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POMORSKI ODJEL

PREDDIPLOMSKI STUDIJ BRODOSTROJARSTVO

MARINE ENGINEERING COURSE

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1. CLASSIFICATION SOCIETIES

Every ship is designed and constructed to the certain class and is operated in the conditions related to the given class. Class means the character assigned to a vessel by a classification society, depending on the design of the vessel, the quality of materials employed, the scantlings of the various structural members, and the outfit and equipment, all of which should be up to the standard specified by the society's rules. To ensure that the condition and seaworthiness of classed ships are maintained they are examined periodically and the continuance of the class depends upon the result of such survey.

Classification society is a special institution which has as its purpose supervision of vessels during their construction and afterwards, in respect to their seaworthiness and upkeep, and the placing of vessels in grades or "classes" according to the society's rules for each particular type of vessel. The principle classification societies are: Lloyd's Register of Shipping, London; American Bureau of Shipping, New York; Bureau Veritas, Paris; Germanischer Lloyd, Berlin; Det Norske Veritas, Oslo; Japanese Marine Corporation, Tokyo; Russian Maritime Register of Shipping, St. Petersburg. Lloyd's Register of Shipping is the largest and oldest British classification society, established in 1834. In Croatia there is the Croatian Register of Shipping (Hrvatski registar brodova).

Classification societies are known to have a profound influence on shipping, ship design and ship safety. The fundamental purpose of classification is to ensure maintenance of seaworthiness of all classed ships. Withdrawal of a class means cessation of the Register supervision when renewal of a class seems impossible for the Register. The class might be withdrawn by the Register at the shipowner's desire as well. The Classification societies operate throughout the world and publish rules and regulations directly related to the structural efficiency of the ship and reliability of the propelling machinery. Classification implies the ship and the machinery conform to the standards published in the rules of the Society.

The societies' rules are not absolutely rigid in every detail, as the progress of shipbuilding methods and materials makes it necessary that a certain amount of latitude be allowed. They represent the minimum standards which the society considers necessary for a particular type of vessel. In classed vessels the materials and the actual construction are under the supervision of the society's surveyors. At completion of the building and after trials at sea, classification certificates are issued and handed to the owners.

Classification certificate states that the ship has been found to comply with the rules of the society. It also mentions the class granted to the ship and the conditions which have to be complied with if the class is to be maintained. The record in the Register Book is given in symbols.

100A.1. indicates the highest class for steel ships and is assigned to all vessels built under survey and in accordance with the society's rules and regulations. The figure 1 after letter A indicates that the anchors and cables have been tested by the society's surveyors and are in accordance with the rules and in good condition. If there is anything amiss, it is replaced by a dash, so "100A.1." and "100A.-" respectively. The class 100A.1. is followed by the descriptive notation, such as "oil tanker", "bulker", etc. The Maltese cross ✠ indicates that the vessel has been built under survey.

L.M.C. signifies that a "Lloyd's Machinery Certificate" has been granted.

Surveys, repairs and any alterations to the hull or machinery of the vessel are mentioned on the certificate. Two certificates are issued to the mechanically propelled vessels, one for the hull and another for the engines and/or boilers.

2. HOW MERCHANT SHIPS OPERATE

Merchant vessels can operate in the following three basic ways:

They can operate as liners. These are employed on regular routes on a fixed timetable. A list of their arrival and departure dates is published in advance and they sail whether they are full or not. Liners can be classed as either deep-sea liners or short-sea liners. Ferries are also classed as liners. These offer a daily or weekly service for passengers and vehicles across channels and narrow seas. A few ships are still employed as passenger liners. They not only carry passengers but also some cargo on routes from Europe to North America and to the Far East. Nowadays the passenger trade is very small and passenger liners usually operate as cruise ships for part of the year.

Merchant ships can also operate as tramps. These vessels do not sail on regular routes or keep to a fixed timetable, but are employed where there is cargo for them to carry. Coasters are also tramps and these ply on coastal routes and up rivers to inland ports. The traditional tramp cargoes are dry bulk cargoes, but some vessels are designed to carry general cargoes.

A large number of merchant ships operate as specialised vessels. These are designed to carry a particular type of cargo. There are several types of specialised vessel. The most common are oil tankers. They are owned by the major oil companies or by independent operators. Two other types of liquid bulk carrier of growing importance are chemical carriers and liquefied natural gas (LNG) carriers.

2.1 TYPES OF MERCHANT SHIPS

Merchant ships can be classified according to what they carry. Most are designed to carry cargo. Some are also designed to carry passengers.

Cargo ships can be divided into two basic types. One type carries dry cargo, the other carries liquid cargo; however an OBO ship is designed to carry both. A traditional dry cargo ship is the multi-deck vessel. Her holds are divided horizontally by one or two 'tween decks, because these make stowage of individual packages easier. Dry bulk cargo is carried in bulk carriers. These do not have 'tween decks as cargo is carried loose. The most modern type of dry cargo carrier is the container ship. They carry containers of standard dimensions, consequently stowage is easier. Fruit, meat and dairy produce are carried in refrigerated ships. Oil tankers are the most common type of liquid cargo carrier. They are often very large, because huge quantities of oil need to be transported and one large vessel is more economical to operate than two smaller ones. Two other types of liquid bulk carrier of growing importance are the liquefied natural gas (LNG) carrier and the chemical carrier, although chemicals can also be carried in drums in general cargo ships.

In comparison with cargo vessels, passenger ships are fewer in number and type. The traditional passenger ship is the passenger liner. Nowadays their number has been greatly reduced, because of competition from air transport. Another type of passenger vessel is the cruise ship. These are similar in appearance to passenger liners. The most common type of passenger vessel is the ferry. Many of them are also designed to carry vehicles, therefore these have doors at the stern or bows.

Table 1 – Types of merchant ships

- Merchant Ships
    - Bulk carriers
    - Oil tankers
    - Chemical tankers
    - LNG tankers
    - Container ships
    - Passenger liners
- Auxiliary vessels
- Tugs

3. SHIP CONSTRUCTION

Ships are large, complex units which must be self-sustaining in their environment for long periods with a high degree of reliability. A ship is the product of two main areas of skill, those of the naval architect and the marine engineer. The naval architect is concerned with the hull, its construction, form, habitability and ability to endure its environment. The marine engineer is responsible for the various systems which propel and operate the ship. More specifically, this means the machinery required for propulsion, steering, anchoring and ship securing, cargo handling, air conditioning, power generation and its distribution. Some overlap in responsibilities occurs between naval architects and marine engineers in areas such as propeller design, the reduction of noise and vibration in the ship's structure, and engineering services provided to considerable areas of the ship.

A ship may be divided into three distinct areas: the cargo-carrying holds or tanks, the accommodation and the machinery space. Depending upon the type each ship will assume varying proportions and functions. An oil tanker, for instance, will have the cargo-carrying region divided into tanks by two longitudinal bulkheads and several transverse bulkheads. There will be considerable quantities of cargo piping both above and below decks. The general cargo ship will have various cargo holds which are usually the full width of the vessel and formed by transverse bulkheads along the ship's length. Cargo handling equipment will be arranged on deck and there will be large hatch openings closed with steel hatch covers. The accommodation areas in each of these ship types will be sufficient to meet the requirements for the ship's crew, provide a navigating bridge area and a communications centre. The machinery space size will be decided by the particular machinery installed and the auxiliary equipment necessary. A passenger ship, however, would have a large accommodation area, since this might be considered the 'cargo space'. Machinery space requirements will probably be larger because of air conditioning equipment, stabilisers and other passenger related equipment.

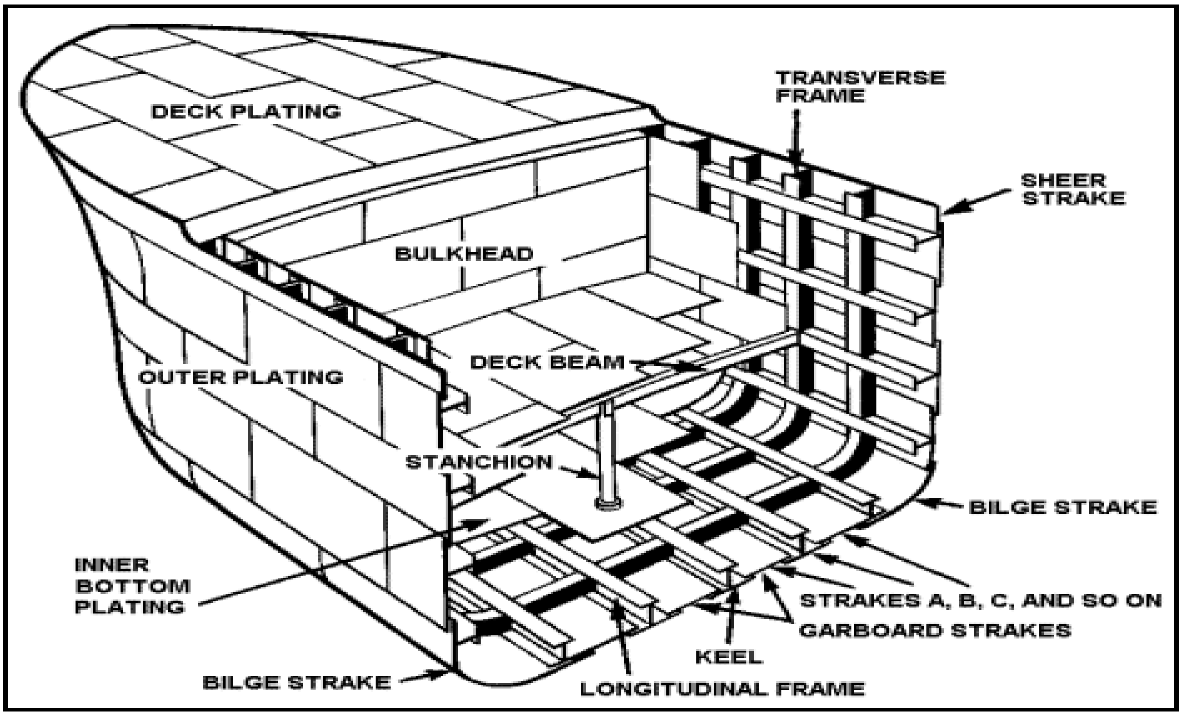
3.1 TERMS RELATING TO THE HULL

The hull is the main body of the ship below the main outside deck. The hull consists of an outside covering (or shell plating) and an inside framework to which the plating is secured. The plating and framework are usually made of steel and secured by welding. However, there may still be some areas where rivets are used.

If the coatings applied to the hulls of modern commercial vessels are maintained, they act as a deterrent to the settlement of marine organisms on vessel surfaces below the water line. Studies have shown that there are areas on the hull where the coatings are compromised, thus allowing settlement of marine fouling organisms. Fouling organisms have also been noted to exist in sheltered areas around rudder posts, and within sea chest intakes.

The main centreline structural part of the hull is the keel, which runs from the stem at the bow to the sternpost at the stern. The keel is the backbone of the ship. To the keel are fastened the frames, which run athwartships. These are the ribs of the ship and give shape and strength to the hull. Deck beams and bulkheads support the decks and give added strength to resist the pressure of the water on the sides of the hull.

Figure 1 – Construction of a hull



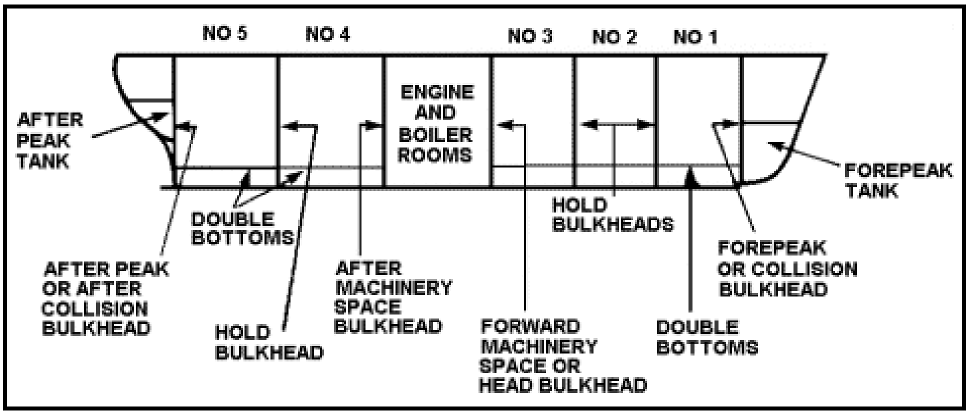
SHELL PLATING

The shell plating provides water-tightness. The plates, the principal strength members of a ship, have various thickness. The heaviest plates are put on amidships. The others are put on so that they taper toward both ends of the ship (from the keel toward the bilge and from the bilge toward the upper row of plates). Using plates of various thickness reduces the weight of the metal used and gives the vessel additional strength at its broadest part. The plates, put on in rows from bow to stern, are called strakes. They are lettered consecutively, beginning at the keel and going upward.

BULKHEADS

The interior of the ship is divided by the bulkheads and decks into watertight compartments. A vessel could be made virtually unsinkable if it were divided into enough small compartments. However, too many compartments would interfere with the arrangement of mechanical equipment and the operation of the ship. Engine rooms must be large enough to accommodate bulky machinery. Cargo spaces must be large enough to hold large equipment and containers.

Figure 2 – Bulkheads and decks



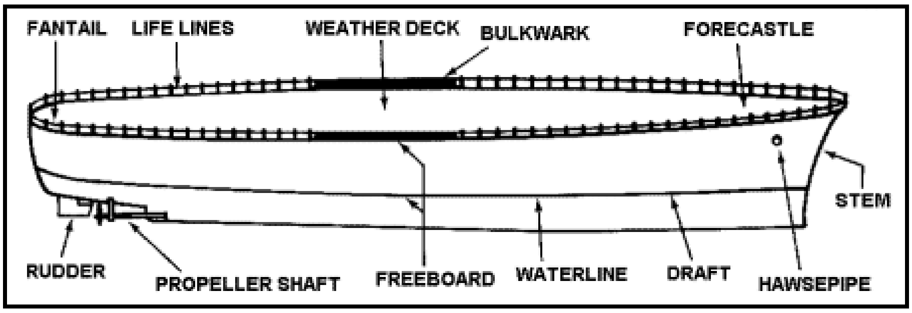
ENGINE ROOM

The engine room is a separate compartment containing the propulsion machinery of the vessel. Depending on the size and type of propulsion machinery, other vessel machinery may be located there (such as generators, pumping systems, evaporators, and condensers for making fresh water).

EXTERNAL PARTS OF THE HULL

The waterline is the water-level line on the hull when afloat. The vertical distance from the waterline to the edge of the lowest outside deck is called the freeboard. The vertical distance from the waterline to the bottom of the keel is called the draft. The waterline, draft, and freeboard will change with the weight of the cargo and provisions carried by the ship. The draft of the ship is measured in feet and inches. Numbered scales are painted on the side of the ship at the bow and stern.

Figure 3 – External parts of the hull



The relationship between the drafts at the bow and stern is the trim. When a ship is properly balanced fore and aft, she is in trim. If the vessel is out of balance laterally or athwartships (leaning to one side) she has a list. She may be listing to starboard or listing to port. Both trim and list can be adjusted by shifting the weight of the cargo or transferring the ship's fuel and water from one tank to another in various parts of the hull.

The general area in the forward part of the ship is the forecastle. Extensions of the shell plating above the deck are called bulwarks. The small drains on the deck are scuppers. The uppermost deck running from the bow to the stern is called the weather deck. The main deck area over the stern is called the poop deck.

Below the waterline are the propellers or screws which drive the ship through the water. The propellers are attached to and are turned by the propeller shafts. A ship with only one propeller is called a single-screw ship. Ships with two propellers are called twin-screw ships. The rudder is used to steer the ship.

4. SHIPBOARD DIRECTIONS AND LOCATIONS

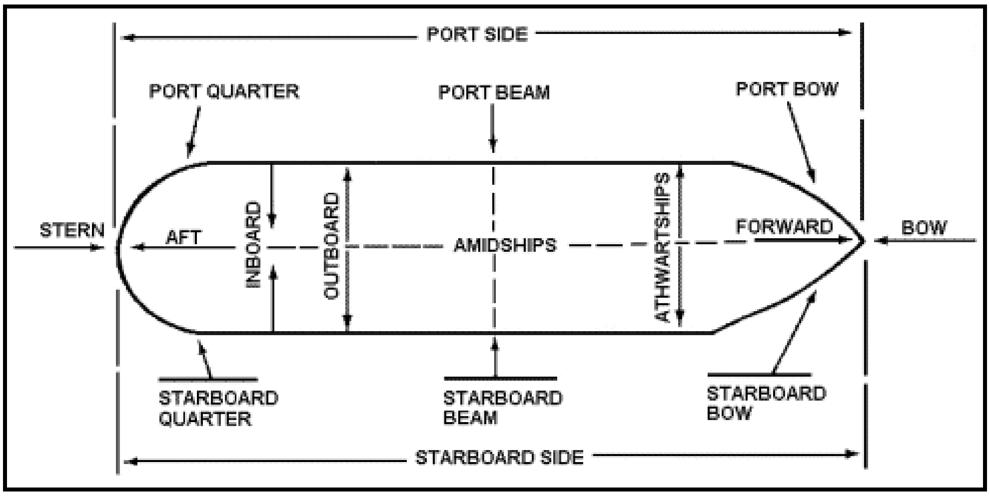
The front end of the ship is the bow. When the vessel is moving forward, it is going ahead. When facing toward the bow, the front-right side is the starboard bow and the front-left side is the port bow.

The central or middle area of a ship is amidships. The right centre side is the starboard beam and the left centre side is the port beam.

The rear of a vessel is the stern. When the ship moves in that direction she is going astern. When looking forward, the right-rear section is called the starboard quarter and the left-rear section is called the port quarter.

The entire right side of a vessel from bow to stern is the starboard side and the left side is the port side. A line, or anything else, running parallel to the longitudinal axis or centreline of the vessel is said to be fore and aft and its counterpart, running from side to side, is athwartships.

Figure 4 – Locations and directions aboard ship



5. THE ORGANISATION OF A SHIP'S CREW

The man in charge of a ship is the Master. He is responsible for the ship, her cargo and the safety of the crew. He must be well qualified and an experienced navigator. Although his correct title is the Master, he is addressed as 'Captain'.

The organisation of the crew of a cargo ship is changing, but it is still customary to find Deck, Engine and Catering Departments in ships of a reasonable size. Each department is made up of a varied number of officers, petty officers and ratings.

The Chief Officer, or First Mate as he is often called, is the Master's chief officer and head of the Deck Department. He is assisted by a Second Officer (Mate), a Third Officer (Mate), and sometimes a Fourth Officer (Mate). Several companies employ a First Officer as well as a Chief Officer. The Deck Department also includes a Boatswain (Bosun) and a Carpenter, both petty officers, and a number of ratings. These are made up of Able Seamen (AB), Ordinary Seamen (OS) and a middle grade known as Efficient Deck Hands (EDH). There are other grades of seamen. On some ships Navigating Cadets are carried for training purposes.

The Chief Engineer is head of the Engine Department. He is assisted by a Second, Third, Fourth and sometimes Fifth Engineer. An Electrical Officer may also be carried. The engine room petty officers are the Storekeeper and Donkeyman. On tankers there is also a Pump man. He is also a petty officer. There may also be Engineer Cadets.

The Catering Department is under the Chief Steward. It is divided into a saloon and galley section. The former is headed by the Second Steward, the latter by the Ship's Cook. They are both usually petty officers. They are assisted by several stewards and cooks, and by a number of junior ratings.

5.1 THE DECK DEPARTMENT:

They are responsible for navigation of the ship, loading/discharge of cargo, radio communication and control/safety of the crew, and passengers. The Master is in overall command of the ship and is responsible for the safety, efficiency and commercial feasibility of his ship. His duties are navigational at sea. While in ports he is responsible for cargo operations.

Master/ Captain carries out the following tasks:

- Manages navigation of the ship
- Maintains orderliness and discipline
- Ensures safety of passengers, crew and the cargo

- Commands manoeuvring to avoid hazards
- Checks the location of the ship's position using navigational aids
- Acts as the representative of the ship's owner
- Assigns organisational duties for ship's operation, navigation and maintenance with the Chief Officer

The Chief Officer:

- Is second in command, on the ship
- Is the head of the Deck Department
- Is in charge of all maintenance, cargo loading and discharging
- Assists in navigation and discipline

The Second Officer:

- Takes charges of mails
- Maintenance of all equipment and charts used for navigation
- Cargo supervision in ports

The Third Officer:

- Undertakes responsibility for maintenance of life-boats and fire-fighting equipment
- Cargo supervision in ports
- Acts as a signal officer in charge of all signalling equipment
- Is in charge of the navigation bridge by rotation

Deck ratings are responsible for cleaning, sweeping, chipping of rust, polishing, etc. They help in loading and unloading of cargo and in port they assist in the mooring of the ship.

5.2 THE ENGINE DEPARTMENT:

The Chief Engineer is directly responsible to the Master for the satisfactory operation of all machinery and equipment. Apart from assuming all responsibility his role is mainly that of consultant and adviser. It is not usual for the Chief Engineer to keep a watch.

The Second Engineer is responsible for the practical upkeep of machinery and the manning of the engine room: he is in effect an executive officer. On some ships the Second Engineer may keep a watch.

The Third and Fourth Engineers are usually senior watch-keepers or engineers in charge of a watch. Each may have particular areas of responsibility, such as generators or boilers.

Fifth and Sixth Engineers may be referred to as such, or all below Fourth Engineer may be classed as Junior Engineers. They will make up as additional watch-keepers, day workers on maintenance work or possibly act as Refrigeration Engineer.

Electrical Engineers may be carried on large ships or where company practice dictates. Where no specialist Electrical Engineer is carried the duty will fall on one of the engineers.

Various **engine room ratings** will usually form part of the engine room complement. Donkeymen are usually senior ratings who attend the auxiliary boiler while the ship is in port. Otherwise they will direct the ratings in the maintenance and upkeep of the machinery space. Engine room ratings are responsible for the day to day cleanliness of the engine room and for the routine oiling, greasing and servicing of machinery.

6. UMS OPERATION

The machinery spaces will usually be manned at least eight hours per day. During this time the engineers will be undertaking various maintenance tasks, the duty engineer having particular responsibility for the watch-keeping duties and dealing with any alarms which may occur. When operating unmanned anyone entering the machinery space must inform the deck officer on watch. When working or making a tour of inspection alone, the deck officer on watch should be telephoned at agreed intervals of perhaps 15 or 30 minutes. Where the machinery space is unattended, a duty engineer will be responsible for supervision. He will normally be one of three senior watch-keeping engineers and will work on a 24 hour on, 48 hours off rota. During his rota period he will make tours of inspection about every four hours beginning at 7 or 8 o'clock in the morning. The tour of inspection will be similar to that for a conventional watch with due consideration being given to the unattended mode of machinery operation. Trends in parameter readings must be observed, and any instability in operating conditions must be rectified, etc. A mini-log of readings may have to be taken during the various tours. Between tours of inspection the duty engineer will be on call and should be ready to investigate any alarms relayed to his cabin or the various public rooms. The duty engineer should not be out of range of these alarms without appointing a relief and informing the bridge. The main log book readings will be taken as required while on a tour of inspection. The various regular duties, such as fuel transfer, pumping of bilges, and so on, should be carried out during the daywork period, but it remains the responsibility of the duty engineer to ensure that they are done.

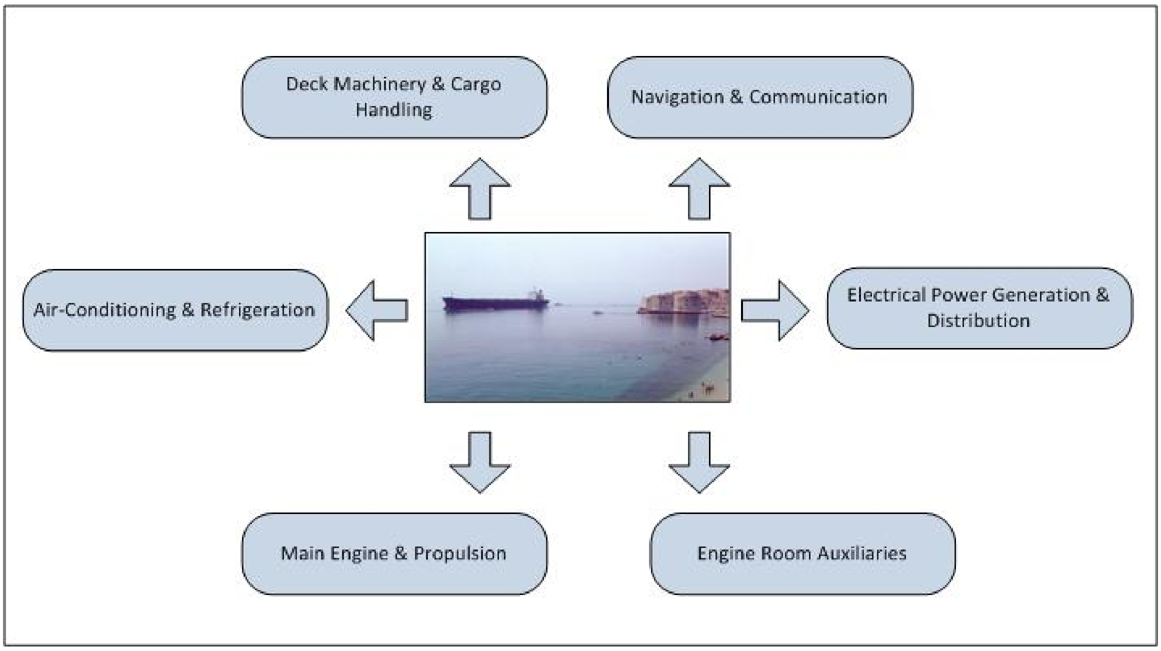
7. PERIODIC SAFETY ROUTINES

In addition to watch-keeping and maintenance duties, various safety and emergency equipment must be periodically checked. As an example, the following inspections should take place at least weekly:

1. Emergency generator should be started and run for a reasonable period. Fuel oil, lubricating oil and cooling water supplies and tank levels should be checked.
2. Emergency fire pump should be run and the deck fire main operated for a reasonable period. AH (audible low suction pressure alarm) operating parameters should be checked.
3. Carbon dioxide cylinder storage room should be visually examined.
4. One smoke detector in each circuit should be tested to ensure operation and correct indication on the alarm panel. Aerosol test sprays are available to safely check some types of detector.
5. Fire pushbutton alarms should be tested, by operating a different one during each test.
6. Any machinery space ventilators or skylights should be operated and greased, if necessary, to ensure smooth, rapid closing should this be necessary.
7. Fire extinguishers should be observed in their correct location and checked to ensure they are operable.
8. Fire hoses and nozzles should likewise be observed in their correct places. The nozzles should be tried on the hose coupling. Any defective hose should be replaced.
9. Any emergency batteries, e.g. for lighting or emergency generator starting, should be examined, and be topped up, as required.
10. All lifeboat engines should be run for a reasonable period. Fuel oil and lubricating oil levels should be checked.
11. All valves and equipment operated from the fire control point should be checked for operation, where this is possible.
12. Any watertight doors should be opened and closed by hand and power. The guides should be checked to ensure that they are clear and unobstructed.

8. SHIP'S EQUIPMENT

Figure 5 – Ship's equipment



The vessel's bridge is the navigating centre of the ship where her course is determined. It is generally situated aft. In recent years the tendency to have machinery aft has caused the **navigating bridge** to be similarly located, particularly on cargo ships and tankers. Included on the navigating bridge is the helm, and also a large amount of nautical equipment, including radar sets, a gyro compass, a radio direction finder, etc. The bridge is in direct communication with all parts of the vessel.

The **deck machinery** is extensive and varied. It can be divided into anchor handling machinery - windlass and capstans, mooring machinery - winches and capstans and **cargo handling** machinery - winches and cranes. It also includes cargo oil pumps. The handling of cargo is carried out either by the ship's own cargo gear or by shore cranes. The derricks are the ship's cranes, and their lifting capacity can vary from 3 tonnes to 50 tonnes or more. If heavy items such as locomotives or boilers are carried, jumbo derricks capable of lifting up to 200 tonnes are provided. They are operated by the ship's winches. Derricks are necessary when cargo is loaded or discharged into barges and are also used on the quayside, where they can work in conjunction with shore cranes. The derricks are supported by masts or samson posts.

There are basically two types of **machinery** on board:

- machinery for the main engine propulsion
- auxiliary machinery.

8.1 AUXILIARY MACHINERY

The auxiliary machinery is used to serve the main engine and the necessities of the ship. It consists of a large group. It includes pumps, purifiers, electrical generators, fresh water generators, heaters, coolers, oily water separator, auxiliary steam boilers, steering gears, air conditioning machines, refrigerator machines, cargo winches, cranes, air compressors, air tanks, oil tanks, water tanks, shafts, bow thrusters, stabilisers, fire-fighting installations, life-boat engines, filters, and many others. This is the equipment which supports the systems of the main engines. Some are run independently. Each auxiliary has its role to play:

- To apply the main power of the engines for propulsion and manoeuvring. The engine power is transmitted to the propeller by a line of steel shafting. This is made up of the thrust shaft, intermediate shafts and the propeller shaft. Steering gear is also necessary to operate the rudder for manoeuvring.
- Steam or diesel power generators supply the ship with electric power and lighting.
- The auxiliary equipment serving to supply domestic needs e.g. fresh water from distillation plant, sanitation from sewage plant and heating & ventilation from heaters and air conditioners.
- Oil purifiers are used for conditioning of the bunker oil, or lubricating oil.
- Coolers are used for cooling either oil or water.
- Air compressors supply compressed air for starting engines.
- Water for the boilers is heated before being admitted into the boiler by feed water heaters. This increases the efficiency of the boiler.
- Auxiliary boiler is used to heat up fuel oil. This is essential especially during the winter months, when fuel oil can become very viscous.
- Fire-fighting and fire detection equipment, life-boat engines and launching gear provide for safety.
- The bilge and ballast piping systems are installed to keep the ship dry and trimmed. The former removes water which has gathered in machinery, cargo and other spaces. The latter pumps water into and out of ballast tanks. In general cargo ships, these systems are usually interconnected and served by the same pumps. In tankers and other bulk carriers, these systems are entirely separate, because these ships may need to ballast at 12,000 tonnes/hour and therefore need larger pumps.

8.2 MAIN ENGINES

There are four main types of marine engine: the diesel engine, the steam turbine, the gas turbine and the marine nuclear plant. Each type of engine has its own particular application.

8.2.1 DIESEL ENGINE

The **diesel engine** is a ship's reciprocating machine, the internal combustion engine. To understand how a diesel engine works imagine the piston just near the top of its upstroke. All access from the outer air is closed but a given volume of air has been drawn in and trapped in between the bottom of the cylinder top and the top of the piston. Air is compressed and it heats. At the point of maximum compression a needle valve in the cylinder head opens, a spray of fuel enters. An explosion takes place and the piston is driven down the cylinder. Working via the piston rod, crosshead and connecting rod, it rotates the crankshaft. No diesel engine is a single cylinder engine, there may be as many as twelve driving one crankshaft, but each cylinder is self-sufficient in operation.

The diesel engine is started by means of compressed air admitted into the cylinder at high pressure via a special starting valve. There are two main types of diesel engines: one is the two-cycle and the other is the four-cycle. The power output of a modern marine diesel engine is about 40,000 brake horse power (bhp). This is now expressed in kilowatts. Large diesel engines, which have cylinders near 3 ft in diameter, turn at the relatively small speed of about 108 r.p.m. These are known as slow-speed diesel engines. They can be connected directly to the propeller without gearing. Although higher power could be produced by higher revolutions, this would reduce the efficiency of the propeller, because a propeller is more efficient the larger it is and the slower it turns. These large slow-running engines are used in the larger merchant ships, particularly in tankers and bulk carriers. The main reason is their low-fuel consumption.

More and more of the larger merchant vessels are being powered by medium-speed diesel engines. These operate between 150 and 450 r.p.m., therefore they are connected to the propeller by gearing. This type of engine was once restricted to smaller cargo ships, but now they are used in fast cargo liners as well as in tankers and bulk carriers.

INTERNAL COMBUSTION ENGINE OPERATING CYCLE:

FOUR STROKE VS. TWO STROKE CYCLES

Each piston, regardless of engine type, completes two strokes for each rotation of the crankshaft.

A **stroke** is defined as either an up or down movement of the piston.

A **two stroke cycle** = one power stroke every shaft revolution.

Intake/Exhaust: As the piston moves towards the bottom of its stroke, air is forced into the cylinder by a blower. At the same time, exhaust gases from the previous power stroke are forced out of the cylinder.

Compression: As the piston moves upward, air is compressed and heated. Fuel is then injected into the cylinder.

Combustion: Ignition occurs after fuel injection, forcing the cylinder down once again.

A **four stroke cycle** = one power stroke every two shaft revolutions.

Intake: The process by which air is drawn into the engine cylinders through intake valves as the piston moves downward.

Compression: The process of reducing the area occupied by the volume of air introduced during the intake stroke. Pressure and air temperature rise sufficiently to ignite the fuel injected into the engine cylinders. Air is compressed and heated as the piston moves upward.

Combustion: The burning of the fuel and air in a chemical process to produce work. Fuel is injected into the cylinder and combustion occurs causing the piston to move downward once again.

Exhaust: The process by which the products of combustion are removed from the engine. The piston moves upward and forces the products of combustion out of the cylinder.

CLASSIFICATION OF INTERNAL COMBUSION ENGINES:

IN-LINE: Simplest arrangements, all cylinders parallel and in a single line. Usually there are no more than 8 cylinders due to weight and strength limitations.

V-TYPE: Piston cylinders are angled (45-75°) in a V configuration. Most V-type engines have either 8 or 16 cylinders.

8.2.2 STEAM TURBINE

The **steam turbine** has until recently been the first choice for very large power main propulsion units. Its advantages of little or no vibration, low weight, minimum space requirements and low maintenance costs are considerable. In steam turbines high pressure steam is directed into a series of blades or vanes attached to a shaft, causing it to rotate. This rotary motion is transferred to the propeller shaft by gears. Steam is produced by boiling water in a boiler, which is fired by oil. Recent developments in steam turbines which have reduced fuel consumption and raised power output have made them more attractive as an alternative to diesel power in ships. They are 50% lighter and on very large tankers some of the steam can be used to drive the large cargo oil pumps. Turbines are often used in container ships, which travel at high speeds.

8.2.3. GAS TURBINE

Gas turbines differ from steam turbines in that gas rather than steam is used to turn a shaft. These have also become more suitable for use in ships. Many naval vessels are powered by gas turbines and several container ships are fitted with them. A gas turbine engine is very light and easily removed for maintenance. It is also suitable for complete automation. The gas turbine efficiency being low, its main advantage is its small weight and size which makes a gas turbine installation very attractive for naval applications. Most of modern warships of about to 5,000 tonne displacement are powered with gas turbines usually combined with diesel engines. Gas turbines are easier to start and reliable in operation. However, the use of astern gas turbines is a rather complex problem therefore ships powered with main gas turbine units are equipped with either controllable pitch propellers (CPP) or other reversing gears.

8.2.4. NUCLEAR PLANT

Nuclear power in ships has mainly been confined to naval vessels, particularly to submarines. But this form of power can be used more in merchant ships as oil fuels become more expensive. The atomic ice-breakers opened new possibilities in exploring the northern areas. They can sail for a long time without re-fuelling. A nuclear-powered ship differs from a conventional turbine ship in that it uses the energy released by the decay of radioactive fuel to generate steam. The steam is used to turn a shaft via a turbine in the conventional way.

9. STEAM TURBINE

The steam turbine has until recently been the first choice for very large power main propulsion units. Its advantages of little or no vibration, low weight, minimal space requirements and low maintenance costs are considerable. However, the higher specific fuel consumption when compared with a diesel engine offsets these advantages, although refinements such as reheat have narrowed the gap.

The steam turbine is a device for obtaining mechanical work from the energy stored in steam. Steam enters the turbine with high energy content and leaves after giving up most of it. The high-pressure steam from the boiler is expanded in nozzles to create a high-velocity jet of steam. The nozzle acts to convert heat energy in the steam into kinetic energy. This jet is directed into blades mounted on the periphery of a wheel or disc. The steam does not 'blow the wheel around'. The shaping of the blades causes a change in direction and hence velocity of the steam jet. Change in velocity for a given mass flow of steam will produce a force which acts to turn the turbine wheel.

This is the operating principle of all steam turbines, although the arrangements may vary considerably. The steam from the first set of blades then passes to another set of nozzles and then blades and so on along the rotor shaft until it is finally exhausted. Each set comprising nozzle and blades is called a stage.

9.1 TURBINE TYPES

There are two main types of turbine, the 'impulse' and the 'reaction'. The names refer to the type of force which acts on the blades to turn the turbine wheel.

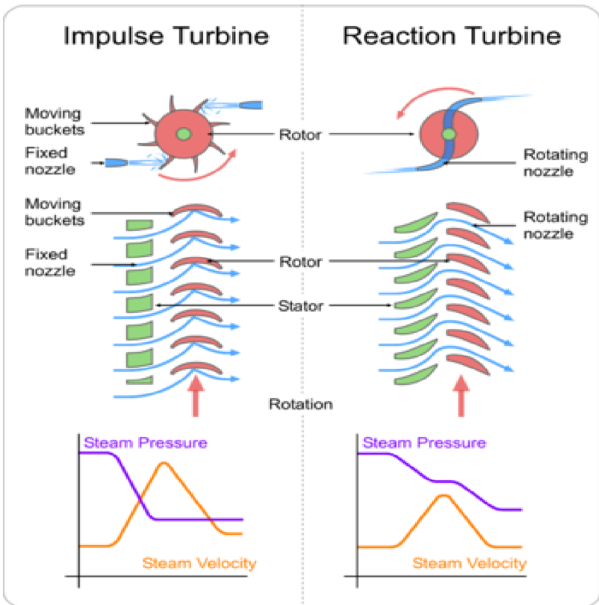
Impulse

The impulse arrangement is made up of a ring of nozzles followed by a ring of blades. The high-pressure, high-energy steam is expanded in the nozzle to a lower-pressure, high-velocity jet of steam. This jet of steam is directed into the impulse blades and leaves in a different direction. The changing direction and therefore velocity produces an impulsive force which mainly acts in the direction of rotation of the turbine blades. There is only a very small end thrust on the turbine shaft.

Reaction

The reaction arrangement is made up of a ring of fixed blades attached to the casing, and a row of similar blades mounted on the rotor, i.e. moving blades. The blades are mounted and shaped to produce a narrowing passage which, like a nozzle, increases the steam velocity. This increase in velocity over the blade produces a reaction force which has components in the direction of blade rotation and also along the turbine axis. There is also a change in velocity of the steam as a result of a change in direction and an impulsive force is also produced with this type of blading. The more correct term for this blade arrangement is 'impulse-reaction'.

Figure 6 – Turbine types



9.2 TURBINE CONSTRUCTION

In an impulse turbine the turbine rotor carries various wheels around which the blades are mounted. The steam decreases in pressure as it passes along the shaft and increases in volume requiring progressively larger blades on the wheels. The astern turbine is mounted on one end of the rotor and is much shorter than the ahead turbine. The turbine rotor is supported by bearings at either end.

The turbine casing completely surrounds the rotor and provides the inlet and exhaust passages for the steam. At the inlet point a nozzle box is provided which by use of a number of nozzle valves admits varying amounts of steam to the nozzles in order to control the power developed by the turbine. The first set of nozzles is mounted in a nozzle ring fitted into the casing. Diaphragms are circular plates fitted between the turbine wheels. They have a central circular hole through which the rotor shaft passes. The diaphragms contain nozzles for steam expansion and a gland is fitted between the rotor and the diaphragm.

The construction of a reaction turbine differs somewhat in that there are no diaphragms fitted and instead fixed blades are located between the moving blades.

Lubricating oil system

Lubricating oil serves two functions in a steam turbine:

1. It provides an oil film to reduce friction between moving parts.

2. It removes heat generated in the bearings or conducted along the shaft.

A common lubrication system is used to supply oil to the turbine, gearbox and thrust bearings and the gear sprayers. The turbine, rotating at high speed, requires a considerable time to stop. If the main motor driven lubricating oil pumps were to fail an emergency supply of lubricating oil would be necessary. This is usually provided from a gravity tank, although main engine driven lubricating oil pumps may also be required.

In a lubricating oil system employing both a gravity tank and an engine driven pump the oil is drawn from the drain tank through strainers and pumped to the coolers. Leaving the coolers, the oil passes through another set of filters before being distributed to the gearbox, the turbine bearings and the gearbox sprayers. Some of the oil also passes through an orifice plate and into the gravity tank from which it continuously overflows (this can be observed through the sight-glass). The engine driven pump supplies a proportion of the system requirements in normal operation.

In the event of a power failure the gearbox sprayers are supplied from the engine driven pump. The gravity tank provides a low-pressure supply to the bearings over a considerable period to enable the turbine to be brought safely to rest.

9.3 TURBINE CONTROL

The valves which admit steam to the ahead or astern turbines are known as 'manoeuvring valves'. There are basically three valves, *the ahead, the astern* and *the guarding* or *guardian* valve. The guardian valve is an astern steam isolating valve. These valves are hydraulically operated by an independent system employing a main and stand-by set of pumps. Provision is also made for hand operation in the event of remote control system failure.

Operation of the ahead manoeuvring valve will admit steam to the main nozzle box. Remotely operated valves are used to open up the remaining nozzle boxes for steam admission as increased power is required. A speed-sensitive control device acts on the ahead manoeuvring valve to hold the turbine speed constant at the desired value.

Operation of the astern manoeuvring valve will admit steam to the guardian valve which is opened in conjunction with the astern valve. Steam is then admitted to the astern turbines.

9.4 TURBINE PROTECTION

A turbine protection system is provided with all installations to prevent damage resulting from an internal turbine fault or malfunction of some associated equipment. Arrangements are made in the system to shut the turbine down using an emergency stop and solenoid valve. Operation of this device cuts off the hydraulic oil supply to the manoeuvring valve and thus shuts off steam to the turbine. This main trip relay is operated by a number of main fault conditions which are:

1. Low lubricating oil pressure.
2. Overspeed.
3. Low condenser vacuum.
4. Emergency stop.
5. High condensate level in condenser.
6. High or low boiler water level.

Other fault conditions which must be monitored and form part of a total protection system are:

1. HP and LP rotor eccentricity or vibration.
2. HP and LP turbine differential expansion, i.e. rotor with respect to casing.
3. HP and LP thrust bearing weardown.
4. Main thrust bearing weardown.
5. Turning gear engaged (this would prevent starting of the turbine).

Such 'turbovisory' systems, as they may be called, operate in two ways. If a tendency towards a dangerous condition is detected a first stage alarm is given. This will enable corrective action to be taken and the turbine is not shut down. If corrective action is not rapid, is unsuccessful, or a main fault condition quickly arises, the second stage alarm is given and the main trip relay is operated to stop the turbine.

10. THE MAIN TYPES OF SHIP PROPULSION SYSTEMS

The main engine of a ship is connected to its propeller with the help of a shaft. This whole system, along with other vital machineries is known as the ship propulsion system. The type of propulsion system used in a ship depends on several factors such as speed, power, ship type etc.

Since the time man started using ships, various types of propulsion systems have been used depending on the ship's requirement. Herebelow is a brief overview of the kinds of propulsion systems that are available in the market and their selection procedure according to the requirement.

10.1 DIRECT DRIVE PROPULSION SYSTEM

Direct propulsion system is the most commonly used system on ships. Direct propulsion system is an invariable choice for low-speed diesel engines and has a very basic arrangement. It consists of a propeller, which is connected to the main engine with the help of the shaft. Manoeuvring of the ship is done by controlling the speed of the main engine and by changing the direction of rotation of the propeller. Initially this system was used in almost all the ships. Direct drive propulsion system is generally used by ships plying in confined waters and in areas wherein higher speeds are not allowed.

10.2 GEARED DRIVE PROPULSION SYSTEM

Geared drive propulsion system is extensively used nowadays. Gearing has more than one function; it reduces the number of revolutions from the engine output in such a way that the system can derive maximum propeller efficiency. Gearing can also be used to connect one shaft to two prime movers or can be used to share power between two shafts or to connect a shaft alternator to the shaft connected to the propeller.

The reversing can also be done easily by using controlled pitch propeller. However, gearing can make the task much easier.

10.3 ELECTRICAL PROPULSION SYSTEM

Nowadays most electrical drives have medium- or high-speed diesel engines as their prime movers. The only disadvantage of the electrical drive is that it is extremely expensive in the first cost when compared with geared drive. This is mainly because of lower mechanical efficiency, which leads to more fuel consumption and cost.

In earlier times, DC motors were used with the electrical drives and the ships used to have completely separate electrical system for propulsion and other purposes. But after the invention of marine type thyristor converters the ships are able to connect all their machineries to one single electrical system, just as in a power station. Thus the power for the propulsion system, marine auxiliary machinery, and ship’s hotel load all comes from a common energy pool. Generators are also used with the main engine to get the near peak efficiency.

Also, combining all the electrical power sources into one system has drastically helped in reducing the extra costs and method is chosen for almost all the ships now. The system is suitable especially for ships with high power requirements such as large cruise liners and specialist ships such as research vessels, ice breakers, fish factory ships, oil production and drilling vessels, cable laying ships etc. An electrical drive is thus advantageous for a ship that has a large non propulsion electrical load or for a ship wherein the number of propulsion devices are installed throughout the ship e.g. dynamically positioned offshore vessel.

Apart from this, advantages of electrical propulsion also include drastic reduction in noise and vibration levels, power for the occasional use of bow thrusters without the help of any other power source, and smooth operation at very low speeds with high level of reliability. Moreover, an electrical propulsion system can be easily maintained and repaired. It provides the facility of using all machineries on one fuel type. The requirement of spares is also absolutely low. The system can work on low grade fuels, increasing the cost efficiency of the whole operation.

11. BASIC MATHEMATICAL SYMBOLS

Table 2 – Basic mathematical symbols

Symbol	Symbol Name	Meaning / Definition	Example
=	equals sign	equality	$5 = 2+3$
>	strict inequality	greater than	$5 > 4$
<	strict inequality	less than	$4 < 5$
( )	parentheses	calculate expression inside first	$2 \times (3+5) = 16$
[ ]	brackets	calculate expression inside first	$[(1+2) \cdot (1+5)] = 18$
+	plus sign	addition	$1 + 1 = 2$
−	minus sign	subtraction	$2 - 1 = 1$
*	asterisk	multiplication	$2 * 3 = 6$
×	times sign	multiplication	$2 \times 3 = 6$
·	multiplication dot	multiplication, times	$2 \cdot 3 = 6$
÷	division sign	division	$6 \div 2 = 3$
/	division slash	division; per	$6 / 2 = 3$; 20 rev/s
.	period	decimal point, decimal separator	$2.56 = 2+56/100$
%	percent	1% = 1/100	$10\% \times 30 = 3$
‰	per-mille	1‰ = 1/1000 = 0.1%	$10‰ \times 30 = 0.3$
x	x variable	unknown value to find	when $2x = 4$, then $x = 2$
≈	approximately equal	approximation	$sin(0.01) \approx 0.01$
∝	proportional to	proportional to	$f(x) \propto g(x)$
∞	infinity	infinity symbol	¹/o ∞ infinity
x^2	squared	squared	3^2
x^3	cubed	cubed	3^3
x^4	fourth	to the fourth; to the power four	
x^n	nth	to the n; to the nth; to the power n	
$\sqrt{}$	root	square root	
$\sqrt[3]{}$	root	cube root	
$\sqrt[4]{}$	root	fourth root	

Table 3 – Mathematical symbols - examples

$x + 1$	x plus one
$x - 1$	x minus one
xy	x y; x times y; x multiplied by y
$(x - y)(x + y)$	x minus y, x plus y
x/y	x over y; x divided by y;
$x = 5$	x equals 5; x is equal to 5
$x \approx y$	x is approximately equal to y
$x \neq y$	x is not equal to y
$x > y$	x is greater than y
$x < y$	x is less than y
x^2	x squared
x^3	x cubed
x^4	x to the fourth; x to the power four
x^n	x to the n; x to the nth; x to the power n
x^{-n}	x to the minus n; x to the power of minus n
$\sqrt{}$	root x; square root x; the square root of x
$\sqrt[3]{}$	the cube root of x
$\sqrt[4]{}$	the fourth root of x
$\sqrt[n]{}$	the nth root of x
$(x + y)^2$	x plus y all squared
$(x/y)^2$	x over y all squared
x%	x percent
∞	infinity
$x \propto y$	x varies as y; x is (directly) proportional to y
m/sec	metres per second

12. ENGINEERING MATERIALS

Groups of engineering materials

Based on their properties, the engineering materials can be grouped into:

1. metals
2. non-metals

Metals can be classified as ferrous and non-ferrous.

The former contain iron and the latter do not. The two most important ferrous metals are cast iron and steel, which are both alloys, i.e. mixtures of iron and carbon. Mild steel contains from 0,15% to 0,3% of carbon. High carbon steel consists of 0,7% to 1,4% of carbon.

Aluminium, copper and the alloys (bronze and brass), zinc, tin, titanium and lead are common non-ferrous metals.

Non-metals are plastics and ceramics.

Plastics can be classified into two types: thermoplastics (ABS, acrylic, nylon) and thermosetting plastics (epoxy resin, polyester resin, urea formaldehyde). Thermoplastics can be shaped and reshaped by heat and pressure, but thermosetting plastics cannot be reshaped because they undergo chemical changes as they harden.

Ceramics are often employed by engineers when materials which can withstand high temperatures are needed. Examples of ceramics are natural and man-made glasses used to make bottles, windows and lenses, cements etc.

12.1 PROPERTIES OF ENGINEERING MATERIALS

Engineering materials commonly exhibit the following properties:

1. physical properties
2. mechanical properties

The physical properties of engineering materials, metals in particular, are colour, size, shape, density, thermal and electrical conductivity, melting point, etc.

The mechanical properties exhibited by engineering materials include strength, elasticity, plasticity, ductility, stiffness, malleability, toughness, brittleness, hardness, fatigue and creep.

Strength is the ability of a material to resist or withstand externally applied forces to which it is subjected during a test or in service without breaking. The internal resistance by a material to the externally applied force is called stress. Tensile strength is the main single criterion with reference to metals.

Elasticity is the property of a material to regain its original shape and size after deformation when the external load or force causing the deformation is removed. A material is said to be perfectly elastic if all the stresses (which lead to the deformation of the material) disappear completely upon the removal of the load. This property is desirable for materials used in machine cutting tools.

Stiffness is the ability of a material to resist deformation under stress.

Plasticity is the property of a material to remain deformed permanently or to retain a deformation caused by an applied load permanently after the removal of the load.

Ductility is the ability of a material to withstand bending or elongation without breaking. A material that has this characteristic is said to be ductile. This property is valuable in chains and ropes because they don't snap off or break due to elongation and bending during service.

Malleability is the ability of a material to be hammered or rolled easily into thin sheets without rupturing. Malleability of a material increases with the increase in temperature.

Toughness is the resistance of a material to rupture. This resistance to rupture is due to the force of attraction between each molecule which gives them the power to resist any force tending to tear them apart.

Brittleness is when a body breaks easily when subjected to shocks. Such a material is said to be brittle.

Hardness is the resistance of a material to penetration. The hardness of engineering materials is generally carried out by pressing an indentor into the surface of the material through slowly applied load. The extent of the resulting impression caused by the indentor is then measured mechanically and optically. A large impression means that the material is soft while a small impression means that the material is hard.

Fatigue – When materials are subjected to fluctuating or repeating loads (or stresses), they tend to fail. This type of failure is different from that which they experience when subjected to steady loads. This type of failure is called FRACTURE. The phenomenon that leads to fracture is fatigue.

Creep is the slow plastic deformation of metals under constant stress or when they are subjected to prolonged loading at high temperature. Creep can lead to fracture at static stresses which are much smaller than those which will break the material by loading quickly. Creep is specially taken care of in internal combustion engines, boilers and turbines.

13. CORROSION

A major consideration in engineering design is maintenance. One of the commonest causes of failure in the long term is corrosion. This is any deterioration in the component's appearance of physical properties.

Corrosion covers a number of processes whereby a metal changes state as a result of some form of interaction with its environment. It often occurs where water, either as a liquid or vapour in air of high humidity, is present.

In general, corrosion becomes worse when impurities are present in damp conditions. It never starts inside a material, and there will always be surface evidence that indicates corrosion exists, although close examination may be needed.

Iron and steel corrode in an attempt to return to their stable oxide form. This oxidising, or 'rusting' as it is called, will take place wherever steel is exposed to oxygen and moisture. Unfortunately the metal oxide formed permits the reaction to continue beneath it. Some metals however produce a passive oxide film, that is, no further corrosion takes place beneath it. Aluminium and chromium are examples of metals which form passive oxide coatings. Corrosion control of this process usually involves a coating. This may be another metal, such as tin or zinc, or the use of paints or plastic coatings.

Electrochemical corrosion usually involves two different metals with an electrolyte between them. (An electrolyte is a liquid which enables current to flow through it.) A corrosion cell or galvanic cell is said to have been set up. Current flow occurs in the cell between the two metals since they are at different potentials. As a result of the current flow through the electrolyte, metal is removed from the anode or positive electrode and the cathode or negative electrode is protected from corrosion. A corrosion cell can occur between different parts of the same metal, perhaps due to slight variations in composition, oxygen concentration, and so on. The result is usually small holes or pits and the effect is known as 'pitting corrosion'. A more serious form of this effect results in greater damage and is known as "crevice corrosion'. The prevention of electrochemical corrosion is achieved by cathodic protection. Pitting and crevice corrosion can be countered by a suitable choice of materials, certain copper alloys for instance.

'Erosion' is a term often associated with corrosion and is the wearing away of metal by abrasion. Sea water systems are prone to problems of this nature. Increasing water velocity can reduce pitting problems in some materials but will increase their general surface corrosion, for example copper base alloys. Water impinging on a surface can cause erosion damage and this is usually found where turbulent flow conditions occur. Careful material selection is necessary to reduce this type of erosion.

It is imperative that a design takes into account whether a material will be affected in a particular environment and, if corrosion is likely, at what rate.

14. MECHANISMS

Small mechanical systems can be combined to make more complex systems. Mechanisms deliver the power to do the work. A cam which is turned by an electric motor can operate a micro switch which could be used to turn a light on or off. Two mechanical systems can be connected together to give complex movements.

All mechanisms involve some kind of motion. The four basic kinds of motion are:

- **Rotary motion** is turning round in a circle, such as wheels or gears.
- **Linear motion** is moving in a straight line, such as on a paper trimmer.
- **Reciprocating motion** is moving backwards and forwards in a straight line, such as the piston in a combustion engine.
- **Oscillating motion** is swinging from side to side, like a pendulum in a clock.

Many mechanisms involve changing one kind of motion into another. For example the reciprocating motion of a piston is changed into a rotary motion by the crankshaft, while a camshaft converts the rotary motion of the engine into the reciprocating motion required to operate the valves.

15. PISTONS

Piston skirt, piston rod and trunk piston are three important parts of the piston arrangement in marine diesel engines.

Piston Skirts

Piston skirt is fitted in both two-stroke and four-stroke engines. It has different function for different engines. In large cross-head two-stroke engines with uniflow scavenging these skirts are short in length and are fitted to act as a guide and to stabilize the position of the piston inside the liner. It is generally made of cast iron. The diameter of the skirt is usually kept slightly larger than that of the piston. This is done to prevent damage to the liner surface due to the piston movement.

Soft bronze rings are also fitted in the piston skirts. These bronze rings help during the running-in of the engine, when the engine is new, and can be replaced if necessary.

In two stroke engines having loop or cross scavenging arrangements the skirts are slightly larger as these help in blanking off the scavenge and the exhaust ports in the liner.

In four-stroke or trunk piston engines the skirt has arrangement for gudgeon pin, which transmits power from the piston to the gudgeon pin or top end bearing. As there are no cross head guides in four-stroke engines, these skirts help in transferring the side thrust produced from the connecting rod to the liner walls.

Piston Rods

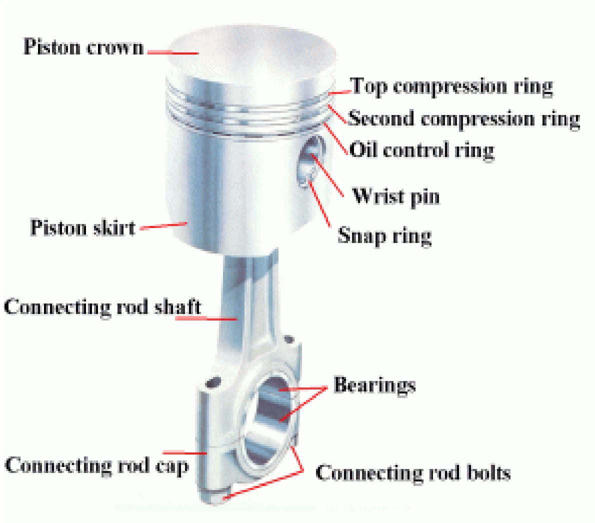
Piston rods are generally found in large two-stroke engines. Piston rods help in transmitting the power produced in the combustion space to the cross head and the running gear of the engine.

The lengths of these rods depend on the length of the engine stroke and the manufacturers design. The top end of the rod is flanged or attached to the underside of the piston and the bottom end is connected to the cross head.

The piston rod passes through the piston gland or stuffing box so the rod should have smooth running surface and low coefficient of friction.

Trunk Piston

Figure 7 – Trunk piston



Trunk piston is a term usually given to the pistons in four-stroke medium speed engines. These pistons have composite design which comprises of thin sectioned alloy steel piston crown along with aluminium alloy skirt. These pistons are light, strong and rigid in construction and are capable of resisting high temperatures and corrosion.

The piston is forged and the space inside is provided for arrangement of cooling spaces, which is done by cooling oil. The skirt consists of space for gudgeon pin which transmits power to the connecting rod. The skirt also helps in transferring the side thrust produced by the connecting rod.

The piston consists of rings grooves for fitting piston rings. The landing of piston rings is hardened and plated with chrome to reduce wear. The top surface of the crown may be recessed to provide clearance for inlet and exhaust valves. Compression rings are fitted in the crown and are generally plasma coated whereas other rings are chrome plated. The oil control ring is fitted in the top of the piston skirt.

16. FORCES IN ENGINEERING

The principal forces in engineering are:

- **Gravity**. The weight, W – acts downwards. That is the gravity force. When designing and building a vessel, weight and centre of gravity are key parameters for successful performance.
- **Buoyancy**. The buoyancy force, B, acts upwards supporting the ship. Buoyancy depends on weight, fluid displacement, shape and density. The weight of the displaced water equals the upwards buoyant force.
- **Elasticity**. The property of the material of a body by virtue of which, the body regains its original length, volume and shape after the deforming forces have been removed, is called elasticity. A good example is a spring. Springs exert more force the more they are stretched. This property provides a way of measuring force. A spring balance can be calibrated in Newtons, the unit of force.
- **Friction**. Friction is a help in some circumstances but a hindrance in others. In order to go faster, a ship must reduce its air and water friction as much as possible, as friction force acts in the opposite direction than motion, i.e. slows the object down. In general, the force opposing motion is slightly greater before one surface starts moving over another surface than after movement has started. This slightly greater force is called static friction. The force which must be overcome to keep one surface moving over another is known as sliding friction. Static friction is greater than sliding friction. However, it is friction that allows the propulsion system to 'push' the ship forward. Because friction is related to the area of contact and the vector of the velocity, it is ideal to have the least amount of surface area facing to the direction of motion, which is why most ships have a V-shape in the front.

17. LUBRICATION

An engine contains many moving parts, and to prevent any wear or damage as a result of friction, a **lubricant** must be applied between these parts.

Lubricating oil has many properties that have positive influences on the engine.

One of its properties is its cooling ability – the lube oil will carry away the heat that is generated by friction between various moving parts. Furthermore, lubricating oil has the ability to prevent impurities from clogging together. Instead, these particles will suspend and float on the surface of the liquid. This makes it easy to remove them.

The lube oil will also serve as an anti-corrosive agent – it will prevent forming of rust. The thin oil layer (or oil film) will seal off pits and scratches in cylinder walls.

Finally, the thickness of the lubricant will reduce engine noise considerably. This thickness of lubricating oil is indicated by the viscosity grade. When a liquid is very ''viscous'' it will resist the tendency to flow. A liquid of low viscosity, such as water, will flow very easily through pumps and piping systems. When the engine temperature rises, viscosity of the oil will be reduced and the oil will become less effective. That is why it is very important to indicate the viscosity grade of a lubricant at higher temperatures.

The lube oil is stored in the drain tank. This oil sump, as it is also called, is often integrated in the double bottom. ''Ullage'' is the space between the level of the oil and the top of the tank and will allow for expansion of the oil when the engine gets hot. The air in this space will also expand, and to prevent the lubricant from being forced down by the pressure that will arise from expansion of hot air, the drain tank is fitted with an air vent. This air vent, or breather, serves as an escape for the hot fumes that have accumulated in the drain tank.

In a forced lubricating system the lube oil is pumped from the drain tank to distribution branches in the engine and to the shafting. Before it is entered into the engine the used oil must first be filtered and cooled by seawater or fresh water.

18. COOLING

Due to very high temperatures caused by combustion of the fuel and friction between various moving parts, cooling is necessary to reduce wear and thermal deformation as a consequence of the constant expansion and shrinking of machinery parts.

Coolants that are used in the cooling process are: seawater, fresh water, oil and air.

<u>Seawater</u>

The advantages of seawater as a coolant are: it is free of charge and can absorb a lot of heat. Furthermore, a seawater cooling system can be made very simple since the used seawater can be discharged into the sea.

The disadvantages of seawater are obvious: it contains a lot of minerals that will stick to all heated surfaces and form a deposit. This ''scale'' as it is called, must be removed, because it will form an insulation that will prevent exchange of heat. Seawater will also cause corrosion to the engine parts and piping. Seawater is used as a cooling medium in an indirect cooling process (cooling the coolant). Before the coolant will be circulated through the engine again, it is cooled with seawater by a heat exchanger. The seawater enters the ship through seawater inlets. These inlets are fitted with sea-chests that filter the water before it is led to the heat exchangers.

<u>Fresh water</u>

Freshwater has the ability to absorb much heat and will hardly cause any forming of scale. Compared to seawater, however, fresh water is very costly. Therefore, it is only used in closed circuits, so that it can be reused.

<u>Oil</u>

Oil as a coolant has a lot of advantages. Apart from cooling, it will reduce engine noise, because the thickness of the oil will serve as a ''muffler''. Oil is anti-corrosive and has a purifying function (unwanted particles and impurities will be carried away by the oil). Another advantage is that the oil will form a thin sealing layer that will seal off pits and scratches. Most importantly, oil has lubricating function, which, in an engine with numerous moving parts, is a very important aspect.

As its disadvantage, the amount of absorbed heat per cubic metre of oil is less than that of water. Oil may also cause carbon deposit on the surfaces that need cooling.

Air

Air has the advantage of being free of charge. However, its disadvantage is the enormous amount of air needed to cool a small area or surface.

19. BOILERS

A boiler in one form or another will be found on every type of ship. Where the main machinery is steam powered, one or more large water-tube boilers will be fitted to produce steam at very high temperatures and pressures. On a vessel propelled by a diesel engine, a smaller (usually fire-tube type) boiler will be fitted to provide steam for the various ship services. Even within the two basic design types, water-tube and fire-tube, a variety of designs and variations exist.

A boiler is used to heat feed water in order to produce steam. The energy released by the burning fuel in the boiler furnace is stored (as temperature and pressure) in the steam produced. All boilers have a furnace or combustion chamber where fuel is burnt to release its energy. Air is supplied to the boiler furnace to enable combustion of the fuel to take place. A large surface area between combustion chamber and water enables the energy of combustion, in the form of heat, to be transferred to the water.

A drum must be provided where steam and water can separate. There must also be a variety of fittings and controls to ensure that fuel oil, air and feedwater supplies are matched to the demand for steam. Finally, there must be a number of fittings or mountings which ensure safe operation of the boiler.

In the steam generation process feedwater enters the boiler where it is heated and becomes steam. The feedwater circulates from the steam drum to the water drum and is heated in the process. Large-bore downcomer tubes are used to circulate feedwater between the drums. The downcomer tubes pass outside of the furnace and join the steam and water drums. The steam is produced in a steam drum and may be drawn off for use from here. It is known as 'wet' or saturated steam in this condition because it will contain small quantities of water. Alternatively, the steam may pass to a superheater which is located within the boiler. Here steam is further heated and 'dried', i.e. all traces of water are converted into steam. This superheated steam then leaves the boiler for use in the system. The temperature of superheated steam will be above that of the steam in the drum. An 'attemperator', i.e. a steam cooler, may be fitted in the system to control the superheated steam temperature.

The hot gases produced in the furnace are used to heat the feedwater to produce steam and also to superheat the steam from the boiler drum. The gases then pass over an economiser through which the feedwater passes before it enters the boiler. The exhaust gases may also pass over an air heater which warms the combustion air before it enters the furnace. In this way a large proportion of the heat energy from the hot gases is used before they are exhausted from the funnel.

19.1 BOILER TYPES

Basically there are two different types of boiler:

- the water-tube boiler and
- the fire-tube boiler.

The design and arrangement of both the types is just the opposite. In the water-tube the feedwater is passed through the tubes and the hot gases pass over them. In the fire-tube boiler the hot gases pass through the tubes and the feedwater surrounds them.
The water-tube boiler is employed for high-pressure, high-temperature, high-capacity steam applications, e.g. providing steam for main propulsion turbines or cargo pump turbines. Fire-tube boilers are used for auxiliary purposes to provide smaller quantities of low-pressure steam on diesel engine powered ships.

19.1.1 WATER-TUBE BOILERS

The construction of water-tube boilers, which use small-diameter tubes and have a small steam drum, enables generation or production of steam at high temperatures and pressures. The weight of the boiler is much smaller than an equivalent fire-tube boiler and the steam raising process is much quicker. Design arrangements are flexible, efficiency is high and the feedwater has a good natural circulation. These are some of the many reasons why the water-tube boiler has replaced the fire-tube boiler as the major steam producer.
Early water-tube boilers used a single drum. Headers were connected to the drum by short, bent pipes with straight tubes between the headers. The hot gases from the furnace passed over the tubes, often in a single pass.
A later development was the bent tube design. This boiler has two drums, an integral furnace and is often referred to as the 'D' type because of its shape.

19.1.2 FIRE-TUBE BOILERS

The fire-tube boiler is usually chosen for low-pressure steam production on vessels requiring steam for auxiliary purposes. Operation is simple and feedwater of medium quality may be employed. The name 'tank boiler' is sometimes used for fire-tube boilers because of their large water capacity. The terms 'smoke tube' and 'donkey boiler' are also in use.

Most fire-tube boilers are now supplied as a completely packaged unit. This will include the oil burner, fuel pump, forced-draught fan, feed pumps and automatic controls for the system. The boiler will be fitted with all the appropriate boiler mountings.

19.2 BOILER MOUNTINGS

Certain fittings are necessary on a boiler to ensure its safe operation. They are usually referred to as boiler mountings. The mountings usually found on a boiler are:

Safety valves. These are mounted in pairs to protect the boiler against overpressure. Once the valve lifting pressure is set in the presence of a surveyor it is locked and cannot be changed. The valve is arranged to open automatically at the pre-set blow-off pressure.

Main steam stop valve. This valve is fitted in the main steam supply line and is usually of the non-return type.

Auxiliary steam stop valve. This is a smaller valve fitted in the auxiliary steam supply line, and is usually of the non-return type.

Feed check or control valve. A pair of valves is fitted: one is the main valve, the other the auxiliary or standby. They are non-return valves and must give an indication of their open and closed position.

Water level gauge. Water level gauges or 'gauge glasses' are fitted in pairs, at opposite ends of the boiler. The construction of the level gauge depends upon the boiler pressure.

Pressure gauge connection. Where necessary on the boiler drum, superheater, etc., pressure gauges are fitted to provide pressure readings.

Air release cock. These are fitted on the boiler drum to release air when filling the boiler or initially raising steam.

Sampling connection. A water outlet cock and cooling arrangement is provided for the sampling and analysis of feed water. A provision may also be made for injecting water treatment chemicals.

Blow down valve. This valve enables water to be blown down or emptied from the boiler. It may be used when partially or completely emptying the boiler.

Scum valve. A shallow dish positioned at the normal water level is connected to the scum valve. This enables the blowing down or removal of scum and impurities from the water surface.

Whistle stop valve. This is a small bore non-return valve which supplies the whistle with steam straight from the boiler drum.

19.3 BOILER MOUNTINGS (WATER-TUBE BOILERS)

Water-tube boilers, because of their smaller water content in relation to their steam raising capacity, require certain additional mountings:

Automatic feed water regulator. Fitted in the feed line prior to the main check valve, this device is essential to ensure the correct water level in the boiler during all load conditions. Boilers with high evaporation rate will use a multiple-element feed water control system.

Low level alarm. A device to provide audible warning of low water level conditions (indication).

Low low level alarm. Immediately shuts down the boiler.

Superheater circulating valves. Acting also as air vents, these fittings ensure a flow of steam when initially warming through and raising steam in the boiler.

Sootblowers. Operated by steam or compressed air, they act to blow away soot and the products of combustion from the tube surfaces. Several are fitted in strategic places.

20. GENERATORS

In order to provide electric power for the lighting system, auxiliaries, cranes, derricks, hatches and for domestic use, the ship is equipped with one or more generators. The generator is the heart of the ship. The electrical system should be characterised in such a way that it supplies sufficient energy to all systems of the ship and for that it is extremely essential that the correct sizing of the generators is done. The correct sizing of the generator is the key to a safe, workable and economic electrical system. The size of the generator depends on the load. The load often varies or undergoes swings as the generator is connected to various other elements such as motors, heating elements and air conditioning systems. Therefore, considerable care should be taken that generators are susceptible to heavy system load swings.

Maritime law requires that every ship should have at least two generators. However, it is always advisable to have three generators on board all having their individual power sources. If the ship has three generators on board, two are used under normal working conditions and one is kept as stand-by.

The typical marine generator burns either diesel fuel or petrol (gas). The generator produces either alternating current (AC) or direct current (DC). A converter is used to convert AC into DC. DC generator is a machine which produces direct current electric power. It consists of two main parts, namely, (1) field winding and (2) armature winding. A 3 phase AC generator is called an "alternator". Like a DC generator, it also consists of two windings. However, unlike in a DC generator, its poles are on rotor and armature winding is on stator.

The main parts of a generator are the rotor, the stator and the commutator. The rotor is a rotating electro-magnet. It produces a magnetic field. The rotor rotates within the stator. Around this stator, or armature, coils of wire are wound. These coils induce electric current. The process is called induction. The induced current is collected by the commutator. Carbon brushes pass the current to the circuit.

Most of today's marine generators have an "electronic control module". This system keeps track of the generator unit's performance. The electronic control module automatically adjusts the system to maintain maximum performance level.

Maintenance of generators at regular time intervals is extremely important.

21. SAFE WORKING PRACTICES

Accidents are usually the result of carelessness, mistakes, lack of thought or care, and often result in injury. Consideration should be given to avoiding accidents, largely by adoption of safe working practices.

Working clothes should be chosen with the job and its hazards in mind. They should fit fairly closely with no loose flaps, straps or ragged pockets. Clothing should cover as much of the body as possible and a stout pair of shoes should be worn. Neck chains, finger rings and wristwatches should not be worn, particularly in the vicinity of rotating machinery. Where particular hazards are present appropriate protection, such as goggles or ear muffs, should be worn.

When overhauling machinery or equipment it must be effectively isolated from all sources of power. This may involve unplugging from an electrical circuit or removal of fuses.

Suction and discharge valves of pumps should be securely closed and the pump casing relieved of pressure. Special care should be taken with steam-operated or steam-using equipment to ensure no pressure build-up can occur.

Before any work is done on the main engine, the turning gear should be engaged and a warning posted at the control position.

Lubricating oil in the working area should be cleaned up and where necessary suitable staging erected.

The turning gear should be made inoperative if not required during the overhaul. Where it is used, care must be taken to ensure all personnel are clear before it is used.

Where overhead work is necessary suitable staging should be provided and adequately lashed down. Staging planks should be examined before use and where suspect discarded. Where ladders are used for access they must be secured at either end. Personnel working on staging should take care with tools and store them in a container.

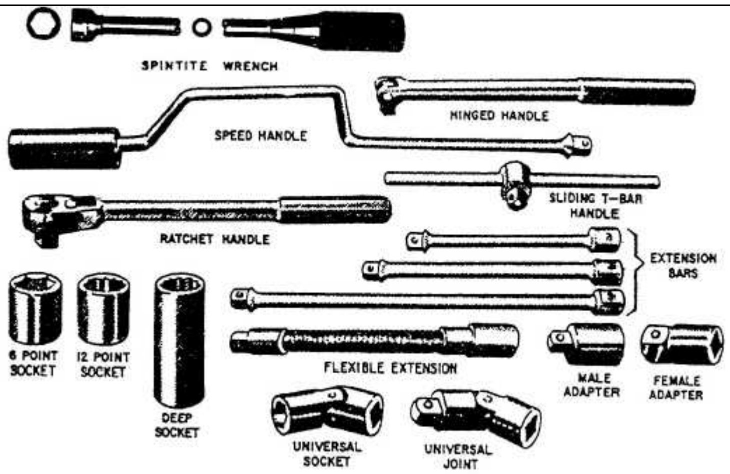
Boiler blowbacks can cause serious injury and yet with care can usually be avoided. The furnace floor should be free of oil and burners regularly checked to ensure that they do not drip, particularly when not in use. The manufacturer's instructions should be followed with regard to lighting up procedures. Generally this will involve blowing through the furnace (purging) with air prior to lighting up. The fuel oil must be at the correct temperature and lit with a torch. If ignition does not immediately occur the oil should be turned off and purging repeated before a second attempt is made. The burner should be withdrawn and examined before it is lit.

Entry into an enclosed space should only take place under certain specified conditions. An enclosed space, such as a duct keel, a double bottom tank, a cofferdam, boiler, etc. cannot be assumed to contain oxygen. Anyone requiring to enter such a space should only do so with the permission of a responsible officer. The space should be well ventilated before entry takes place and breathing apparatus taken along; it should be used if any discomfort or drowsiness is felt. Another person should remain at the entrance to summon assistance if necessary, and there should be a means of communication arranged between the person within the space and the attendant. Lifelines and harness should be available at the entrance to the space. The attendant should first raise the alarm where the occupant appears in danger but should not enter the space unless equipped with breathing apparatus.

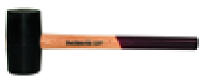
Training in the use of safety equipment and the conduct of rescues is essential for all personnel involved.

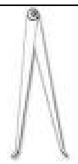
22. TOOLS AND ACCESSORIES

Table 4 – Tools and accessories

	adjustable wrench (heavy duty) shifter	francuski ključ
	open and 12 point box end wrench	ključ okasto vilasti
	double open end wrench	vilasti ključ
	12 double offset wrench	dvostruki okasti ključ
	socket wrench	nasadni ključ

	monkey wrench, pipe wrench	engleski ključ
	general purpose screwdriver	odvijač ravni
	square blade screwdriver	odvijač križni
	electricians screwdriver	ispitivač
	thin bent nose pliers	povijena kliješta
	long nose straight pliers	špicasta kliješta
	electrical cable strippers	kliješta za skidanje izolacije
	water pump pliers	kliješta za cijevi, papagaj

	combination pliers	kombinirana kliješta
	cold chisel	dlijeto plosnato
	wood rasp, file	rašpa za drvo, turpija
	chipping hammer	čekić
	rubber hammer	gumeni čekić
	bolt	svornjak
	wing bolt	leptirasti vijak
	nuts	matice

	washers for bolts	podloške
	set screw	šesterokutni vijak
	deck screw	vijak za drvo
	socket head cap screw, Allen screw	imbus vijak
	eye screw	okasti vijak
	thickness gauges, filler gauges	mjerni listići
	Vernier caliper gauges	pomično mjerilo, šubler
	inside calipers	šestar za otvore (rupe)
	bench vice	škripac, morsa

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24. LIST OF TABLES AND FIGURES