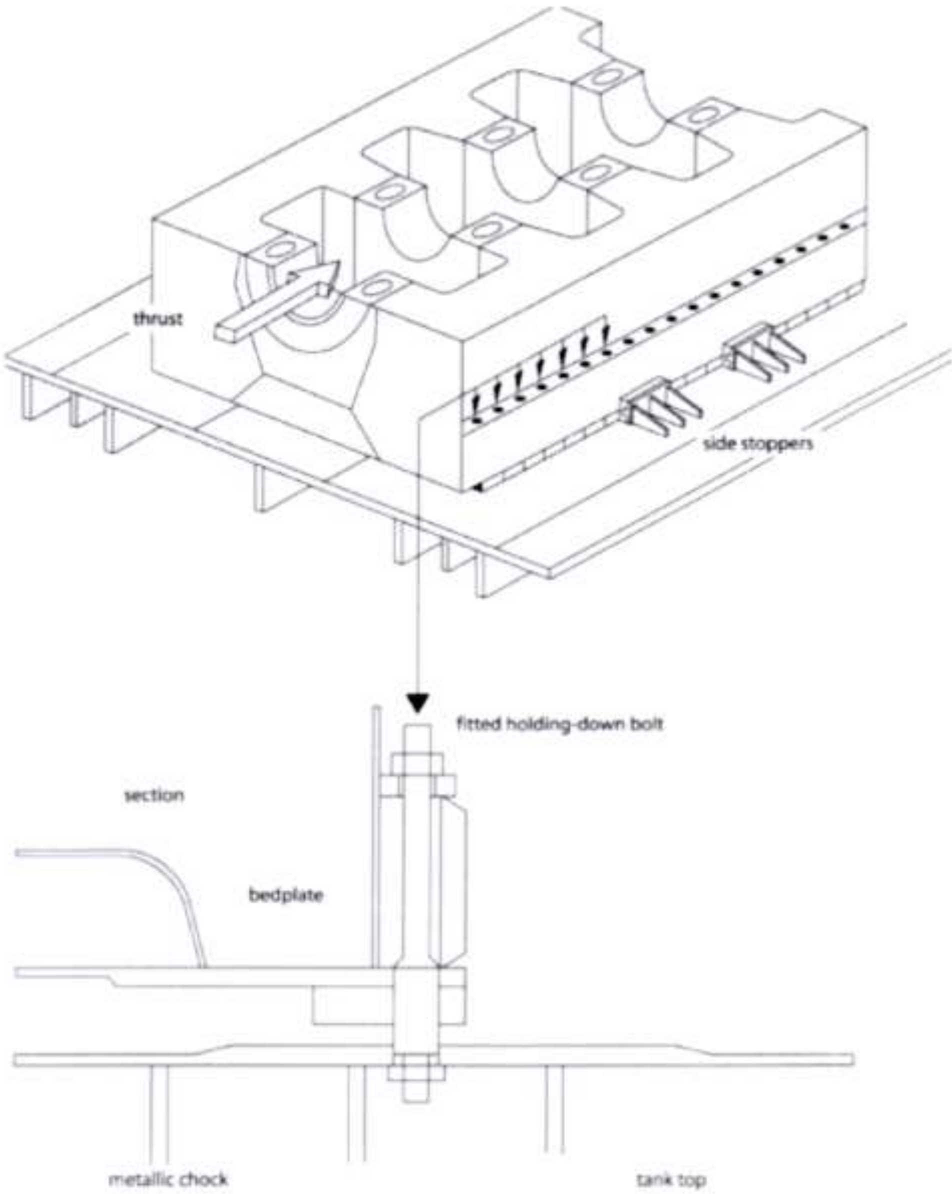
6-7 Expansion. Combustion completed, the hot gases expand forcing the piston downwards and converting the heat energy from combustion into work on the piston.

7-8 Exhaust blowdown. Exhaust has opened allowing gas to pass to exhaust manifold, and pressure drops rapidly in the cylinder.
8-1 Scavenge. Scavenge ports have opened and air enters to expel the remaining exhaust gas.
1-etc Scavenging then continues for the next cycle.

- **Four-stroke cycle**

The majority of medium and high speed diesel engines for main or auxiliary drive operate on the four-stroke cycle, which takes place during four consecutive strokes, or two complete revolutions, of the engine. Exhaust Stroke, and Aspirating or Air Induction stroke. Numbering the operations in sequence on the timing diagram:
4 and 9 are TDC positions. 1 and 7 are BDC positions.
1-2 Completion of aspiration.
2-3 Compression. Air inlet valve has closed, air in cylinder is now compressed to raise its temperature for combustion of fuel.
3-4-5 Fuel injection. Combustion takes place with corresponding rise in pressure.
Period controlled by fuel pump setting.
5-6 Expansion. Combustion completed, gas pressure does work on piston during downward stroke.
6-7-8 Exhaust. Exhaust valve opened, piston expels exhaust gas on upward stroke.
8-9-10Overlap. Air inlet valve opened while exhaust remains open. The length of this is increased in supercharged or high speed engines.
10-1 Aspiration. Exhaust valve closed, piston draws air into cylinder during downward stroke.
1-etc. Aspiration continues for next cycle.

- **Engine Foundation**



A main engine is secured to a foundation built into the ship's structure, specially designed and stiffened to support rigidly the weight of the engine and the forces generated during operation. Stiffening will extend outside of the engine to allow the distribution of stresses through a wider area of structure. The top surface of the tank top must be level and shaped to match the engine bedplate base.

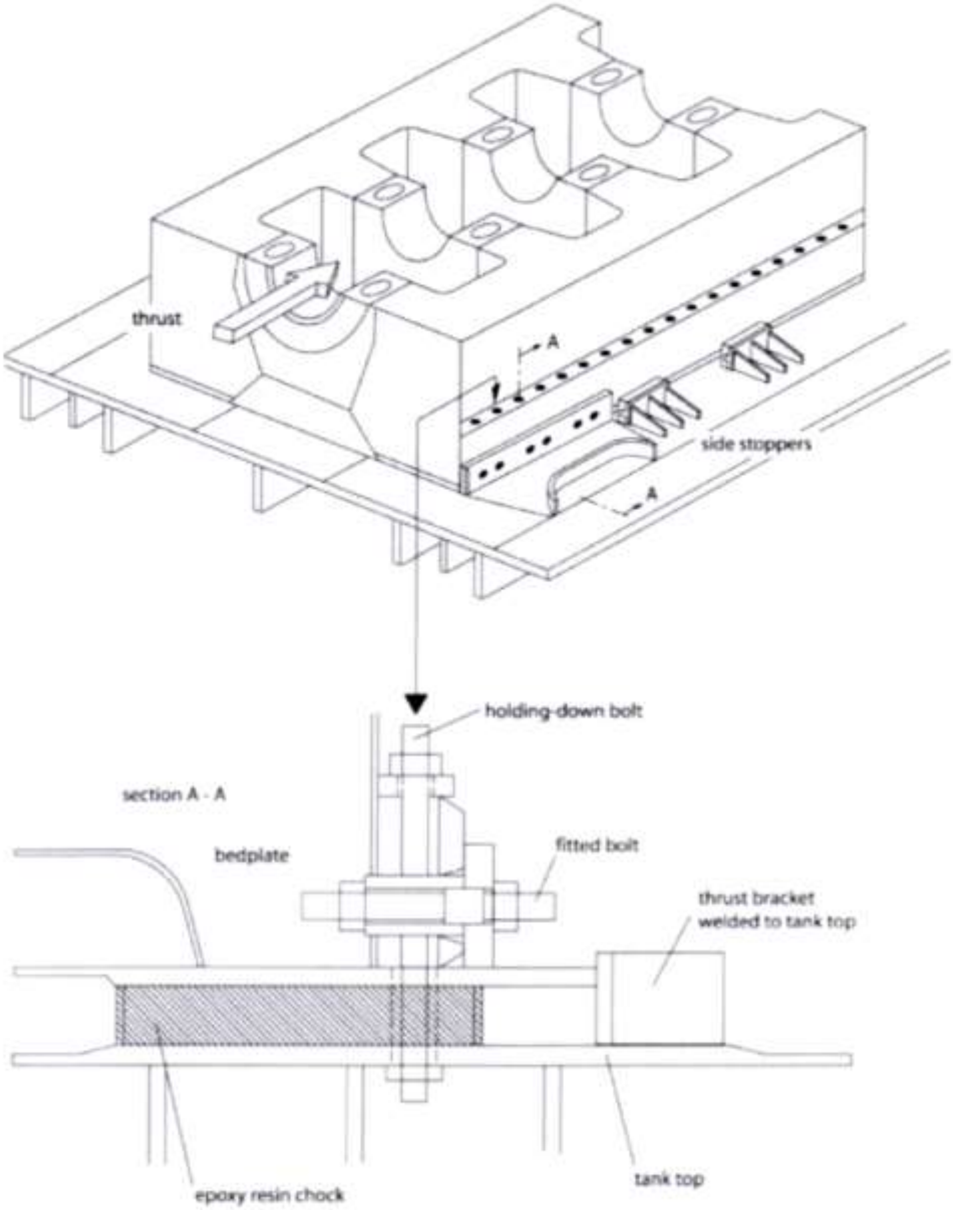
Direct drive engines are jacked up accurately to align the main bearing centreline with the propeller shafting. Holding down bolt holes are then drilled and tapped in the tank tops.

Cast iron or steel chocks are carefully machined and fitted between the tank top and bedplate. In addition to the chocks at each bolt, their total area must be sufficient to support the engine. All chocks must be tight when the bolts are hardened down.

Alternatively an approved non-shrink epoxy resin chocking material may be cast into the space between the engine and tank top. This is not as strong as cast iron, but by filling a larger area and by the intimate matching of surfaces left by casting it will give excellent load-bearing and avoid the possibility of fretting which can occur with metal chocks.

- **Holding-Down Bolts or Studs**

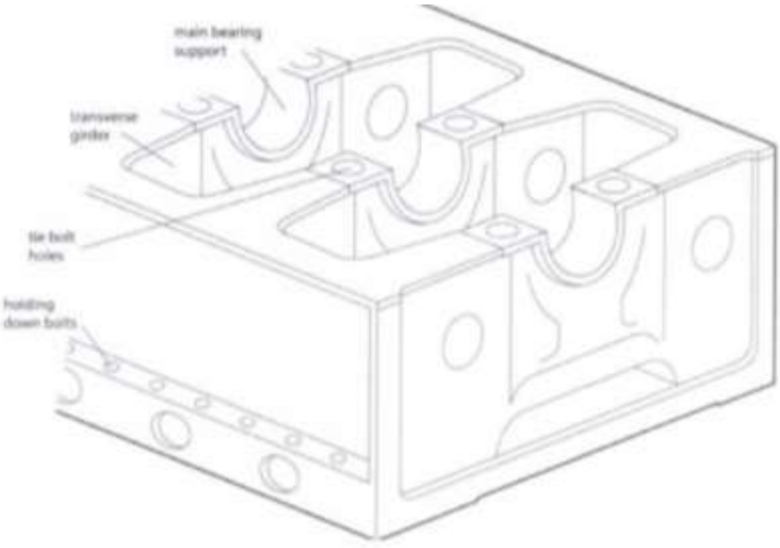
Holding down bolts or studs are screwed into the tank top and nut fitted and locked underneath. Seals must be used to ensure the integrity of the watertight tank tops. Studs will normally have clearance in the bedplate to allow for thermal expansion of the engine. In some cases some fitted bolts may be used to transmit thrust at the drive end of the engine.
To improve the resilience of holding-down studs, their unthreaded section may be of reduced diameter and the overall length increased. The top nuts are hydraulically tightened in sequence to reach the correct tension in the studs and compression in the chocks. Nuts must be hydraulically tested and chocks hammer tested at regular intervals, on a running hours planned maintenance basis, and additionally after heavy weather or damage.



Side and end thrust (transverse and longitudinal) is transmitted through brackets welded to the tank tops at the sides and ends of the bedplate. Vertical chocks or packing pieces are fitted and locked between each bracket and the engine. Side brackets are situated at the ends of each transverse member. End thrust is taken in a similar manner.
Although the main forces are transmitted at the bedplate, further transverse struts to secure large engines to the ship's structure are fitted at upper platform levels.

- Engine Structure

The bedplate of a large engine acts as the main strength part of its section, providing rigid support for the main bearings and crankshaft. It is also a platform on which other structural components such as frames or columns and guides may be accurately mounted to support the engine cylinders and ensure the alignment of all working parts. In high powered engines the bedplate must withstand heavy, fluctuating stresses from working parts. It must transmit engine loads, including the propeller thrust, to the ship’s structure, distributing these over the necessary area, and may complement the ship’s strength and propeller shaft alignment. The bedplate also collects the lubricating oil from the crankcase, returning it to the drain tank for recycling.



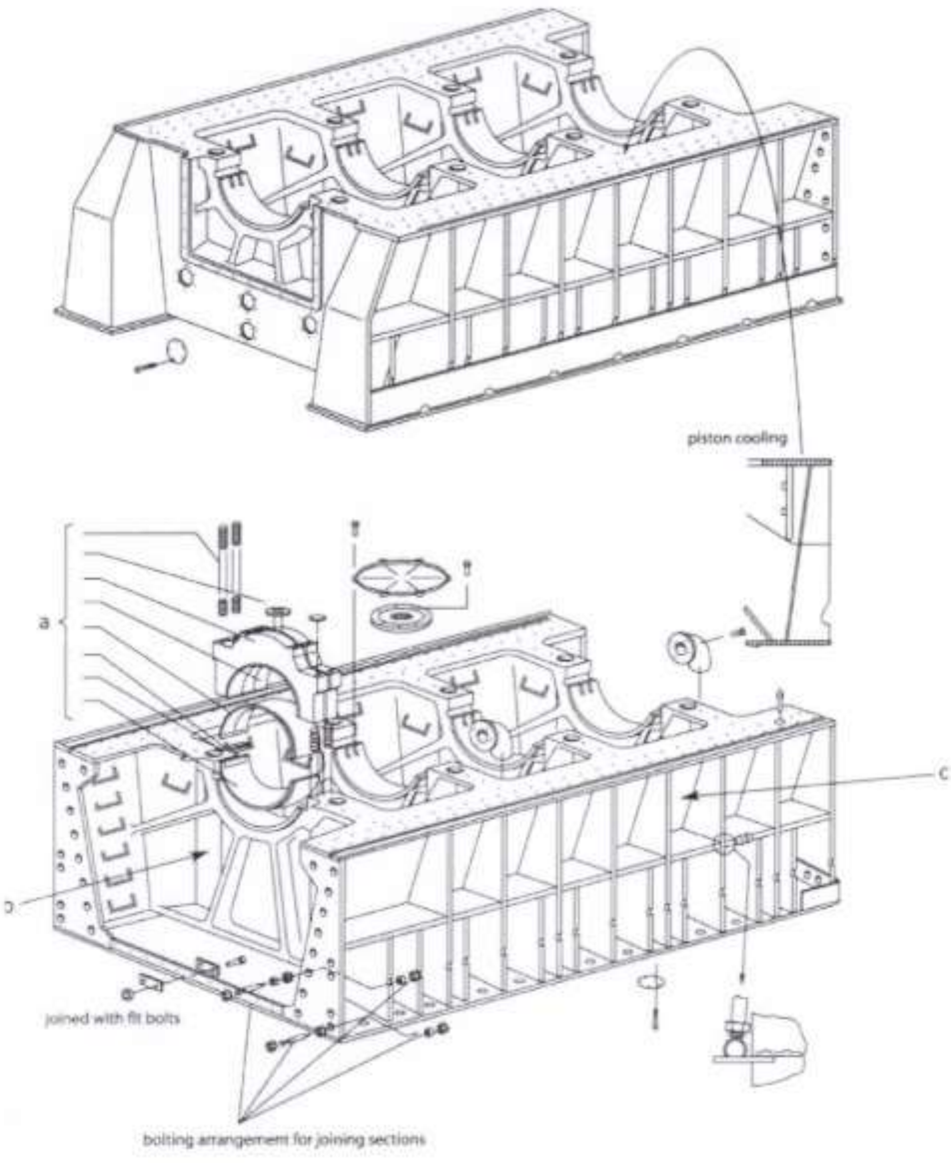
The figure shows part of a bedplate for a large crosshead type of main engine. It is fabricated from steel plates and castings welded together to form a deep longitudinal box structure with stiffening members and webs to give additional rigidity. Lightening and access holes are made with compensating sleeves, to maintain lightness with strength. Transverse members or girders are fitted between each engine unit and at each end of the bedplate. The central section of each is formed by a steel casting shaped to support the main bearing and with holes for a pair of tie bolts. The casting has substantial butt welds securing it to the main box structure.
The depth of the bedplate raises its top flange clear of the sweep of the bottom end bearing in long-stroke engines, keeping overall width to a minimum. To limit overall height, the centre oil pan or sump is lowered and will require a recess in the ship’s structure.

a. Two main bearing caps with associated shell bearings, holding down arrangements and oil supply.
b. Cast transverse girder (with radial webs).
c. Single piece longitudinal girder with substantial ribs.

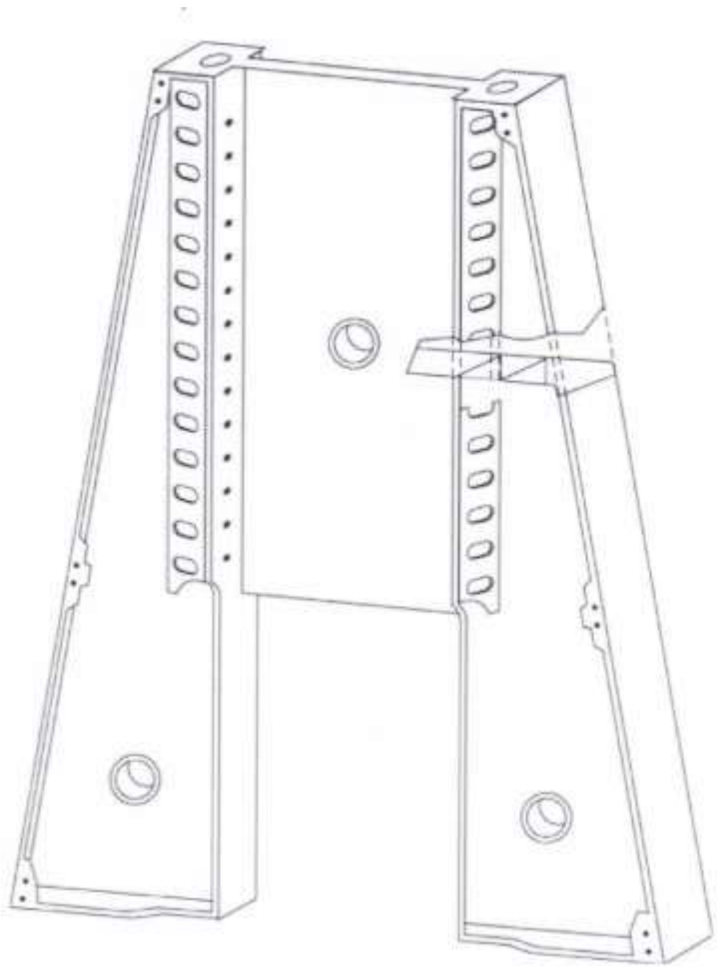
All welding in the bedplate must be to a very high standard, carefully controlled and inspected. It must be stress-relieved, shot blasted and tested for flaws. All plate edges must be correctly prepared, with double butt welds and complete penetration where possible. Plates of different thickness should not be butt welded together. Bedplate flanges are finally machined for landing on support chocks or for assembly of other members.
Fatigue cracks may commence at points of high stress or sudden change in section and regular internal inspection must be carried out, particularly after heavy weather or damage has occurred. All nuts, including holding down and tie bolts, must be checked for

tightness on a running hours planned maintenance basis and to ensure fretting has not occurred between mating surfaces.

Earlier engines with lower stroke/bore ratio had bedplates formed by a longitudinal box shaped girder at each side joined by transverse girders supporting main bearings and tie bolts in steel castings.

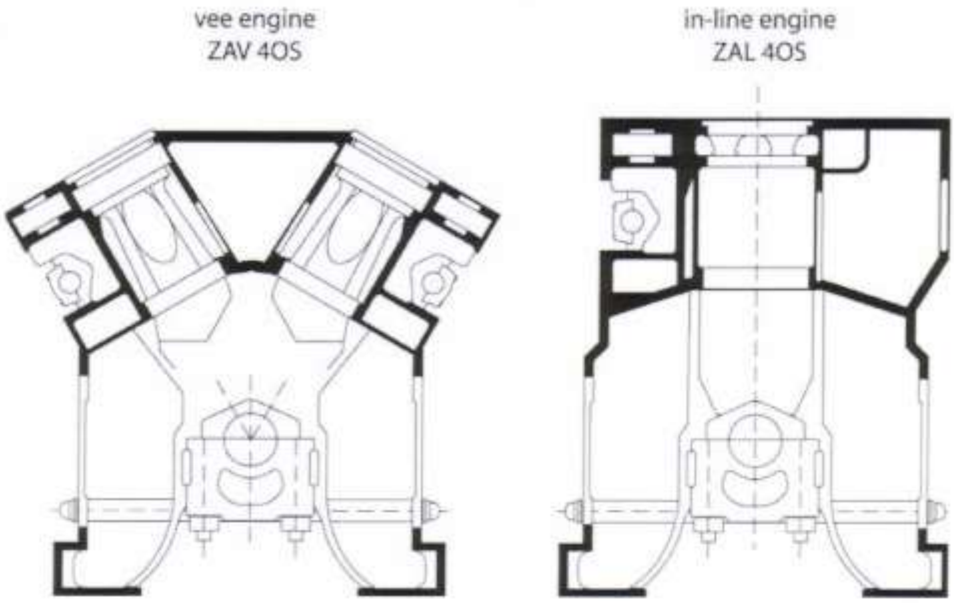


In crosshead type engines frames or columns are used to support the cylinder block from the bedplate. These are terms ‘A’ frames because of their shape; they are fitted at each transverse girder and at both ends of the engine. ‘A’ frames are fabricated from steel plates welded to form a hollow structure on each side. There is clearance to allow access to main bearings. Transverse stiffening webs are fitted and flanges added for necessary connections. Brackets secure the crosshead guides and other internal fittings. Bottom flanges allow the frame to be accurately aligned and secured by fitted bolts and studs to the bedplate and transverse girder. The top flange is fitted to the cylinder block, scavenge trunk etc. Longitudinal bars and crankcase casing plates are attached to the outer edges. Tie bolts pass vertically within the frame; the prestressing of these maintains the frame in compression at all times.



In some designs, a number of frames with the crankcase casing are fabricated together to form a box before attachment to the engine.

In medium speed trunk piston engines the main strength member may consist of a single frame or block which incorporates the crankcase, bedplate, frames and even the cylinder block. These may be formed as a single casting of either grey or nodular cast iron machined on all necessary faces. Alternatively they may be fabricated from steel plates and castings. Main bearings are under-slung from the frames and horizontal tie bolts may add to the rigidity at this position. Typical frames for in-line and Vee engines are shown in the figure.



In most single-acting engines, except opposed piston engines, the main gas loads from the cylinder covers are transmitted by long tie bolts. Two bolts are fitted to each transverse girder and they pass up through the casting, through tubes constructed in the engine frames and entablature to the top of the cylinder block where locking nuts are hydraulically tightened to pre-stress the structure, maintaining the cylinder block and frames in compression. Transverse locating bolts prevent vibration in the tie bolts, which may be assembled in screwed sectional lengths to limit the access and removal height. Tie bolt centres should be as close to the crankshaft axis as possible to reduce bending stress on the girders and to prevent unbalanced loads being transmitted to the welds.

Steam turbine system

A steam turbine is a device that extracts thermal energy from pressurized steam and uses it to do mechanical work on a rotating output shaft. Its modern manifestation was invented by Sir Charles Parsons in 1884.

Because the turbine generates rotary motion, it is particularly suited to be used to drive an electrical generator – about 90% of all electricity generation in the United States (1996) is by use of steam turbines. The steam turbine is a form of heat engine that derives much of its improvement in thermodynamic efficiency from the use of multiple stages in the expansion of the steam, which results in a closer approach to the ideal reversible expansion process.

- **Principle of operation and design**

An ideal steam turbine is considered to be an isentropic process, or constant entropy process, in which the entropy of the steam entering the turbine is equal to the entropy of the steam leaving the turbine. No steam turbine is truly isentropic, however, with typical isentropic efficiencies ranging from 20–90% based on the application of the turbine. The interior of a turbine comprises several sets of blades, or buckets as they are more commonly referred to. One set of stationary blades is connected to the casing and one set of rotating blades is connected to the shaft. The sets intermesh with certain minimum clearances, with the size and configuration of sets varying to efficiently exploit the expansion of steam at each stage.

- **Turbine efficiency**

To maximize turbine efficiency the steam is expanded, doing work, in a number of stages. These stages are characterized by how the energy is extracted from them and are known as either impulse or reaction turbines. Most steam turbines use a mixture of the reaction and impulse designs: each stage behaves as either one or the other, but the overall turbine uses both. Typically, higher pressure sections are reaction type and lower pressure stages are impulse type.

- **Impulse turbines**

An impulse turbine has fixed nozzles that orient the steam flow into high speed jets. These jets contain significant kinetic energy, which is converted into shaft rotation by the bucket-like shaped rotor blades, as the steam jet changes direction. A pressure drop occurs across only the stationary blades, with a net increase in steam velocity across the stage. As the steam flows through the nozzle its pressure falls from inlet pressure to the exit pressure (atmospheric pressure, or more usually, the condenser vacuum). Due to this high ratio of expansion of steam, the steam leaves the nozzle with a very high velocity. The steam leaving the moving blades has a large portion of the maximum velocity of the steam when leaving the nozzle. The loss of energy due to this higher exit velocity is commonly called the carry over velocity or leaving loss.

The law of moment of momentum states that the sum of the moments of external forces acting on a fluid which is temporarily occupying the control volume is equal to the net time change of angular momentum flux through the control volume.

The swirling fluid enters the control volume at radius r_1 with tangential velocity V_{w1} and leaves at radius r_2 with tangential velocity V_{w2}.

A velocity triangle paves the way for a better understanding of the relationship between the various velocities. In the adjacent figure we have:

V_1 and V_2 are the absolute velocities at the inlet and outlet respectively.
V_{f1} and V_{f2} are the flow velocities at the inlet and outlet respectively.
$V_{w1} + U$ and V_{w2} are the swirl velocities at the inlet and outlet respectively.
V_{r1} and V_{r2} are the relative velocities at the inlet and outlet respectively.
U_1 and U_2 are the velocities of the blade at the inlet and outlet respectively.
α is the guide vane angle and β is the blade angle.

Then by the law of moment of momentum, the torque on the fluid is given by:

$$T = \dot{m}(r_2 V_{w2} - r_1 V_{w1})$$

For an impulse steam turbine: $r_2 = r_1 = r$. Therefore, the tangential force on the blades is $F_u = \dot{m}(V_{w1} - V_{w2})$. The work done per unit time or power developed: $W = T * \omega$.

When ω is the angular velocity of the turbine, then the blade speed is $U = \omega * r$. The power developed is then $W = \dot{m}U(\Delta V_w)$.

- **Blade efficiency**

Blade efficiency (η_b) can be defined as the ratio of the work done on the blades to kinetic energy supplied to the fluid, and is given by

$$\eta_b = \frac{Work\ Done}{Kinetic\ Energy\ Supplied} = \frac{2UV_w}{V_1^2}$$

- **Stage efficiency**

A stage of an impulse turbine consists of a nozzle set and a moving wheel. The stage efficiency defines a relationship between enthalpy drop in the nozzle and work done in the stage.

$$\eta_{stage} = \frac{Work\ done\ on\ blade}{Energy\ supplied\ per\ stage} = \frac{U\Delta V_w}{\Delta h}$$

Where $\Delta h = h_2 - h_1$ is the specific enthalpy drop of steam in the nozzle.

By the first law of thermodynamics: $h_1 + \frac{V_1^2}{2} = h_2 + \frac{V_2^2}{2}$

Assuming that V_1 is appreciably less than V_2, we get $\Delta h \approx \frac{V_2^2}{2}$ Furthermore, stage efficiency is the product of blade efficiency and nozzle efficiency, or $\eta_{stage} = \eta_b * \eta_N$

Nozzle efficiency is given by $\eta_N = \frac{V_2^2}{2(h_1 - h_2)}$, where the enthalpy (in J/Kg) of steam at the entrance of the nozzle is $h_1$and the enthalpy of steam at the exit of the nozzle is h_2. $\Delta V_w = V_{w1} - (-V_{w2})$ $\Delta V_w = V_{w1} + V_{w2}$

$\Delta V_w = V_{r1}\cos\beta_1 + V_{r2}\cos\beta_2$ $\Delta V_w = V_{r1}\cos\beta_1(1 + \frac{V_{r2}\cos\beta_2}{V_{r1}\cos\beta_1})$

The ratio of the cosines of the blade angles at the outlet and inlet can be taken and denoted $c = \frac{\cos\beta_2}{\cos\beta_1}$. The ratio of steam velocities relative to the rotor speed at the outlet to the inlet of the blade is defined by the friction coefficient $k = \frac{V_{r2}}{V_{r1}}$.

$k < 1$ and depicts the loss in the relative velocity due to friction as the steam flows around the blades ($k = 1$ for smooth blades).

$$\eta_b = \frac{2U\Delta V_w}{V_1^2} = \frac{2U(\cos\alpha_1 - U/V_1)(1+kc)}{V_1}$$

The ratio of the blade speed to the absolute steam velocity at the inlet is termed the blade speed ratio $\rho = \frac{U}{V_1}$

η_b is maximum when $\frac{d\eta_b}{d\rho} = 0$ or, $\frac{d}{d\rho}(2\cos\alpha_1 - \rho^2(1+kc)) = 0$. That implies $\rho = \frac{\cos\alpha_1}{2}$ and therefore $\frac{U}{V_1} = \frac{\cos\alpha_1}{2}$. Now $\rho_{opt} = \frac{U}{V_1} = \frac{\cos\alpha_1}{2}$ (for a single stage impulse turbine)

Therefore the maximum value of stage efficiency is obtained by putting the value of $\frac{U}{V_1} = \frac{\cos\alpha_1}{2}$ in the expression of η_b/

We get: $(\eta_b)_{max} = 2(\rho\cos\alpha_1 - \rho^2)(1+kc) = \frac{\cos^2\alpha_1(1+kc)}{2}$.

For equiangular blades, $\beta_1 = \beta_2$, therefore $c = 1$, and we get $(\eta_b)_{max} = \frac{cos^2\alpha_1(1+k)}{2}$. If the friction due to the blade surface is neglected then $(\eta_b)_{max} = \cos^2\alpha_1$.

Conclusions on maximum efficiency

$$(\eta_b)_{max} = \cos^2\alpha_1$$

1. For a given steam velocity work done per kg of steam would be maximum when $\cos^2\alpha_1 = 1$ or $\alpha_1 = 0$.

2. As α_1 increases, the work done on the blades reduces, but at the same time surface area of the blade reduces, therefore there are less frictional losses.

- **Reaction turbines**

In the reaction turbine, the rotor blades themselves are arranged to form convergent nozzles. This type of turbine makes use of the reaction force produced as the steam accelerates through the nozzles formed by the rotor. Steam is directed onto the rotor by the fixed vanes of the stator. It leaves the stator as a jet that fills the entire circumference of the rotor. The steam then changes direction and increases its speed relative to the speed of the blades. A pressure drop occurs across both the stator and the rotor, with steam accelerating through the stator and decelerating through the rotor, with no net change in steam velocity across the stage but with a decrease in both pressure and temperature, reflecting the work performed in the driving of the rotor.

- **Blade efficiency**

Energy input to the blades in a stage:

$E = \Delta h$ is equal to the kinetic energy supplied to the fixed blades (f) + the kinetic energy supplied to the moving blades (m).

Or, E = enthalpy drop over the fixed blades, Δh_f + enthalpy drop over the moving blades, Δh_m.

The effect of expansion of steam over the moving blades is to increase the relative velocity at the exit. Therefore the relative velocity at the exit V_{r2} is always greater than the relative velocity at the inlet V_{r1}.

In terms of velocities, the enthalpy drop over the moving blades is given by:

$$\Delta h_m = \frac{V_{r2}^2 - V_{r1}^2}{2}$$

(it contributes to a change in static pressure)

The enthalpy drop in the fixed blades, with the assumption that the velocity of steam entering the fixed blades is equal to the velocity of steam leaving the previously moving blades is given by:

$\Delta h_f = \frac{V_1^2 - V_0^2}{2}$ where V0 is the inlet velocity of steam in the nozzle

V_0 is very small and hence can be neglected

Therefore, $\Delta h_f = \frac{V_1^2}{2}$

$$E = \Delta h_f + \Delta h_m$$

$$E = \frac{V_1^2}{2} + \frac{V_{r2}^2 - V_{r1}^2}{2}$$

A very widely used design has half degree of reaction or 50% reaction and this is known as Parson's turbine. This consists of symmetrical rotor and stator blades. For this turbine the velocity triangle is similar and we have:

$$\alpha_1 = \beta_2, \beta_1 = \alpha_2$$

$$V_1 = V_{r2}, V_{r1} = V_2$$

Assuming Parson's turbine and obtaining all the expressions we get

$$E = V_1^2 - \frac{V_{r1}^2}{2}$$

From the inlet velocity triangle we have $V_{r1}^2 = V_1^2 - U^2 - 2UV_1 \cos\alpha_1$

$$E = V_1^2 - \frac{V_1^2}{2} - \frac{U^2}{2} + \frac{2UV_1 \cos\alpha_1}{2}$$

$$E = \frac{V_1^2 - U^2 + 2UV_1 \cos\alpha_1}{2}$$

Work done (for unit mass flow per second): $W = U * \Delta V_w = U * (2 * V_1 \cos\alpha_1 - U)$

Therefore the blade efficiency is given by

$$\eta_b = \frac{2U(2V_1 \cos\alpha_1 - U)}{V_1^2 - U^2 + 2V_1 U \cos\alpha_1}$$

- **Condition of maximum blade efficiency**

If $\rho = \frac{U}{V_1}$, then

$$(\eta_b)_{max} = \frac{2\rho(\cos\alpha_1 - \rho)}{V_1^2 - U^2 + 2UV_1 \cos\alpha_1}$$

For maximum efficiency $\frac{d\eta_b}{d\rho} = 0$, we get

$$(1 - \rho^2 + 2\rho\cos\alpha_1)(4\cos\alpha_1 - 4\rho) - 2\rho(2\cos\alpha_1 - \rho)(-2\rho + 2\cos\alpha_1) = 0$$

and this finally gives $\rho_{opt} = \frac{U}{V_1} = \cos\alpha_1$

Therefore $(\eta_b)_{max}$ is found by putting the value of $\rho = \cos\alpha_1$ in the expression of blade efficiency

$$(\eta_b)_{reaction} = \frac{2\cos^2\alpha_1}{1+\cos^2\alpha_1}$$

$$(\eta_b)_{impulse} = \cos^2\alpha_1$$

- **Operation and maintenance**

Because of the high pressures used in the steam circuits and the materials used, steam turbines and their casings have highthermal inertia. When warming up a steam turbine for use, the main steam stop valves (after the boiler) have a bypass line to allow superheated steam to slowly bypass the valve and proceed to heat up the lines in the system along with the steam turbine. Also, a turning gear is engaged when there is no steam to slowly rotate the turbine to ensure even heating to preventuneven expansion. After first rotating the turbine by the turning gear, allowing time for the rotor to assume a straight plane (no bowing), then the turning gear is disengaged and steam is admitted to the turbine, first to the astern blades then to the ahead blades slowly rotating the turbine at 10–15 RPM (0.17–0.25 Hz) to slowly warm the turbine. The warm up procedure for large steam turbines may exceed ten hours.

During normal operation, rotor imbalance can lead to vibration, which, because of the high rotation velocities, could lead to a blade breaking away from the rotor and through the casing. To reduce this risk, considerable efforts are spent to balance the turbine. Also, turbines are run with high quality steam: either superheated (dry) steam, or saturated steam with a high dryness fraction. This prevents the rapid impingement and erosion of the blades which occurs when condensed water is blasted onto the blades (moisture carry over). Also, liquid water entering the blades may damage the thrust bearings for the turbine shaft. To prevent this, along with controls and baffles in the boilers to ensure high quality steam, condensate drains are installed in the steam piping leading to the turbine.

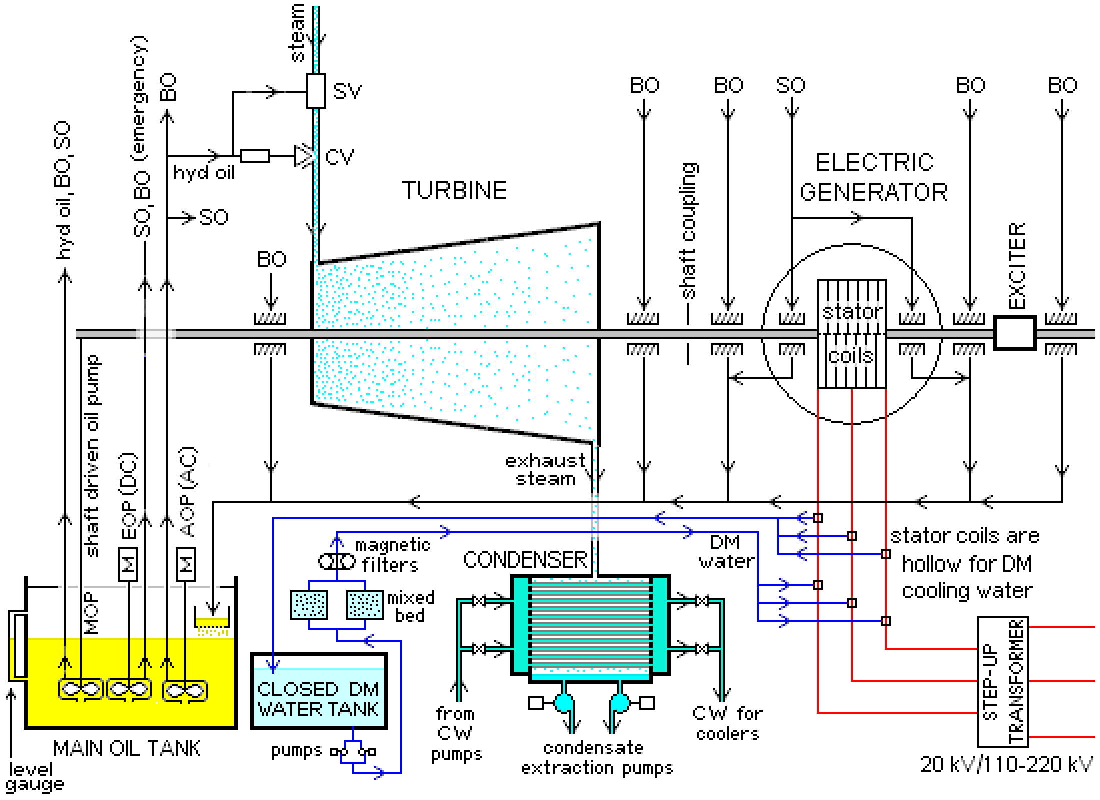
Maintenance requirements of modern steam turbines are simple and incur low costs (typically around $0.005 per kWh); their operational life often exceeds 50 years.

- **Speed regulation**

The control of a turbine with a governor is essential, as turbines need to be run up slowly to prevent damage and some applications (such as the generation of alternating current electricity) require precise speed control. Uncontrolled acceleration of the turbine rotor can lead to an overspeed trip, which causes the nozzle valves that control the flow of steam to the turbine to close. If this fails then the turbine may continue accelerating until it breaks apart, often catastrophically. Turbines are expensive to make, requiring precision manufacture and special quality materials.

During normal operation in synchronization with the electricity network, power plants are governed with a five percent droop speed control. This means the full load speed is 100% and the no-load speed is 105%. This is required for the stable operation of the network without hunting and drop-outs of power plants. Normally the changes in speed are minor. Adjustments in power output are made by slowly raising the droop curve by increasing the spring pressure on a centrifugal governor. Generally this is a basic system requirement for all power plants because the older and newer plants have to be compatible in response to the instantaneous changes in frequency without depending on outside communication.

Turbine generator systems



SO-seal oil; BO-bearing oil; hyd oil-hydraulic oil; SV-stop valve; CV-control valve;
MOP-main oil pump; EOP-emergency oil pump; AOP-auxiliary oil pump; [M] - motor
CW-circulating water; DM-demineralised (water); DC - direct current; AC - alternating current

- **Marine propulsion**

In steam-powered ships, compelling advantages of steam turbines over reciprocating engines are smaller size, lower maintenance, lighter weight, and lower vibration. A steam turbine is only efficient when operating in the thousands of RPM, while the most effective propeller designs are for speeds less than 300 RPM; consequently, precise (thus expensive) reduction gears are usually required, although numerous early ships through World War I, such as Turbinia, had direct drive from the steam turbines to the propeller shafts. Another alternative is turbo-electric transmission, in which an electrical generator run by the high-speed turbine is used to run one or more slow-speed electric motors connected to the propeller shafts; precision gear cutting may be a production bottleneck during wartime. Turbo-electric drive was most used in large US warships designed during World War I and in some fast liners, and was used in some troop transports and mass-production destroyer escorts in World War II. The purchase cost of turbines is offset by much lower fuel and maintenance requirements and the small size of a turbine when compared to a reciprocating engine having an equivalent power. However, from the 1950s diesel engines were capable of greater reliability and higher efficiencies: propulsion steam turbine cycle efficiencies have yet to break 50%, yet diesel engines today routinely exceed 50%, especially in marine applications. Diesel power plants also have lower operating costs since fewer operators are required. Thus, conventional steam power is used in very few new ships.

Nuclear-powered ships and submarines use a nuclear reactor to create steam for turbines. Nuclear power is often chosen where diesel power would be impractical (as in submarine applications) or the logistics of refuelling pose significant problems (for example, icebreakers). It has been estimated that the reactor fuel for the Royal Navy's Vanguard class submarine is sufficient to last 40 circumnavigations of the globe – potentially sufficient for the vessel's entire service life. Nuclear propulsion has only been applied to a very few commercial vessels due to the expense of maintenance and the regulatory controls required on nuclear systems and fuel cycles.

- **Early development**

The development of steam turbine marine propulsion from 1894-1935 was dominated by the need to reconcile the high efficient speed of the turbine with the low efficient speed (less than 300 rpm) of the ship's propeller at an overall cost competitive with reciprocating engines. In 1894, efficient reduction gears were not available for the high powers required by ships, so direct drive was necessary. In the Turbinia, which has direct drive to each propeller shaft, the efficient speed of the turbine was reduced after initial trials by directing the steam flow through all three direct drive turbines (one on each shaft) in series, probably totaling around 200 turbine stages operating in series. Also, there were three propellers on each shaft for operation at high speeds. The high shaft speeds of the era are represented by one of the first US turbine-powered destroyers, USS Smith (DD-17), launched in 1909, which had direct drive turbines and whose three shafts turned at 724 rpm at 28.35 knots. The use of turbines in several casings exhausting steam to each other in series became standard in most subsequent marine propulsion applications, and is a form of cross-compounding. The first turbine was called the high pressure (HP) turbine, the last turbine was the low pressure (LP) turbine, and any turbine in between was an intermediate pressure (IP) turbine. A much later arrangement than Turbinia can be seen on the RMS Queen Mary in Long Beach, California, launched in 1934, in which each shaft is powered by four turbines in series connected to the ends of the two input shafts of a single-reduction gearbox. They are the HP, 1st IP, 2nd IP, and LP turbines.

Propeller and propeller shaft

- **Shafting**

There may be one or more sections of intermediate shafting between the thrust shaft and the tailshaft, depending upon the machinery space location. All shafting is manufactured from solid forged ingot steel with integral flanged couplings. The shafting sections are joined by solid forged steel fitted bolts.

The intermediate shafting has flanges at each end and may be increased in diameter where it is supported by bearings.

The propeller shaft or tailshaft has a flanged face where it joins the intermediate shafting. The other end is tapered to suit a similar taper on the propeller boss. The tapered end will also be threaded to take a nut which holds the propeller in place**.**

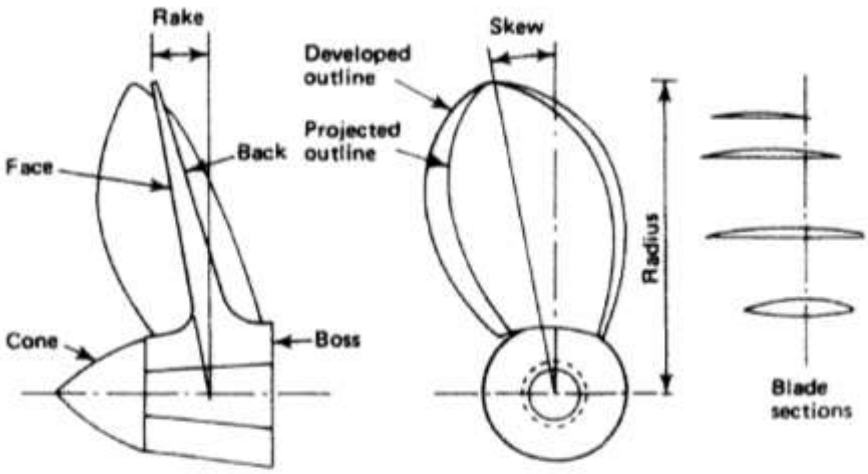
- **Propeller**

The propeller consists of a boss with several blades of helicoidal form attached to it. When rotated it 'screws' or thrusts its way through the water by giving momentum to the column of water passing through it.

The thrust is transmitted along the shafting to the thrust block and finally to the ship's structure.

A solid fixed-pitch propeller is shown in Figure below. Although usually described as fixed, the pitch does vary with increasing radius from the boss. The pitch at any point is fixed, however, and for calculation purposes a mean or average value is used.

A propeller which turns clockwise when viewed from aft is considered right-handed and most single-screw ships have right-handed propellers. A twin-screw ship will usually have a right-handed starboard propeller and a left-handed port propeller.



Solid propeller

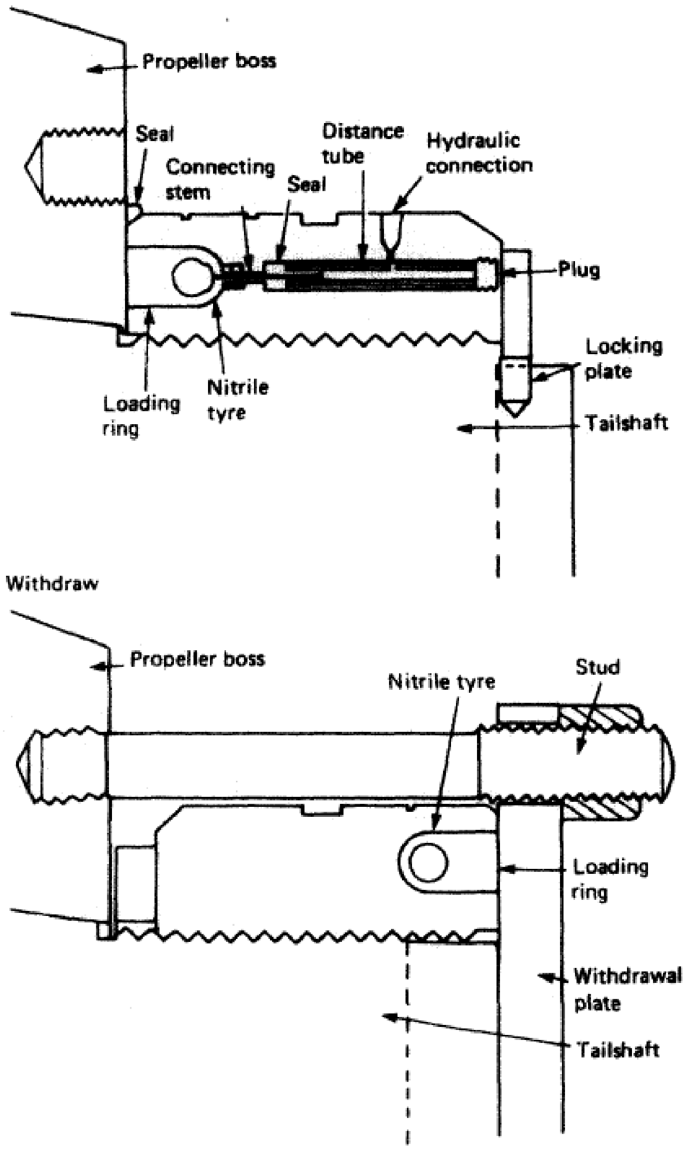
- **Propeller mounting**

The propeller is fitted onto a taper on the tailshaft and a key may be inserted between the two: alternatively a keyless arrangement may be used. A large nut is fastened and locked in place on the end of the tailshaft: a cone is then bolted over the end of the tailshaft to provide a smooth flow of water from the propeller.

One method of keyless propeller fitting is the oil injection system. The propeller bore has a series of axial and circumferential grooves machined into it. High-pressure oil is injected between the tapered section of the tailshaft and the propeller. This reduces the friction between the two parts and the propeller is pushed up the shaft taper by a hydraulic jacking ring. Once the propeller is positioned the oil pressure is released and the oil runs back, leaving the shaft and propeller securely fastened together.

The Pilgrim Nut is a patented device which provides a predetermined frictional grip between the propeller and its shaft. With this arrangement the engine torque may be transmitted without loading the key, where it is fitted. The Pilgrim Nut is, in effect, a threaded hydraulic jack which is screwed onto the tailshaft (Figure below). A steel ring receives thrust from a hydraulically pressurised nitrile rubber tyre. This thrust is applied to the propeller to force it onto the tapered tailshaft.

Propeller removal is achieved by reversing the Pilgrim Nut and using a withdrawal plate which is fastened to the propeller boss by studs. When



Pilgrim Nut operation

the tyre is pressurised the propeller is drawn off the taper. Assembly and withdrawal are shown in Figure above.

- **Controllable-pitch propeller**

A controllable-pitch propeller is made up of a boss with separate blades mounted into it. An internal mechanism enables the blades to be moved

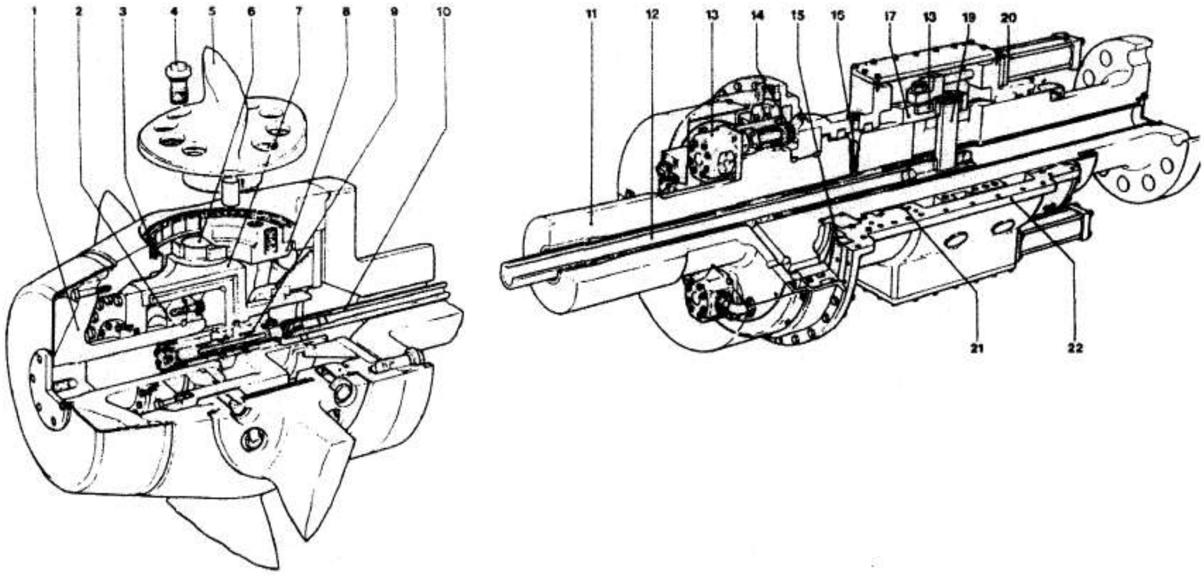


Figure 11.7 Controllable-pitch propeller

1 Piston rod	12 Valve rod
2 Piston	13 Main pump
3 Blade seal	14 Pinion
4 Blade bolt	15 Internally toothed gear ring
5 Blade	16 Non-return valve
6 Crank pin	17 Sliding ring
7 Servo motor cylinder	18 Sliding thrust block
8 Crank ring	19 Corner pin
9 Control valve	20 Auxiliary servo motor
10 Valve rod	21 Pressure seal
11 Mainshaft	22 Casing

simultaneously through an arc to change the pitch angle and therefore the pitch. A typical arrangement is shown in Figure above.

When a pitch demand signal is received a spool valve is operated which controls the supply of low-pressure oil to the auxiliary servo motor. The auxiliary servo motor moves the sliding thrust block assembly to position the valve rod which extends into the propeller hub.

The valve rod admits high-pressure oil into one side or the other of the main servo motor cylinder. The cylinder movement is transferred by a crank pin and ring to the propeller blades. The propeller blades all rotate together until the feedback signal balances the demand signal and the low-pressure oil to the auxiliary servo motor is cut off. To enable emergency control of propeller pitch in the event of loss of power the spool valves can be operated by hand. The oil pumps are shaft driven.

The control mechanism, which is usually hydraulic, passes through the tailshaft and operation is usually from the bridge. Varying the pitch will vary the thrust provided, and since a zero pitch position exists the engine shaft may turn continuously. The blades may rotate to provide astern thrust and therefore the engine does not require to be reversed.

- **Cavitation**

Cavitation, the forming and bursting of vapour-filled cavities or bubbles, can occur as a result of pressure variations on the back of a propeller blade. The results are a loss of thrust, erosion of the blade surface, vibrations in the afterbody of the ship and noise. It is usually limited to high-speed heavily loaded propellers and is not a problem under normal operating conditions with a well-designed propeller.

- **Propeller maintenance**

When a ship is in dry dock the opportunity should be taken to thoroughly examine the propeller, and any repairs necessary should be carried out by skilled dockyard staff.

A careful examination should be made around the blade edges for signs of cracks. Even the smallest of cracks should not be ignored as they act to increase stresses locally and can result in the loss of a blade if the propeller receives a sharp blow. Edge cracks should be welded up with suitable electrodes.

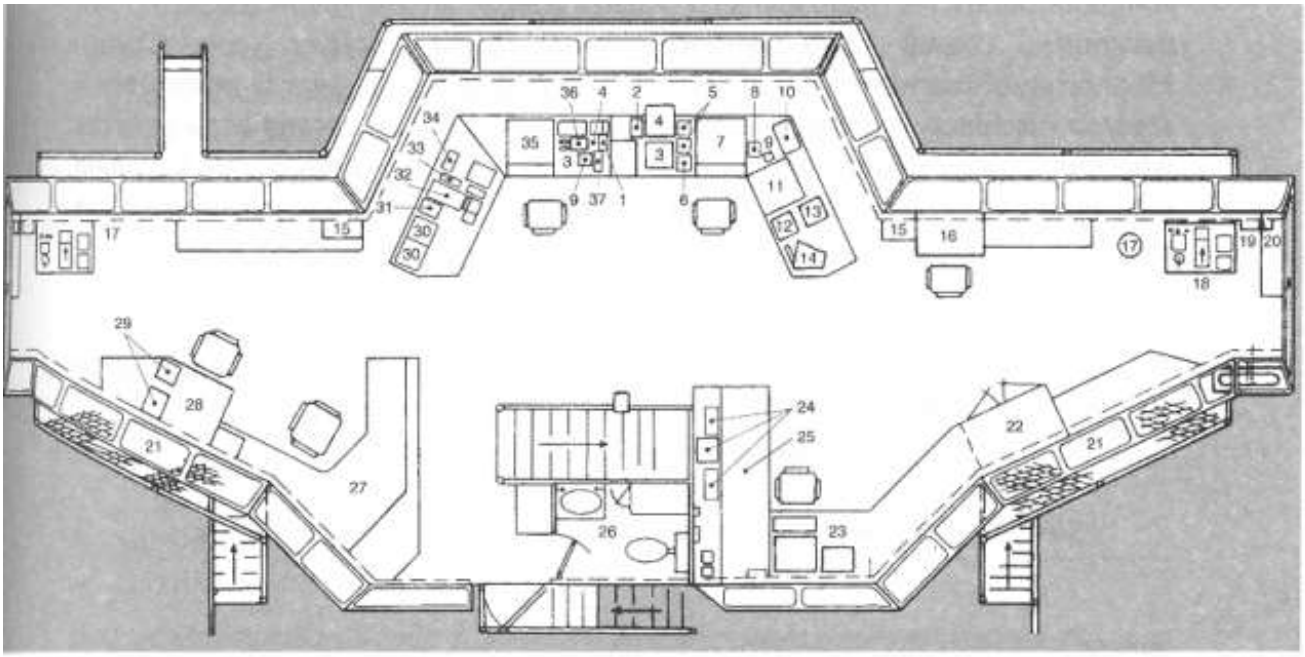
Bent blades, particularly at the tips, should receive attention as soon as possible. Except for slight deformation the application of heat will be required. This must be followed by more general heating in order to stress relieve the area around the repair.

Surface roughness caused by slight pitting can be lightly ground out and the area polished. More serious damage should be made good by

210 Shafting and propellers welding and subsequent heat treatment. A temporary repair for deep pits or holes could be done with a suitable resin filler.

Bridge control

The wheelhouse forms part of the ship’s navigating bridge. It normally runs athwartships and is situated art. From the bridge the ship is nonna1ly navigated, and from there all activities on deck can be seen and controlled by the Captain or
Officer of the Watch.
Today the bridge of a modem ship is tota1ly enclosed by glass screens or windows to give protection from weather. In addition to the steering wheel or steering controls, the ship's main magnetic compass and a repeater from the gyroscopic compass are normally situated on the bridge. It also houses a chart table, radar scanners and a rich array of modem navigating and communication equipment. The type and layout of the wheelhouse and the bridge, as well as bridge wings, varies according to ship types and to the changes in modem technology in shipbuilding and navigation. Here is a layout of a modem wheelhouse.



1 *Autopilot*
2 *VHF Radio*
3 *ME/CPP Controller*
4 *ME Monitor*
5 *Bow Thrusters*
6 *Talk-back System*
7 *Radar with Arpa*
8 *Auto Phone Network*
9 *Windspeed Direction*
10 *Doppler Log*
11 *Voyage Management*
12 *Navigation Lights*
13 *Signal Lights*
14 *CCTV Monitor*
15 *Radar Transceiver*
16 *Desk*
17 *Gyro Repeater*
18 *Wing Control Position*
19 *Talk-back System*
20 *VHF Radio*
21 *Emergency Exit Window*
22 *Master Gyro*
23 *Nav Workstation/PC*
24 *Position Displays*
25 *Chart Table*
26 *Toilet Washroom*
27 *Main Radio Station*
28 *Engineer's Desk*
29 *Alarm Monitor and Control Centre*
30 *Lighting Switchboard*
31 *Group Alarm Display*
32 *Fire Detection Panel*
33 *Duty Indicators*
34 *Watch Receiver*
35 *Radar*
36 *Deadman Alarm Panel*
37 *Emergency Telegraph*

The wheelhouse equipment of a modem ship normally encompasses the main bridge console with the plotting aids (ARPA, i.e. Automatic Radar Plotting Aid), path finder radars (3 cm x-band radar and 10 cm s-band relative motion radar). A number of position fixing and communicational aids may be fitted within the main console, or separately such as satcom and satellite back-up radio-station, navtex receiver, RD finder, satnav with gyro and log interfaces, Loran-C receiver,
Decca navigator, etc. The equipment also includes weather facsimile receivers, autopilot, gyro compass with repeaters, depth sounders, speed logs, sonar, etc.
Radio-equipment is used for safety and commercial messages, and for ship-to-shore communications. It include VHF radio telephone and radiotelegraph, MF transmitter, coastal radio-equipment, watchkeeping receiver (auto alarm).

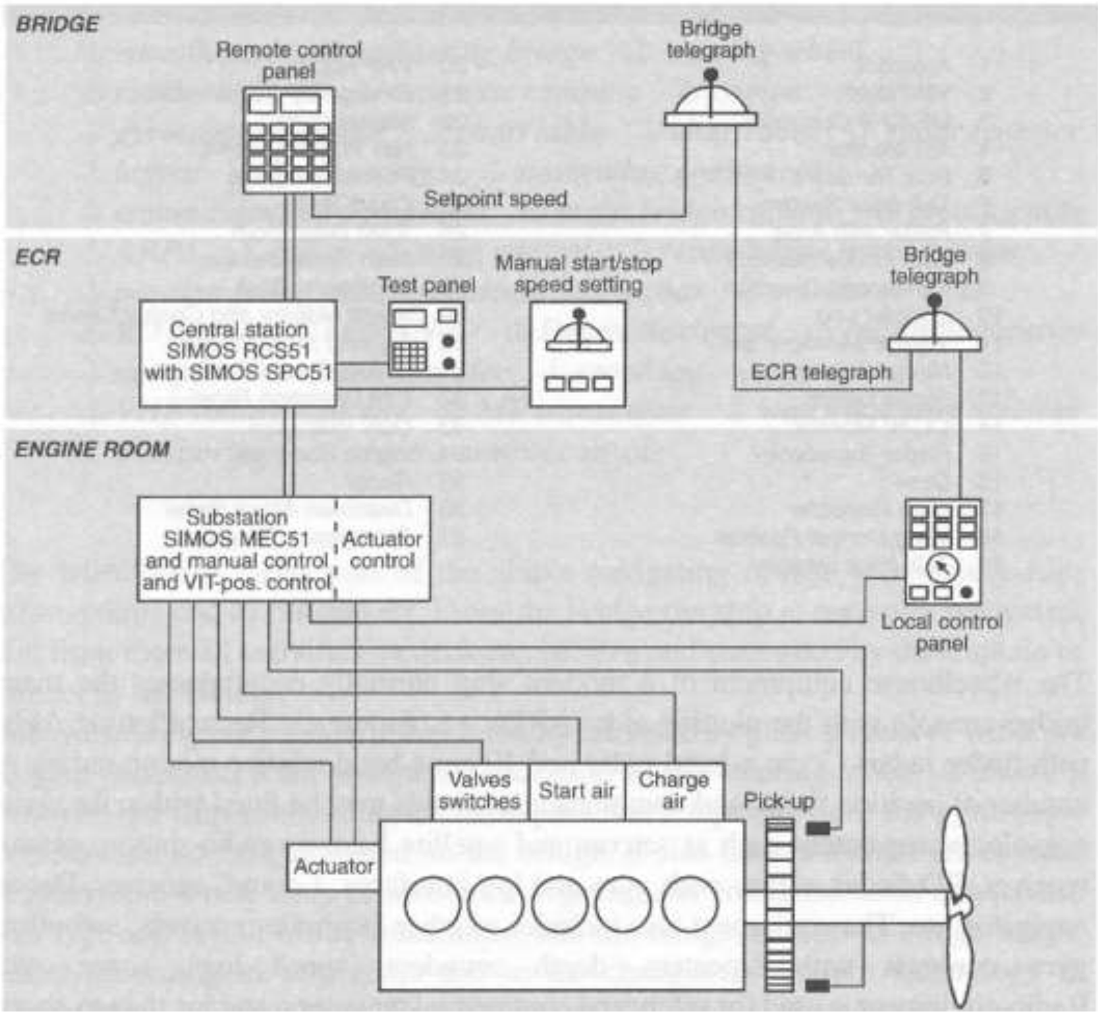
Monitoring of machinery, ship's anchors, steering and cargo gear is made from a separate machinery (engine) control room or from an engine control console in the wheelhouse. The system of monitoring includes engine controls, rudder angle indicator/repeater, how thruster controls, wing controls etc. The wheelhouse can also control the cargo, ballast and loading/discharge system on board.

- **Engine Control**

Where bridge control is installed, the bridge control console may provide the following main engine or bridge control and instrumentation functions:

- ✓ selection of engine or bridge control;

Siemens main engine remote control and speed controller system

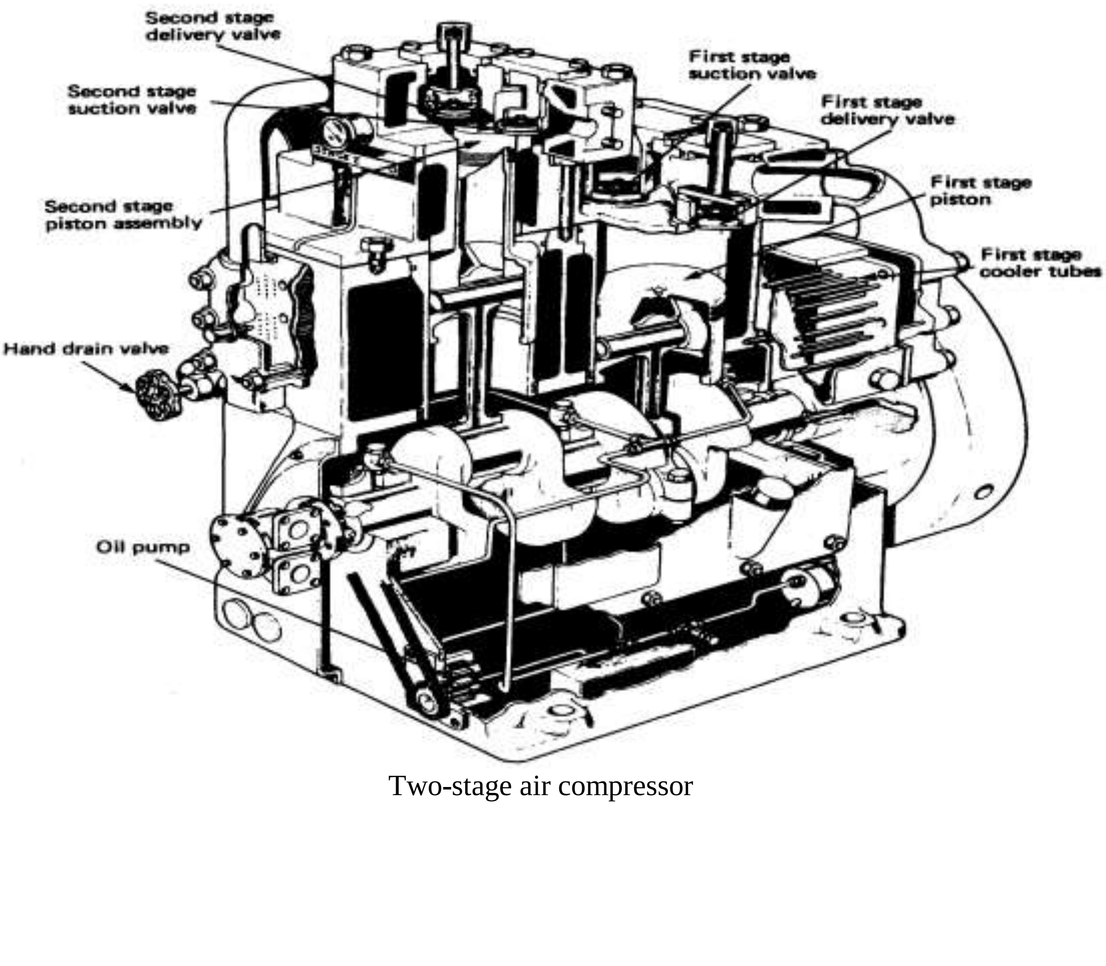


1.11.2. SHIP'S AUXILIARY MACHINERY

Machinery, other than the main propulsion unit, is usually called 'auxiliary' even though without some auxiliaries the main machinery would not operate for long. The items considered are air compressors, heat exchangers, distillation equipment, oil/water separators, sewage treatment plants and incinerators.

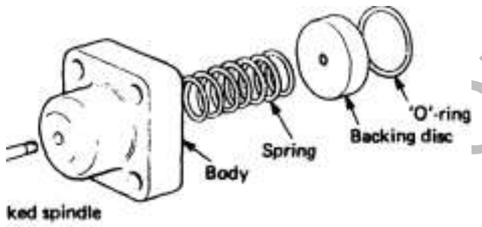
- **Air compressor**

Compressed air has many uses on board ship, ranging from diésel engine starting to the cleaning of machinery during maintenance. The air pressures of 25 bar or more are usually provided in multi-stage machines. Here the air is compressed in the first stage, cooled and compressed to a higher pressure in the next stage, and so on. The two-stage crank machine is probably the most common, and one type is shown in the Figure below.
Air is drawn in on the suction stroke through the first-stage suction valve via the silencer/filter. The suction valve closes on the piston upstroke and the air is compressed. The compressed air, having reached its first-stage pressure, passes through the delivery valve to the first-stage cooler. The second-stage suction and compression now take place in a similar manner, achieving a much higher pressure in the smaller, second-stage cylinder. After passing through the second-stage delivery valve, the air is again cooled and delivered to the storage system.
The machine has a rigid crankcase which provides support for the three crankshaft bearings. The cylinder block is located above and replaceable liners are fitted in the cylinder block. The running gear consists of pistons, connecting rods and the one-piece, two-throw crankshaft. The first-stage cylinder head is located on the cylinder block and the second-stage cylinder head is mounted on the first: each of the heads carries its suction and delivery valves. A chain-driven rotary-gear pump provides lubricating oil to the main bearings and through



Two-stage air compressor

internally drilled passages in the crankshaft to both connecting rod bearings. Cooling water is supplied either from an integral pump or the machinery space system. The water passes into the cylinder block which contains both stage coolers and then into the first and second stage cylinder heads. A water jacket safety valve (Figure below) prevents a build-up of pressure should a cooler tube burst and compressed air escape. Relief valves are fitted to the first and second-stage air outlets and are designed to lift at 10% excess pressure. A fusible plug is fitted after the second-stage cooler to limit delivered air temperature and thus protect the compressed-air reservoirs and pipework.
Cooler drain valves are fitted to compressors. When these are open the machine is 'unloaded' and does not produce compressed air. A compressor when started must always be in the unloaded condition. This



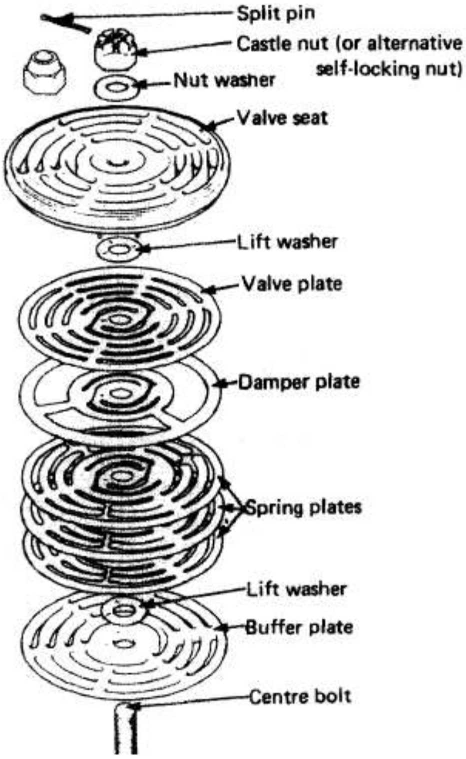
Water jacket safety valve

reduces the starting torque for the machine and clears out any accumulated moisture in the system. This moisture can affect lubrication and may produce oil/water emulsions which line the air pipelines and could lead to fires or explosions.
The compressor motor is started and the machine run up to speed.
The lubricating oil pressure should be observed to build up to the correct value. The first-stage drains and then the second-stage drains are closed and the machine will begin to operate. The pressure gauge cocks should be adjusted to give a steady reading. Where manual drains are fitted they should be slightly opened to discharge any moisture which may collect in the coolers. The cooling water supply should be checked, and also operating temperatures, after a period of running loaded.
To stop the compressor, the first and second-stage cooler drain valves should be opened and the machine run unloaded for two to three minutes. This unloaded running will clear the coolers of condensate.
The compressor can now be stopped and the drains should be left open.
The cooling water should be isolated if the machine is to be stopped for a long period.
Automatic compressor operation is quite usual and involves certain additional equipment. An unloader must be fitted to ensure the machine starts unloaded, and once running at speed will load' and begin to produce compressed air. Various methods of unloading can be used but marine designs favour either depressors which hold the suction valve plates on their seats or a bypass which discharges to suction. Automatic drains must also be fitted to ensure the removal of moisture from the stage coolers. A non-return valve is usually fitted as close as possible to the discharge valve on a compressor to prevent return air flow: it is an essential fitting where unloaders are used.
Control or instrument air supplies have particular requirements with regard to being moisture and oil free and without impurities. A special type of oil-free compressor may

be used to supply control air or it may be treated after delivery from an ordinary air compressor. This treatment results in the air being filtered and dried in order to remove virtually all traces of oil, moisture and any atmospheric impurities.

Maintenance involves the usual checks and overhauls common to reciprocating machinery, e.g. crankcase oil level, cooling water system, operating temperatures and pressures, etc. The suction and delivery air valves for each stage will present the most work in any maintenance schedule. These valves are automatic, requiring a small pressure differential to operate.

The constant rapid opening and closing action of the valves may require the seats to be refaced. Overheating, use of incorrect lubricating oil, or the presence of dirt may result in sticking or pitting of the surfaces. The various buffer plates, spring plates, valve plate and seat which make up a suction or delivery valve can be seen in Figure below. The valves should be stripped and all parts carefully cleaned and examined, any worn parts replaced and the valve seat and plate lightly lapped separately on a flat surface before reassembly to ensure a good seal.



Automatic valve

- **Heat exchangers**

Heat exchangers on board ship are mainly coolers where a hot liquid is cooled by sea water. There are some instances where liquid heating is required, such as heavy fuel oil heaters and sea water heaters for tank cleaning. Although being heat exchangers, the main condenser for a steam ship and the evaporator/distiller are dealt with separately.

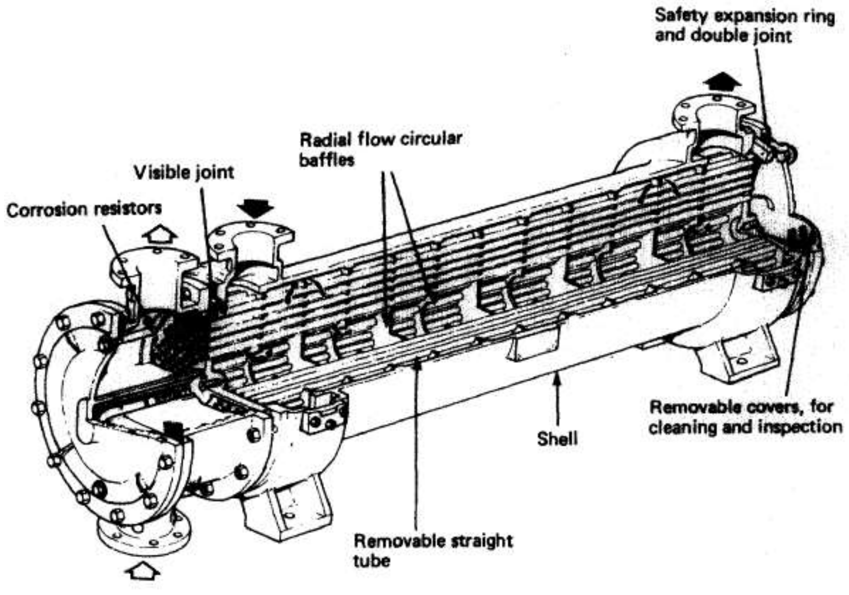
The heat exchange process is accomplished by having the two liquids pass on either side of a conducting surface. The heat from the hot liquid passes to the cold liquid and the conducting surface, i.e. the tube wall, is at a temperature between the two. It is usual for marine heat exchangers to have the two liquids flowing in opposite directions, i.e. counter or contra flow. This arrangement provides a fairly constant temperature difference between the two liquids and therefore the maximum heat transfer for the available surface area.

- **Coolers**

Coolers at sea fall into two groups, shell and tube and the plate type. Both are considered below.

- **Shell and tube**

In the shell and tube design a tube bundle or stack is fitted into a shell (Figure below). The end plates are sealed at either end of the shell and



Shell and tube heat exchanger

provision is made at one end for expansion. The tubes are sealed into the tube plate at either end and provide a passageway for the cooling liquid. Headers or water boxes surround the tube plates and enclose the shell. They are arranged for either a single pass or, as in Figure above, for a double pass of cooling liquid. The tube bundle has baffles fitted which serve to direct the liquid to be cooled up and down over the tubes as it passes along the cooler. The joint arrangements at the tube plate ends are different. At the fixed end, gaskets are fitted between either side of the tube plate and the shell and end cover. At the other end, the tube plate is free to move with seals fitted either side of a safety expansion ring. Should either liquid leak past the seal it will pass out of the cooler and be visible. There will be no intermixing or contamination.

- **Plate type**

The plate-type heat exchanger is made up of a number of pressed plates surrounded by seals and held together in a frame (Figure below). The inlet and outlet branches for each liquid are attached to one end plate.

The arrangement of seals between the plates provides passageways between adjacent plates for the cooling liquid and the hot liquid (Figure below)). The plates have various designs of corrugations to aid heat transfer and provide support for the large, flat surface. A double seal arrangement is provided at each branch point with a drain hole to detect leakage and prevent intermixing or contamination.

- **Operation**

Temperature control of coolers is usually achieved by adjusting the cooling liquid outlet valve. The inlet valve is left open and this ensures a constant pressure within the cooler. This is particularly important with sea water cooling where reducing pressure could lead to aeration or the collecting of air within the cooler. Air remaining in a cooler will considerably reduce the cooling effect. Vents are provided in the highest points of coolers which should be opened on first filling and occasionally afterwards. Vertical mounting of single pass coolers will ensure automatic venting. Positioning the inlet cooling water branch facing downwards and the outlet branch upwards will achieve automatic venting with horizontally mounted coolers. Drain plugs are also fitted at the lowest point in coolers.

- **Maintenance**

Clean heat transfer surfaces are the main requirements for satisfactory operation. With sea water cooling the main problem is fouling of the surfaces, i.e. the presence of marine plant and animal growth.

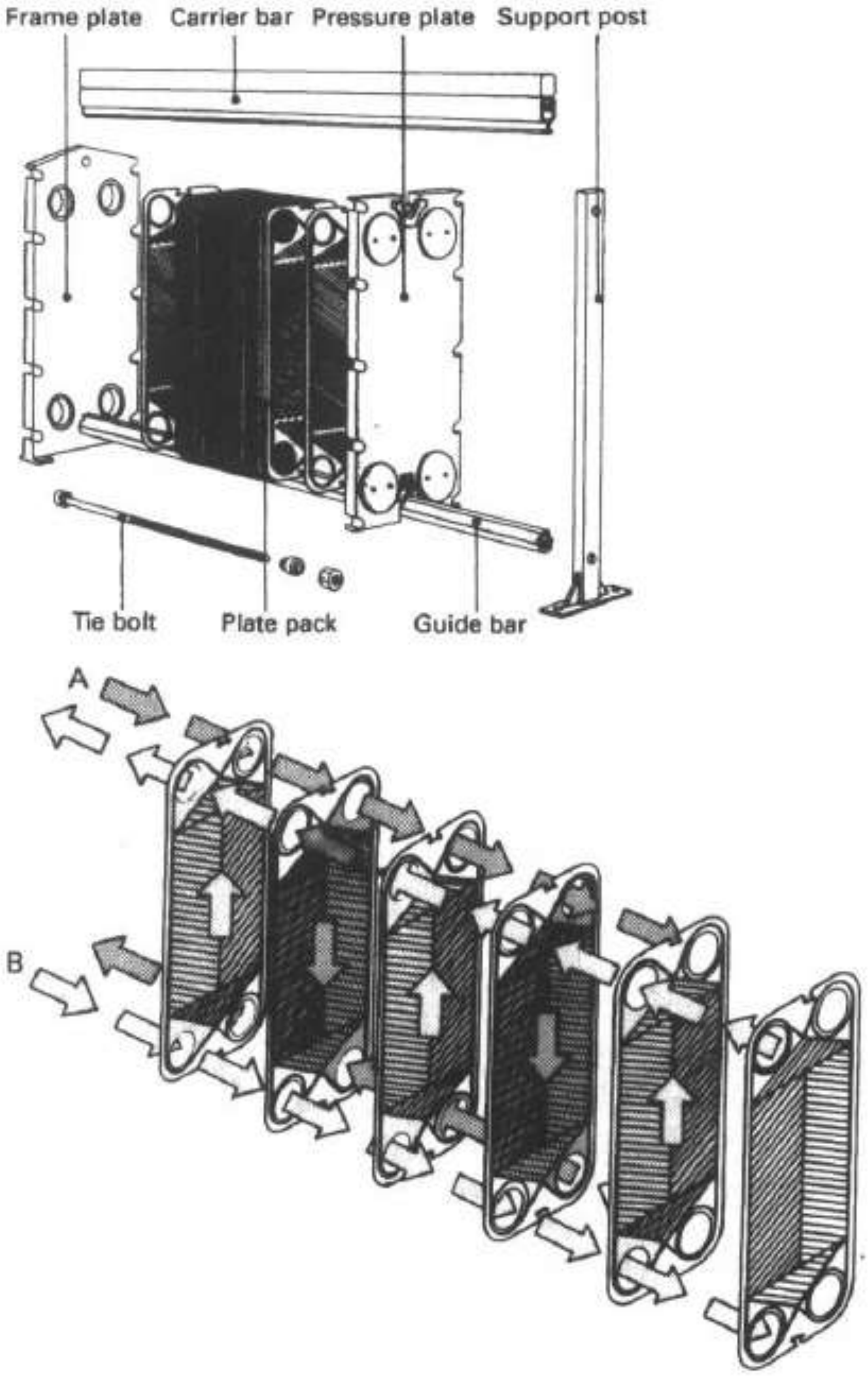


Plate type heat exchange; construction, operation

With shell and tube coolers the end covers are removed to give access to the tubes for cleaning. Special tools are usually provided by the cooler manufacturer for cleaning the tubes. The end covers can also be cleaned.
Tube leakage can result from corrosion. This can be checked for, or identified, by having the shell side of the cooler circulated while the cooling water is shut off and the end covers removed. Any seepage into the tubes will indicate the leak. It is also possible to introduce

fluorescent dyes into the shell-side liquid: any seepage will show under an ultraviolet light as a bright green glow. Leaking tubes can be temporarily plugged at each end or removed and replaced with a new tube.
Plate-type coolers which develop leaks present a more difficult problem.
The plates must be visually examined to detect the faulty point. The joints between the plates can present problems in service, or on assembly of the cooler after maintenance.
Where coolers are out of use for a long period, such as during surveys or major overhauls, they should be drained on the sea water side, flushed through or washed with fresh water, and left to dry until required for service.

- **Heaters**

Heaters, such as those used for heavy oil, are shell and tube type units, similar in construction to coolers. The heating medium in most cases is condensing steam.

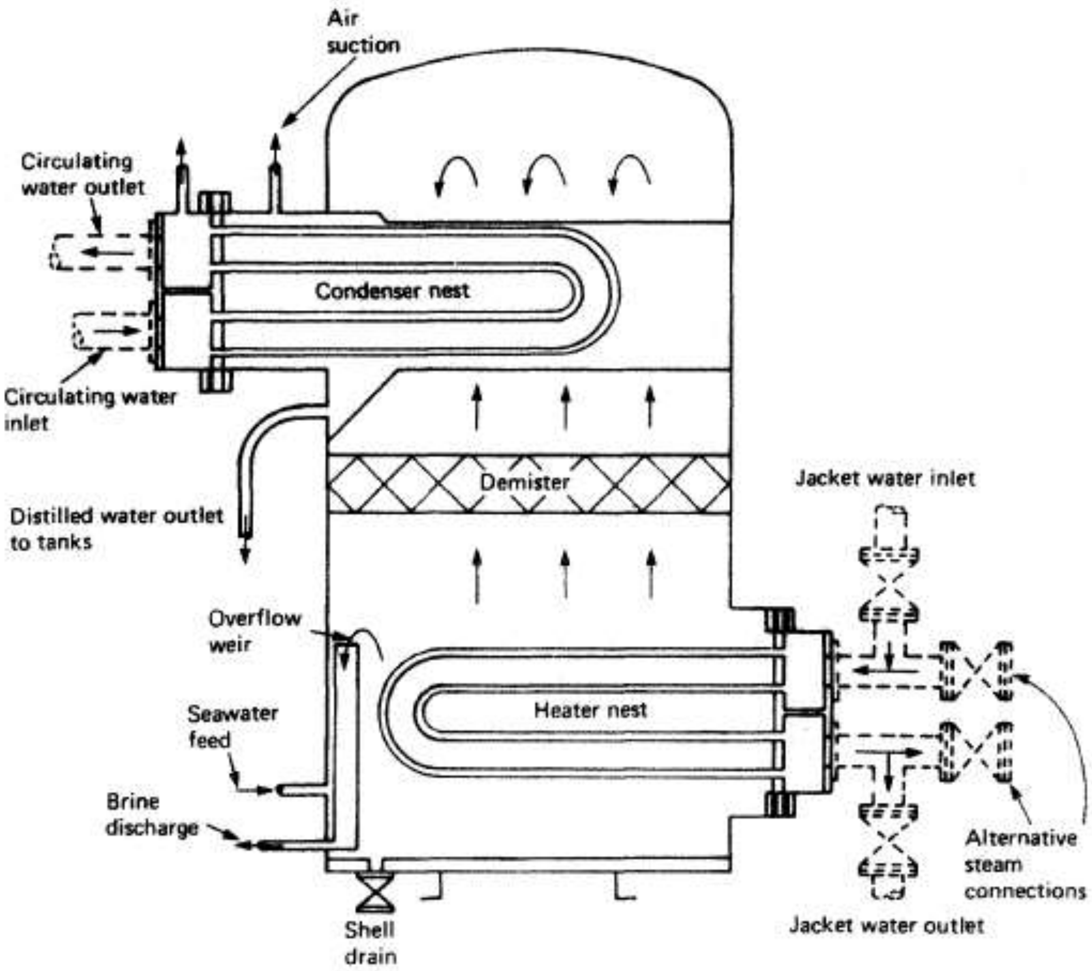
- **Distillation systems**

Distillation is the production of pure water from sea water by evaporation and re-condensing. Distilled water is produced as a result of evaporating sea water either by a boiling or a flash process. This evaporation enables the reduction of the 32000 parts per million of dissolved solids in sea water down to the one or two present in distilled water. The machine used is called an 'evaporator', although the word 'distiller' is also used.

- **Boiling process**

Sea water is boiled using energy from a heating coil, and by reducing the pressure in the evaporator shell, boiling can take place at about 60°C.

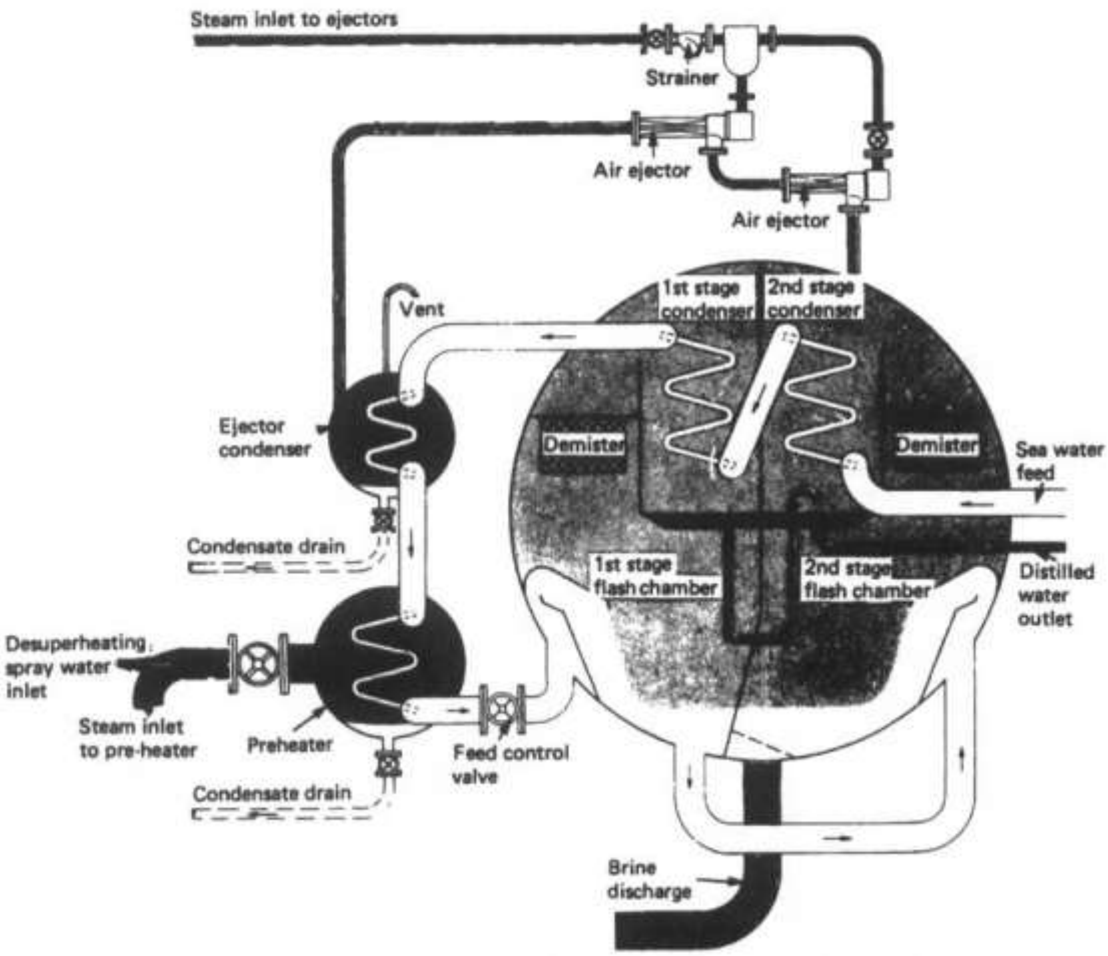
The sea water from the ship's services is first circulated through the condenser and then part of the outlet is provided as feed to the evaporation chamber (Figure below). Hot diesel engine jacket water or steam is passed through the heater nest and, because of the reduced pressure in the chamber, the sea water boils. The steam produced rises and passes through a water separator or demister which prevents water droplets passing through. In the condensing section the steam becomes pure water, which is drawn off by a distillate pump. The sea water feed is regulated by a flow controller and about half the feed is evaporated. The remainder constantly overflows a weir and carries away the extra salty water or brine. A combined brine and air ejector draws out the air and brine from the evaporator.



Boiling process evaporator

- **Flash process**

Flash evaporation is the result of a liquid containing a reasonable amount of sensible heat at a particular pressure being admitted to a chamber at a lower pressure. The liquid immediately changes into steam, i.e. it flashes, without boiling taking place. The sensible heat content, water pressure and chamber pressure are designed to provide a desired rate of evaporation. More than one stage of evaporation can take place by admitting the liquid into chambers with progressively lower pressures.



Two- stage flash evaporate

A two-stage flash evaporator is shown in Figure above. The feed pump circulates sea water through the vapour condensers and the preheater.

The heated sea water then passes to the first-stage flash chamber where some of it flashes off. A demister removes any water droplets from the steam as it rises and is then condensed in the first-stage condenser.

The heated sea water passes to the second-stage flash chamber, which is at a lower pressure, and more water flashes off. This steam is demisted and condensed and, together with the distilled water from the first-stage, is drawn off by the distillate pump.

The concentrated sea water or brine remaining in the second-stage flash chamber is drawn off by the brine pump. The preheater uses steam to heat the sea water and most of the latent heat from the flash steam is returned to the sea water passing through the condensers. An air ejector is used to maintain the low pressure in the chambers and to remove any gases released from the sea water.

- **Maintenance**

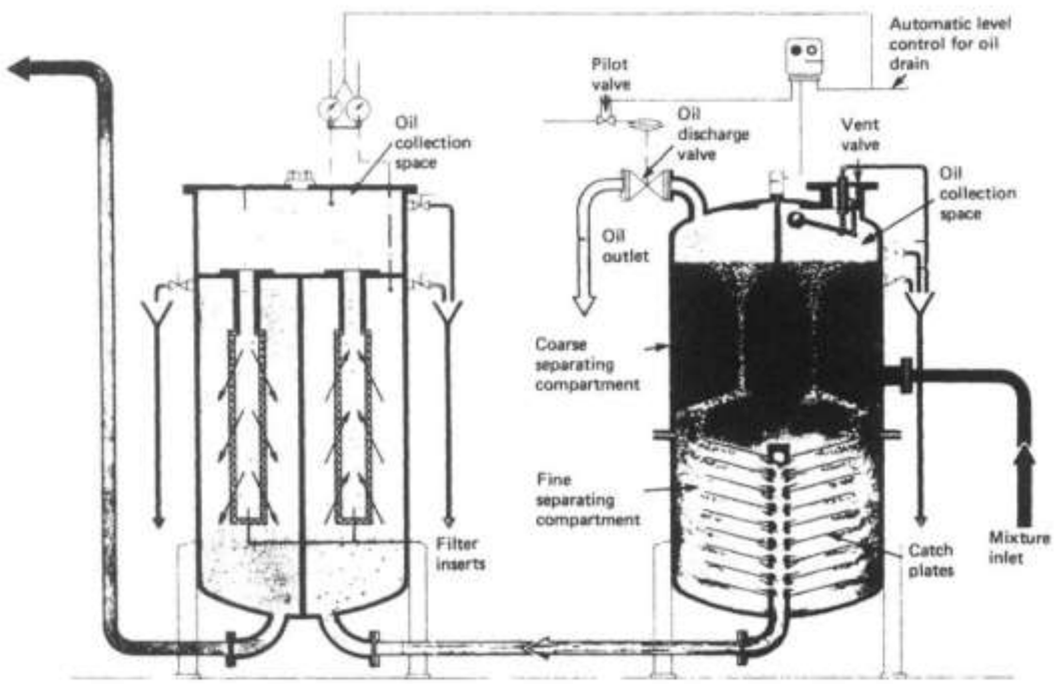
During the operation of evaporating plants, scale will form on the heating surfaces. The rate of scale formation will depend upon the operating temperature, the flow rate and density of the brine.

Scale formation will result in greater requirements for heating to produce the rated quantities of distilled water or a fall-off in production for a fixed heating supply.

Cold shocking, the alternate rapid heating and cooling of the tube surfaces, for a boiling process type, can reduce scale build-up.
Ultimately, however, the plant must be shut down and the scale removed either by chemical treatment or manual cleaning.

- ## Oil/water separators

Oil/water separators are used to ensure that ships do not discharge oil when pumping out bilges, oil tanks or any oil-contaminated space.
International legislation relating to oil pollution is becoming more and more stringent in the limits set for oil discharge. Clean water suitable for discharge is defined as that containing less than 15 parts per million of oil. Oil/water separators using the gravity system can only achieve 100 parts per million and must therefore be used in conjunction with some form of filter.
A complete oil/water separator and filter unit for 15 parts per million purity is shown in Figure below. The complete unit is first filled with clean water; the oily water mixture is then pumped through the separator inlet pipe into the coarse separating compartment. Here some oil, as a result of its lower density, will separate and rise into the oil collection space. The remaining oil/water mixture now flows down into the fine separating compartment and moves slowly between the catch plates.
More oil will separate out onto the underside of these plates and travel outwards until it is free to rise into the oil collecting space. The almost oil-free water passes into the central pipe and leaves the separator unit.
The purity at this point will be 100 parts per million or less. An automatically controlled valve releases the separated oil to a storage tank. Air is released from the unit by a vent valve. Steam or electric heating coils are provided in the upper and sometimes the lower parts of the separator, depending upon the type of oil to be separated.
Where greater purity is required, the almost oil-free water passes to a filter unit. The water flows in turn through two filter stages and the oil removed passes to oil collecting spaces. The first-stage filter removes physical impurities present and promotes some fine separation. The



Oily water separator

second-stage filter uses coalescer inserts to achieve the final de-oiling.

Coalescence is the breakdown of surface tension between oil droplets in an oil/water mixture which causes them to join and increase in size. The oil from the collecting spaces is drained away manually, as required, usually about once a week. The filter inserts will require changing, the period of useful life depending upon the operating conditions.
Current legislation requires the use of a monitoring unit which continuously records and gives an alarm when levels of discharge in excess of 15 parts per million occur.

- **Sewage treatment**

The discharge of untreated sewage in controlled or territorial waters isusually banned by legislation. International legislation is in force to cover any sewage discharges within specified distances from land. As a result, and in order to meet certain standards all new ships have sewage treatment plants installed.
Untreated sewage as a suspended solid is unsightly. In order to break down naturally, raw sewage must absorb oxygen. In excessive amounts it could reduce the oxygen content of the water to the point where fish and plant life would die. Pungent smells are also associated with sewage as a result of bacteria which produce hydrogen sulphide gas. Particular bacteria present in the human intestine known as E, coli are also to be found in sewage. The E. coli count in a measured sample of water indicates the amount of sewage present.
Two particular types of sewage treatment plant are in use, employing either chemical or biological methods. The chemical method is basically a storage tank which collects solid material for disposal in permitted areas or to a shore collection facility. The biological method treats the sewage so that it is acceptable for discharge inshore.

- **Chemical sewage treatment**

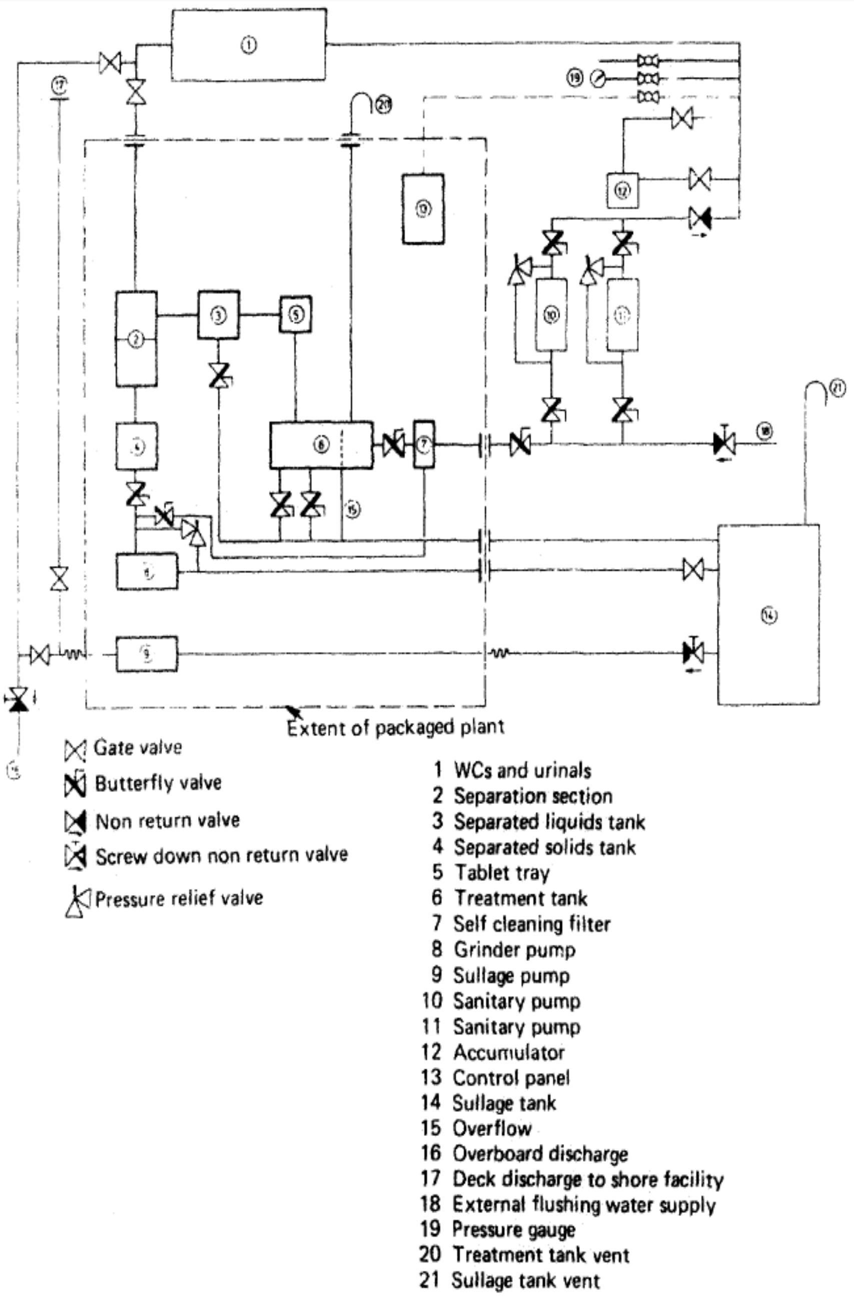
This system minimises the collected sewage, treats it and retains it until it can be discharged in a decontrolled area, usually well out to sea. Shore receiving facilities may be available in some ports to take this retained sewage.
This system must therefore collect and store sewage produced while the ship is in a controlled area. The liquid content of the system is reduced, where legislation permits, by discharging wash basins, bath and shower drains straight overboard. Any liquid from water closets is treated and used as flushing water for toilets. The liquid must be treated such that it is acceptable in terms of smell and appearance.
A treatment plant is shown diagrammatically in Figure below. Various chemicals are added at different points for odour and colour removal and also to assist breakdown and sterilisation. A comminutor is used to physically break up the sewage and assist the chemical breakdown process. Solid material settles out in the tank and is stored prior to discharge into the sullage tank: the liquid is recycled for flushing use.
Tests must be performed daily to check the chemical dosage rates.
This is to prevent odours developing and also to avoid corrosion as a result of high levels of alkalinity.

- **Biological sewage treatment**

The biological system utilizes bacteria to completely break down the sewage into an acceptable substance for discharge into any waters. The extended aeration process provides a climate in which oxygen-loving bacteria multiply and digest the sewage, converting it into a sludge.

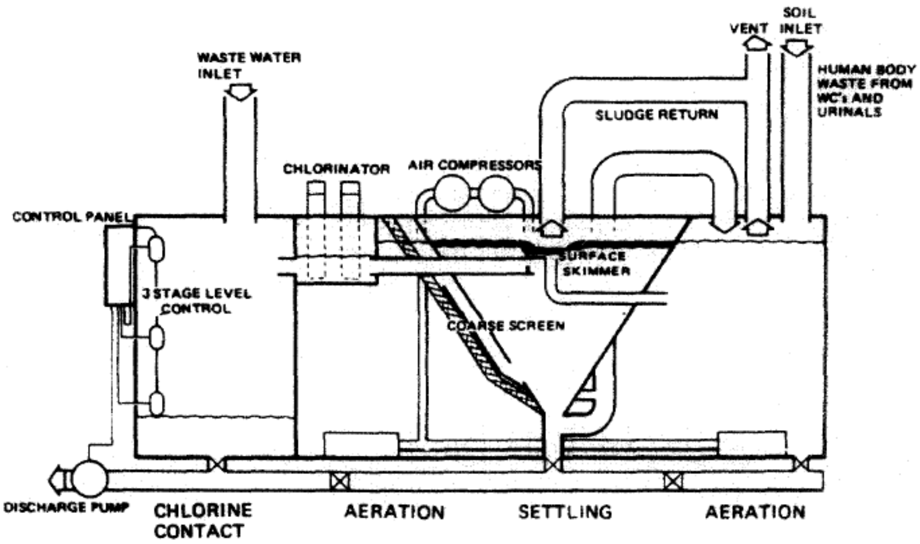
These oxygen-loving bacteria are known as aerobic.

The treatment plant uses a tank which is divided into three watertight compartments: an aeration compartment, settling compartment and a chlorine contact compartment (Figure below). The sewage enters the



Chemical sewage treatment plant

aeration compartment where it is digested by aerobic bacteria and micro-organisms, whose existence is aided by atmospheric oxygen which is pumped in. The sewage then flows into the settling compartment where the activated sludge is settled out. The clear liquid flows to the chlorinator and after treatment to kill any remaining bacteria it is discharged. Tablets are placed in the chlorinator and require



Biological sewage treatment plant

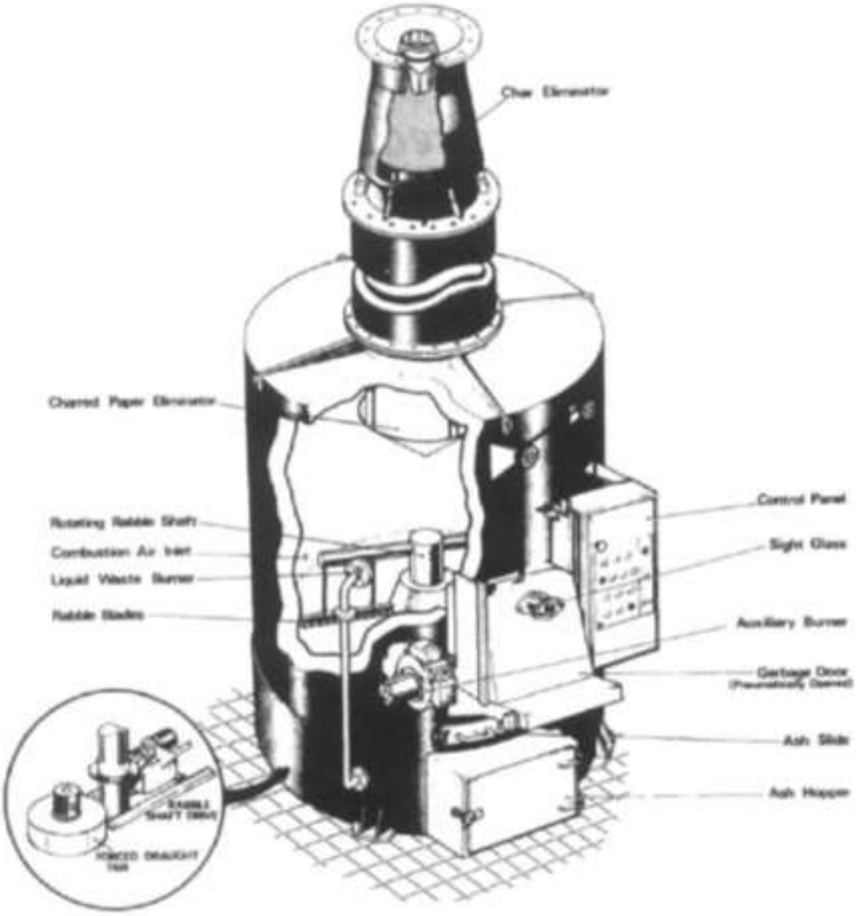
replacement as they are used up. The activated sludge in the settling tank is continuously recycled and builds up, so that every two to three months it must be partially removed. This sludge must be discharged only in a decontrolled area.

Incinerator

Stricter legislation with regard to pollution of the sea, limits and, in some instances, completely bans the discharge of untreated waste water, sewage, waste oil and sludge. The ultimate situation of no discharge can be achieved by the use of a suitable incinerator. When used in conjunction with a sewage plant and with facilities for burning oil sludges, the incinerator forms a complete waste disposal package. One type of incinerator for shipboard use is shown in Figure below.

The combustion chamber is a vertical cylinder lined with refractory material. An auxiliary oil-fired burner is used to ignite the refuse and oil sludge and is thermostatically controlled to minimise fuel consumption.

A sludge burner is used to dispose of oil sludge, water and sewage sludge and works in conjunction with the auxiliary burner. Combustion air is provided by a forced draught fan and swirls upwards from tangential ports in the base. A rotating-arm device accelerates combustion and also clears ash and non-combustible matter into an ash hopper. The loading door is interlocked to stop the fan and burner when opened.



Incinerator

Solid material, usually in sacks, is burnt by an automatic cycle of operation. Liquid waste is stored in a tank, heated and then pumped to the sludge burner where it is burnt in an automatic cycle. After use the ash box can be emptied overboard.

1.11.3. GENERAL KNOWLEDGE OF MARINE ENGINEERING SYSTEMS

Evolution of marine engine

Effort to apply mechanical power to propulsion and operation of ship since eighteen century as never been easy.

Design requirement:

- ✓ It require exceptional number of specialization to plan, design and build a ship.
- ✓ This make maritime technology distinctive integrated technology in part of many engineering disciplines require for the design of system of transport, exploration, naval craft which have one thing in common.
- ✓ Operate on the surface of water
- ✓ The field of engineering under maritime technology – naval architecture and marine engineering is with at least the following:

- Inland waterway and ocean transportation
- Naval engineering
- Ocean engineering
- Contention between naval architecture and marine engineer in system design.

Fuel consumption became in the last few years a critical design parameter in early phases of ship design. Naval ships, which have a large spectrum of operational requirements, need to be also designed to optimize fuel consumption. Throughout, ship resistance predictions during design were the key to a successful design. Many methods were developed for that need; some examples include analytic, numerical, and parametric (based on history and experience). Resistance predictions are the base to machinery and drive train design, speed assessments, tankage, annual fuel usage and life cycle cost (LCC) predictions and many more important parameters leading to critical decision making through the design process.

Even today, early stages of design, and preliminary design of a ship are based on database of former design, and empirical calculation based on very few characteristic parameters of the ship.