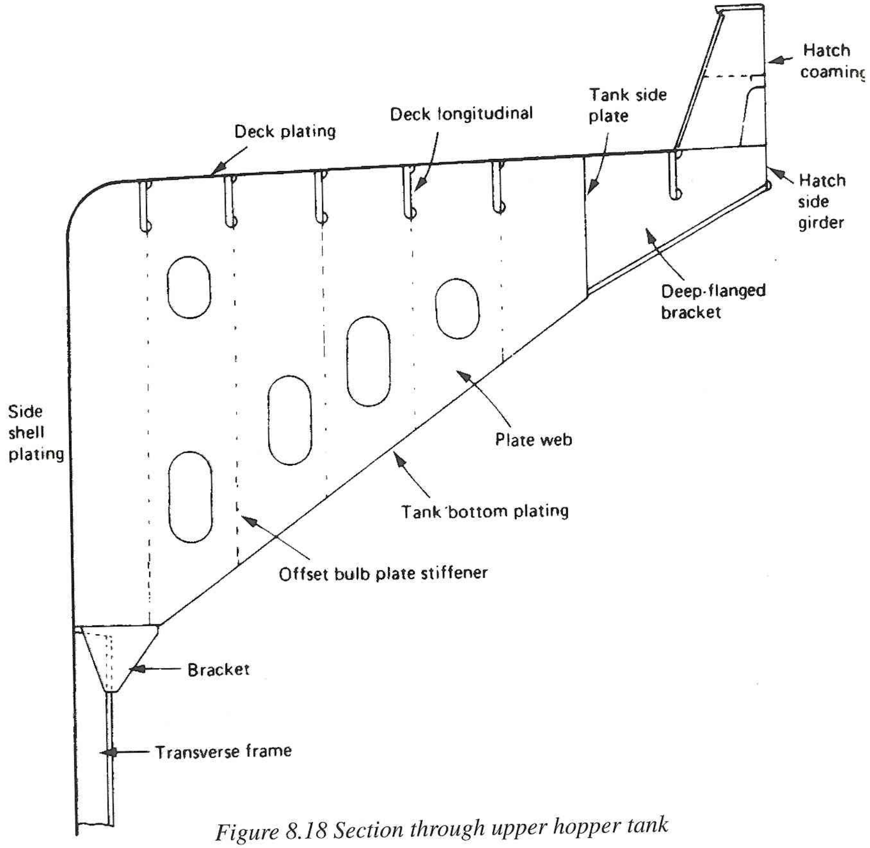


Figure 8.18 Section through upper hopper tank

Details of a bulkhead stool are shown in Figure 8.19. With a corrugated transverse bulkhead as shown, the stool arrangement is used to shape the forward and after lower regions or the cargo hold. This flush tapering shape permits easy discharge of bulk cargoes and simplifies cargo hold cleaning. Shedder plates are fitted inside the troughs of the corrugated bulkhead for the same reason.

Container ships

The cargo holds of a container ship create large open spaces which are uninterrupted by any structure or framing. The rigidity of the structure must be provided by the bulkheads and transverse webs in-between the cargo holds. The regular box shape of the container results in any curved region of the ship being unsuitable for the stowage of containers. The ship structure outboard of the cargo hold is, therefore, used for water ballast tanks or access passages, in addition to providing longitudinal strength for the structure. The loss of cubic capacity in the regular shaped holds is, to a large extent, offset by the stacking of containers on the hatch covers and the deck. Suitable lashing arrangements are then necessary for the various tiers of containers. Pure container ships do not carry cranes but rely on the shoreside gantry cranes at container berths to discharge containers. Hatch covers

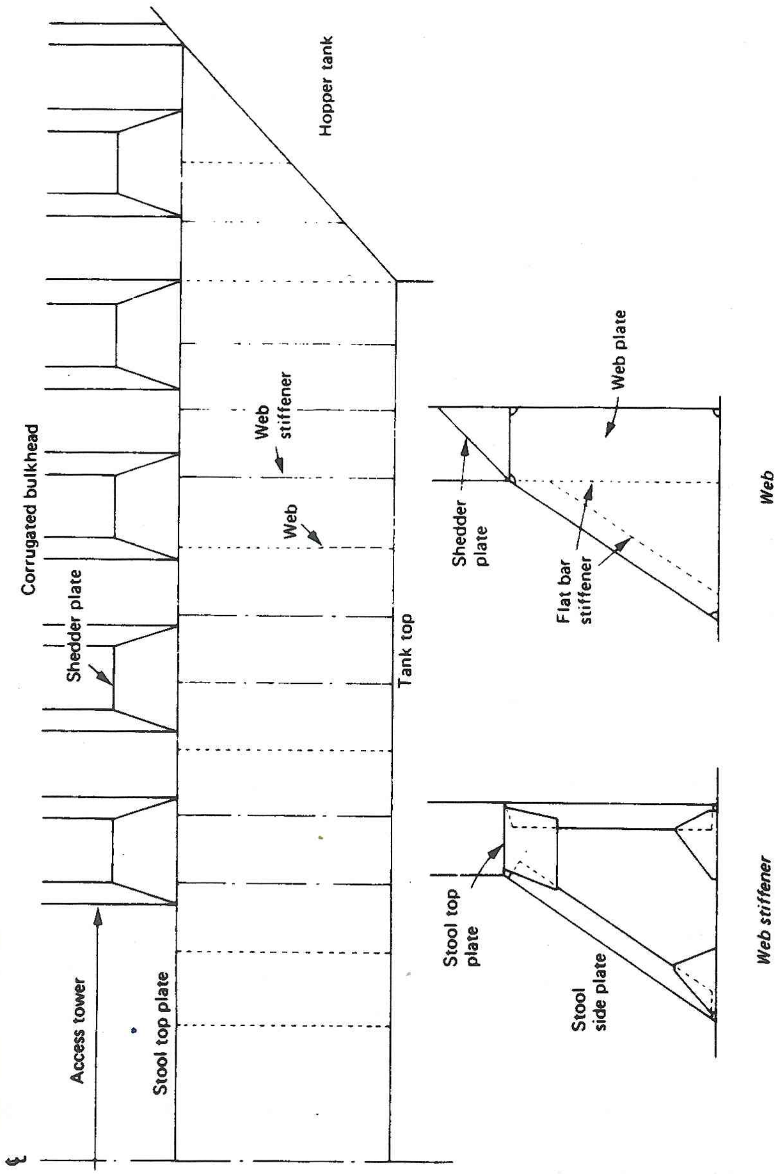


Figure 8.19 Stool arrangement below corrugated bulkhead

Framing

Container ships are longitudinally framed throughout all the continuous structural material. This consists of the wing tanks on either side of the cargo holds and the double bottom. A deep girder is fitted at the upper deck level and runs continuously through the cargo holds. Smaller box girders are located below the upper deck at the level of every second container.

To strengthen this open-box type structure, deep transverse webs are fitted at the ends of each of the cargo holds and the upper deck above the bulkheads, see Figure 8.20. This rigid box structure will resist torsion and racking stresses acting on the ship and extends over four frames. The webs are of solid plate construction at each end with bracket structures in-between.

The fore and after ends of the ship are transversely framed with appropriate strengthening for panting and pounding.

Bottom structure

A double bottom exists along the full length of the ship and is longitudinally framed. Plate floors are fitted every fourth frame in the cargo hold and at every frame in the machinery space. In the pounding region forward, solid floors exist initially at alternate frames and then at every frame. The tank top plating is increased in thickness in the cargo hold and is suitably strengthened for the carriage of either 40 foot or 20 foot containers to the required height.

In the arrangement shown in Figure 8.21, an extra longitudinal stiffener is located on either side of the vertical keel plate for support during docking. Pipe tunnels are located port and starboard in the double bottom with access via watertight doors from the machinery space. The sides of the pipe tunnels are formed from watertight side girders. Intercostal side girders are fitted beneath the side bulkheads and outboard of the pipe tunnels.

Side bulkheads

Side bulkheads are used to create a box-like structure along the shell. The side tanks formed are used for the carriage of water ballast with the upper spaces port and starboard used as an access passage and a cable tunnel respectively. These side bulkheads are transversely stiffened with web frames in line with the plate floors. Continuous horizontal stiffeners are fitted to the side shell and the bulkheads and increase in scantlings as they progress to the bottom shell.

Bulkheads

Watertight bulkheads are fitted at the hold boundaries. They are vertically stiffened across their width and have deep horizontal stringers, (see Figure 8.22). The stringers also serve as inspection and access galleries and are two frames deep. Two additional deep webs are fitted on either side of the centreline. All stringers and webs are fitted with facing plates. The transverse deep girder is fitted between the upper deck and the top of the bulkhead.

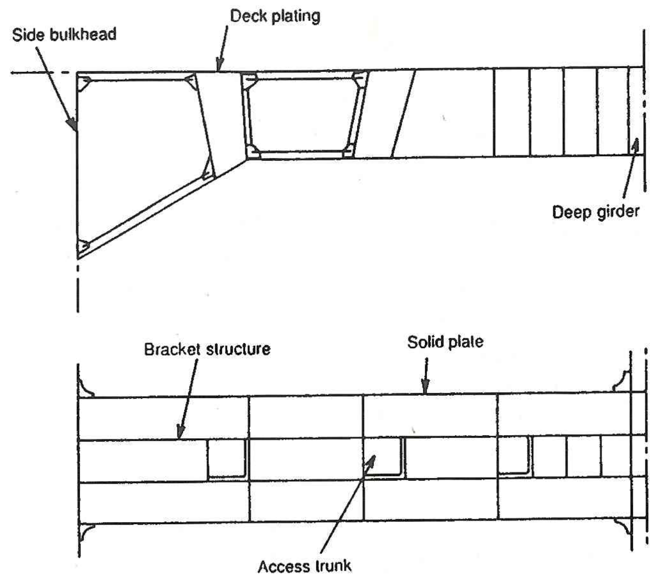
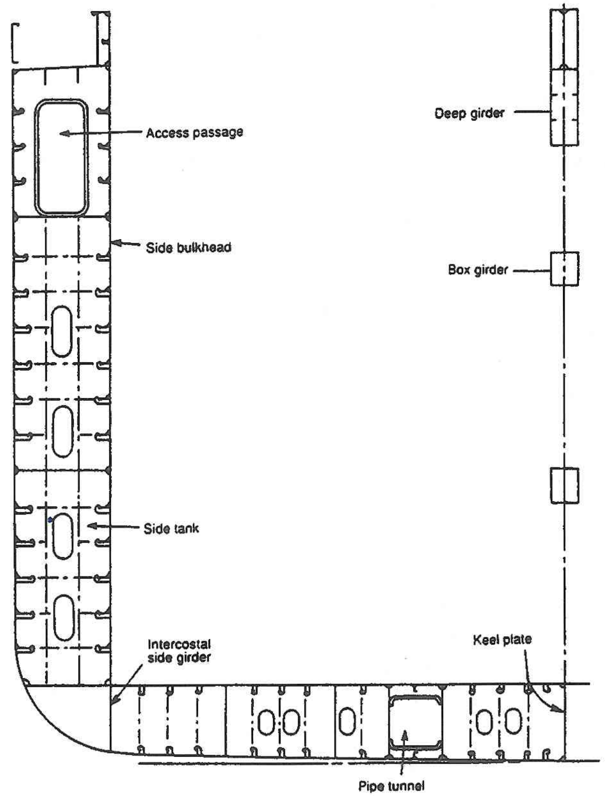


Figure 8.20 Deep transverse web



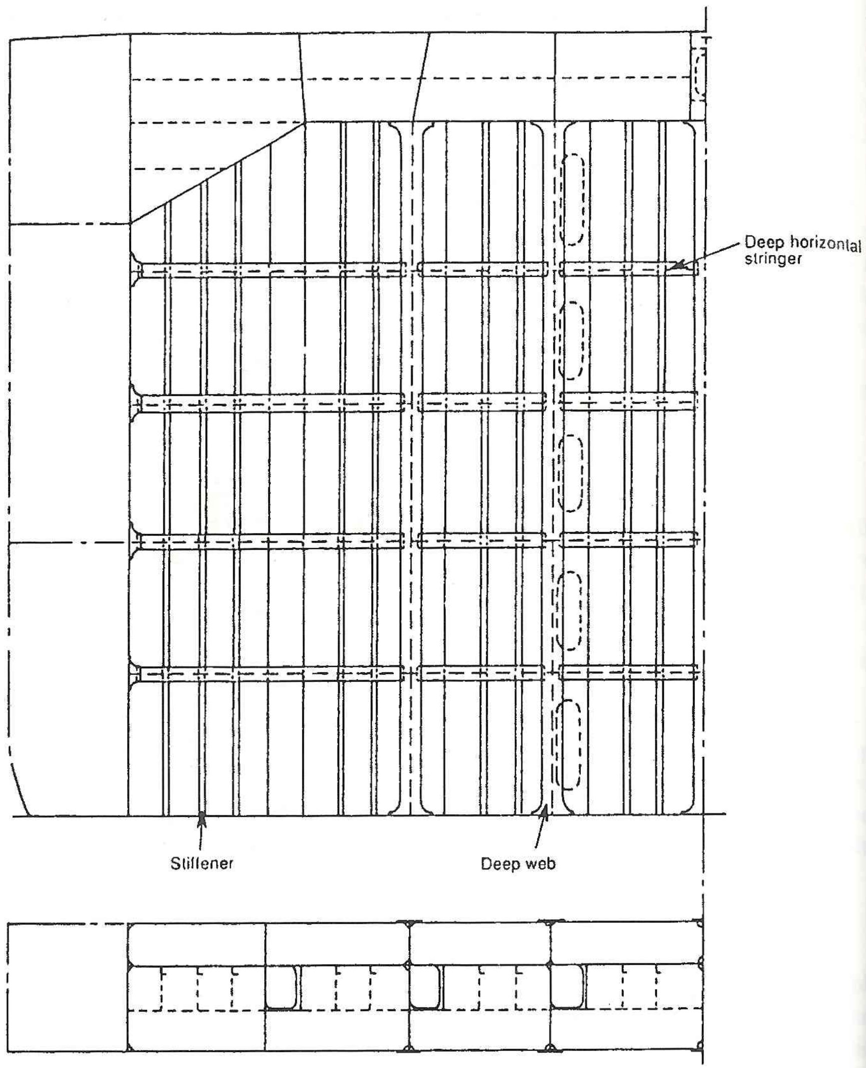


Figure 8.22 Watertight bulkhead

Container guides and fittings

The cargo holds are fitted with vertical cell guides at the corner points of all containers. Angle bars of about 15 x 150 x 12 mm are used. These are supported at intervals by brackets welded to cross ties of channel bar section. The lower end of the guide is welded to a stool about 50 mm thick which is in turn welded to the tank top. The tops of the guides have entry arrangements which may be fixed or movable and serve to assist in aligning the container both fore and aft and athwartships. The guide system may be for 40 foot or 20 foot containers depending upon the owner's requirements. Where guides are provided for 40 foot containers, temporary intermediate guides may be available for use with 20 foot containers.

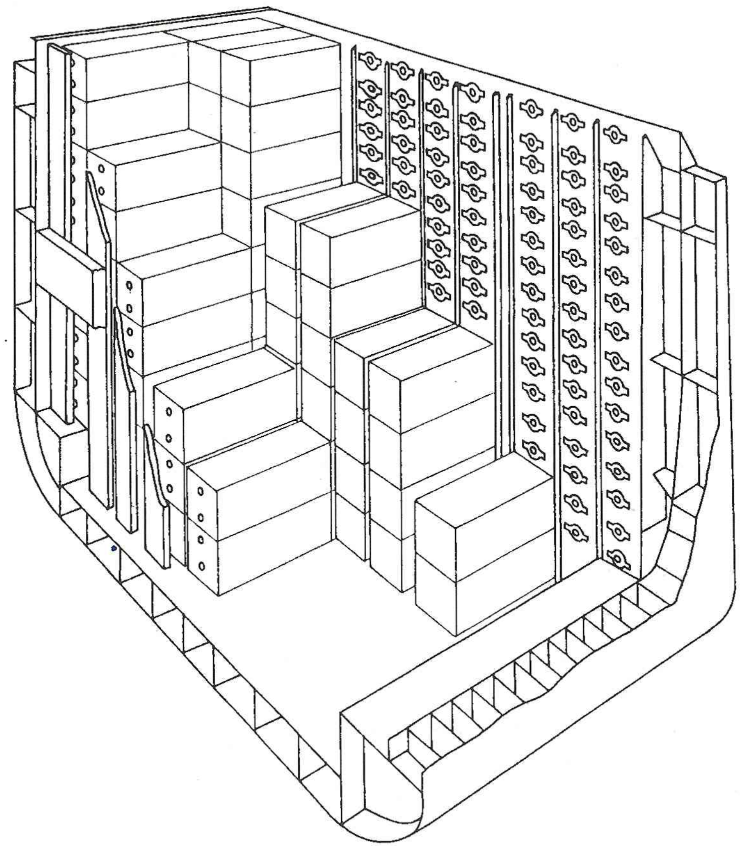
Cell guides must be robustly constructed since they are designed to resist container loading and unloading loads, prevent container movement and to transmit any dynamic loading into the main hull structure.

Where containers are carried on deck the hatch covers must have provision for suitable locking fittings to secure the corners of the containers. Where containers overhang the hatch coamings they must be adequately supported at their corners by stanchions of suitable height and provided with locking arrangements. Where containers are stacked, the tiers must be connected by locking devices at adjacent corners and bridging pieces across the tops.

Lashing arrangements may also be required depending upon the loading calculations or particular company practice. The cell guide structure and all container securing devices will be subject to classification society rules and regular surveys.

Refrigerated containers

Vessels designed specifically for refrigerated container carrying may have built-in ducting systems. These can be in two forms; a horizontal finger duct system in which are fed up to 48 containers from one cooler situated in the wings of the ship or, alternatively, a vertical duct system in which each stack of containers has its own duct and cooler (Figure 8.23).



This type of system is employed for containers having two port holes in the wall opposite the loading doors. Air is delivered into the bottom opening and, after passing through a plenum, rises through a floor grating over the cargo and returns via another section of the plenum to the top port. The connection between the duct and container is made by couplings which are pneumatically controlled.

Where only a small number of refrigerated containers are carried they will probably have refrigeration units integrally fitted which are operated by electricity. These containers are usually stowed on deck as air cooling of the refrigeration plant is required.

Roll-on Roll-off ships

The large open deck areas of roll-on roll-off (ro/ro) ships have become a matter of concern in relation to stability and action has been taken by IMO, following a number of accidents involving ro/ro ferries. Amendments to the 1974 SOLAS Convention, known as SOLAS 90, are considered to give an adequate standard of damage stability protection, following a collision in wave heights up to 1.5 m. A number of Northern European countries have obtained a regional agreement seeking further amendments, where a vessel must have damage stability to withstand 500 mm of water (SOLAS + 50 cm) on a watertight vehicle deck by October 1, 2002, three years earlier than SOLAS 90.

SOLAS 90 entered into force under the tacit acceptance procedure on 1 July 1997, but the SOLAS + 50 cm requirement was not included in the Convention. Contracting Governments may conclude agreements which bring SOLAS + 50 cm into force for vessels using their ports. The installation of a highly efficient drainage system may enable compliance with SOLAS 90, but structural changes, such as the installation of flood control doors are considered necessary to comply with SOLAS + 50 cm.

The International Association of Classification Societies (IACS) has introduced new regulations for the fitting and securing of upward-opening bow visors, side opening outer doors and inner bow doors. Closing arrangements must ensure tightness appropriate to the operational conditions. For example, inner doors must be weathertight, which means able to withstand water pressure from one side of the door only. Furthermore, the bow doors and inner doors must be arranged so that the bow door cannot cause structural damage to the inner door or the collision bulkhead if it is damaged or lost. If this is not feasible, then a separate inner weathertight door must be fitted.

Bow door strength has also been reconsidered, and must now be equivalent to the surrounding structure with securing and supporting structures of similar strength. Mechanical or gravity locking systems are required on opening and closing systems which must be interlocked. Water seepage through doors must be monitored and also the locking devices. The new regulations, while immediately applicable to new ships, will be retrospectively applied to existing vessels.

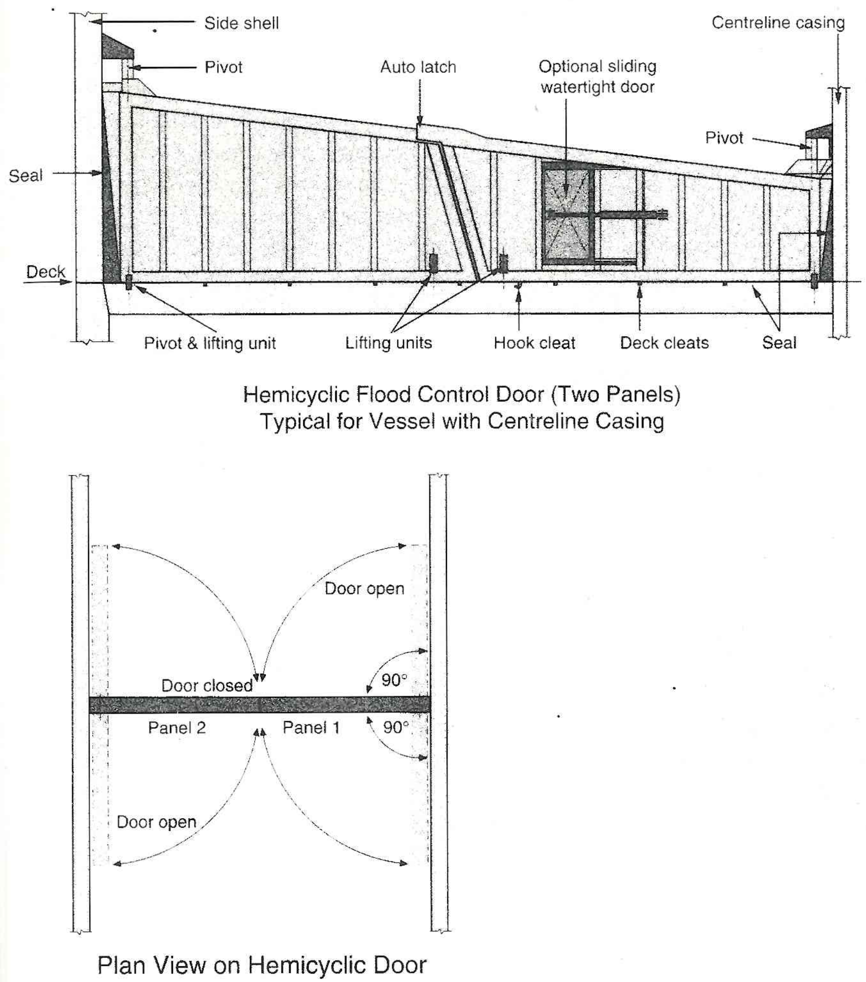


Figure 8.24. Hemicyclic flood control doors

Flood control doors

A MacGregor hemicyclic flood control door is shown in Figure 8.24. This door can rotate through 90 degrees either forward or aft to meet the needs of Ro-Ro vessels which have a drive-through vehicle deck. The two-section door is opened against the flow of traffic and then closed when the area in front of it is fully loaded. Loading can then continue behind the closed door. The two halves of the door, when closed, have sealing arrangements to prevent the passage of large volumes of water either at the sides or beneath the door. Prior to any movement, the door is first raised to relieve seal compression and then rotated. When closed and lowered to seal the opening, the door is locked securely in place. An optional sliding watertight door can be fitted in the flood control door, for crew access along the vehicle deck.

Bow doors

A number of bow door modifications of existing ro/ro ships have been undertaken by Kvaerner Ships Equipment AB, to meet the new IACS requirements. Where the inner door and bow ramp can be separate, the outer section of ramp and door is mounted on an independent, hydraulically-operated frame, which is lowered before the inner bow door is opened (Figure 8.25). The frame is positioned forward of the collision bulkhead door and controls the movement of the outer ramp parts. When the outer ramp parts and frame are folded out, the collision bulkhead door is laid onto the frame and completes the ramp assembly. When fully closed there is a collision bulkhead door in place, and a frame and outer ramp unit stowed forward of it. Interlocking of the various parts prevents operation of the outer door or bow visor out of sequence, to ensure safety.

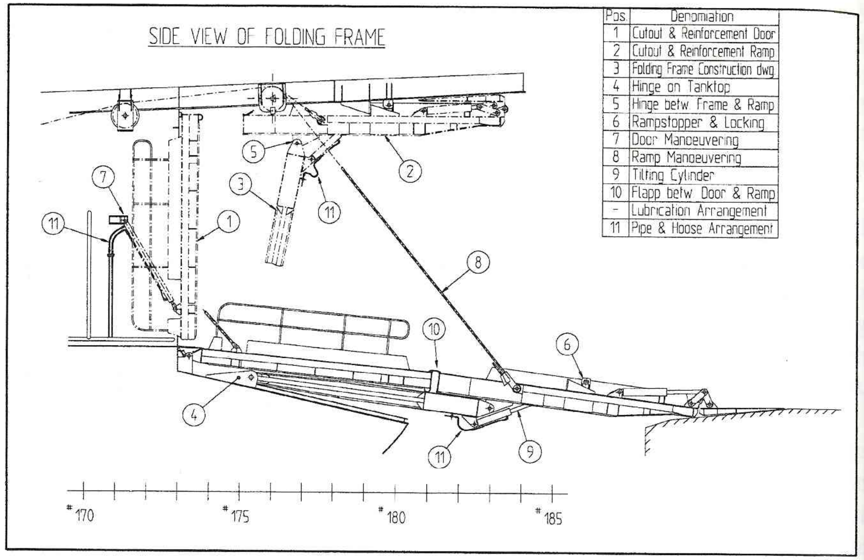


Figure 8.25 Folding frame bow door arrangement

Where the main ramp and door sections cannot be separated, an additional inner bow door must be fitted. This can be arranged in two halves which swing towards the ship's centreline to secure the opening (Figure 8.26). Alternatively a single section can be used which is hinged to swing down (Figure 8.27). The choice is largely determined by the space available within the ship.

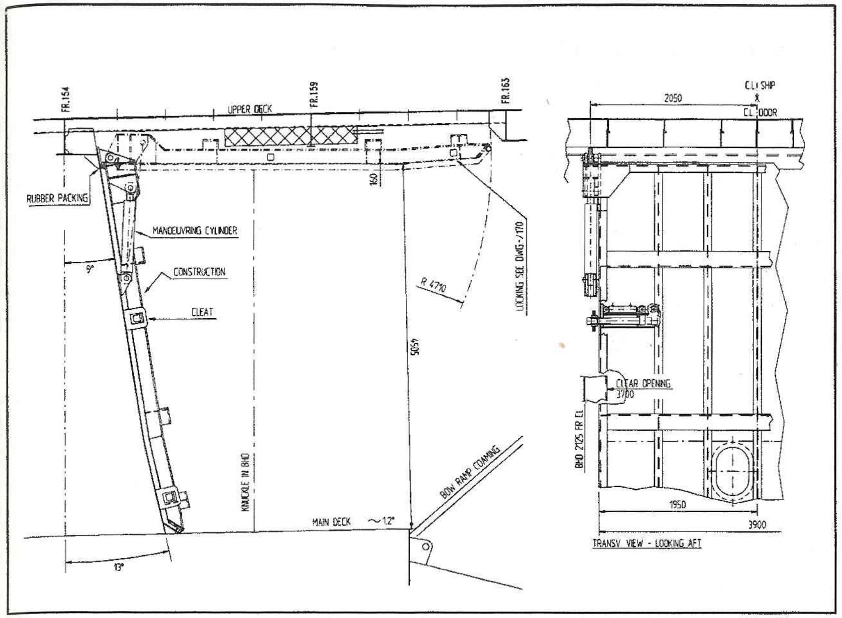


Figure 8.26 Top hinged inner bow door

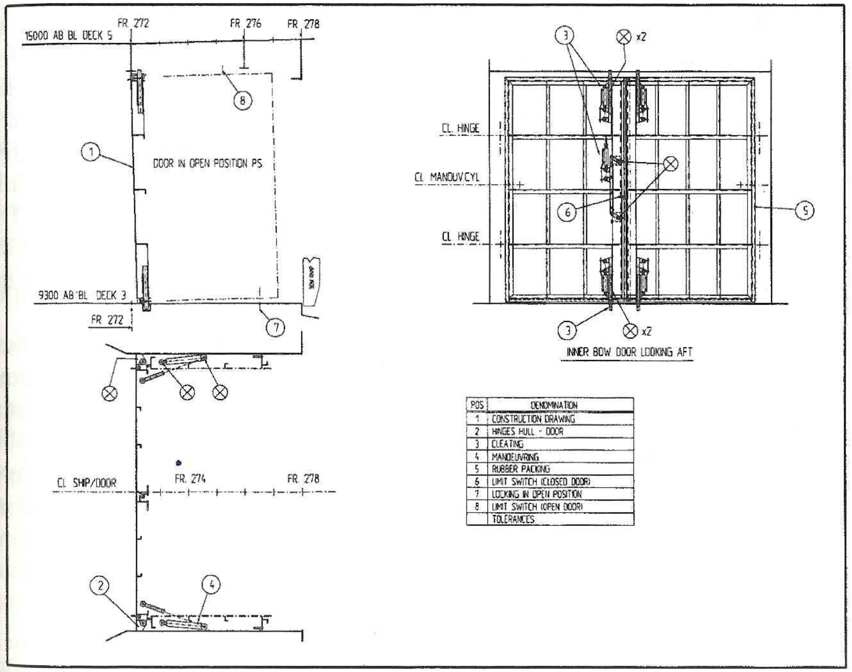


Figure 8.27 Side hinged inner bow door

9 Liquefied Gas Carriers and Chemical Tankers

The bulk transport of liquefied gases requires the use of specialised vessels. Natural gas and petroleum gas each require different transport arrangements and hence the vessel types are particular to their cargo. Chemical tankers, on the other hand, may carry dangerous chemicals or liquids such as wine or vegetable oils. Special constructional arrangements are therefore necessary for this versatile type of bulk carrier.

Liquefied gas carriers

The past 25 years have seen the emergence of the bulk transport of natural gases both for use as fuel and as a refrigerant. Specialist ships are now used to carry the various types of gas in a variety of tank systems, combined with arrangements for pressurising or refrigerating the gas.

Natural gas is found and released as a result of oil-drilling operations. It is a mixture of such gases as methane, ethane, propane, butane and pentane. The heavier gases, propane and butane, are separated by liquefaction and are termed 'petroleum gases'. The properties and therefore the behaviour of these two basic groups vary considerably, thus requiring different means of containment and storage during transportation.

Natural gas is, by proportion, 75-95 per cent methane and has a boiling point of -162°C at atmospheric pressure. Methane has a critical temperature of -82°C. The critical temperature is the temperature above which it cannot be liquefied by the application of pressure. A pressure of 47 bar is necessary to liquefy methane at -82°C. Thus, natural gas cannot be liquefied by pressure at normal temperatures. Liquid natural gas tankers are therefore designed to carry the gas in its liquid form at atmospheric pressure and a low service temperature in the region of -164°C. The problems encountered, therefore, deal with protecting the steel structure from the low temperatures, reducing the loss of gas and avoiding the leakage of gas into the occupied regions of the ship.

Petroleum gas consists of propane, propylene and butane or mixtures of these gases, all of which have critical temperatures above normal ambient temperatures. Thus they can be transported either as a liquid at low temperature and pressure or at normal temperature and under pressure. The design problems for this type of ship are similarly protecting the steel hull where low temperatures are employed, reducing gas loss and avoiding gas leakage, with the added consideration of pressurising the tanks.

Liquefied natural gas tankers

The tank types of LNG carriers are self-supporting and either prismatic, cylindrical or spherical in shape or a membrane construction which is supported by insulation. Materials used include aluminium, 90 per cent nickel steel or membranes composed of stainless steel or nickel iron.

Tank designs are split into three categories, namely self-supporting or free standing, membrane and semi-membrane. The self-supporting tank is strong enough by virtue of its construction to accept any loads imposed by the cargo it carries. A membrane tank requires the insulation between the tank and the hull to be load bearing, such an arrangement being termed an integrated tank design. Single or double metallic membranes can be used, with insulation separating the two membrane skins. The semi-membrane or semi-integrated design is similar to the membrane, except that the tank has no support at its corners.

A double-hull type of construction is used with each of the above designs, the space between being used for water ballast. The basic configurations are shown in Figure 9.1.

Comparison of tank types

Membrane and prismatic tanks use the underdeck cubic capacity most effectively. Cylindrical and spherical tanks involve constructional problems by penetrating the upper deck but provide greater safety in the event of collision or grounding. Membrane tanks are cheaper to build but the insulation, which must be load bearing, is more expensive. The insulation of spherical tanks need not be load bearing since it is only a partial secondary barrier, if needed at all in this respect. The hull and machinery costs are about equal for each type. All the different types are in service, with the firmly established designs being prismatic, spherical and membrane types.

Boil-off

Liquefied natural gas is continually boiling in tanks when transported by sea. There is therefore a need to release this gas to avoid a pressure build-up in the tank. It may be vented directly to atmosphere or burnt in boilers or in specially adapted dual fuel engines. Burning the boil-off gas in a flare mounted on a boom remote from the ship is another possible solution. Re-liquefaction is not economical because of the large power and huge cost of the machinery necessary.

Liquefied petroleum gas tankers

Three basic types of liquefied petroleum gas tankers are currently used—the fully pressurised tank, the semi-pressurised partially refrigerated tank, and the fully refrigerated atmospheric pressure tank.

The fully pressurised tank operates at about 17.5–18.0 bar and requires heavy, expensive tanks of carbon steel which are usually cylindrical in shape. This high pressure is equivalent to the vapour pressure of the cargo at the highest possible ambient temperature, usually taken as 45°C. The tank domes penetrate the upper deck and have fitted all the necessary connections for loading, discharging, sampling, etc.

Semi-pressurised tanks operate at about 8 bar and a temperature of about -7°C must be maintained in the tanks. Insulation is therefore required around the tank and, since some cargo will boil off, a re-liquefaction plant is needed. Horizontal cylindrical tank configurations are again used. Low temperature steels for

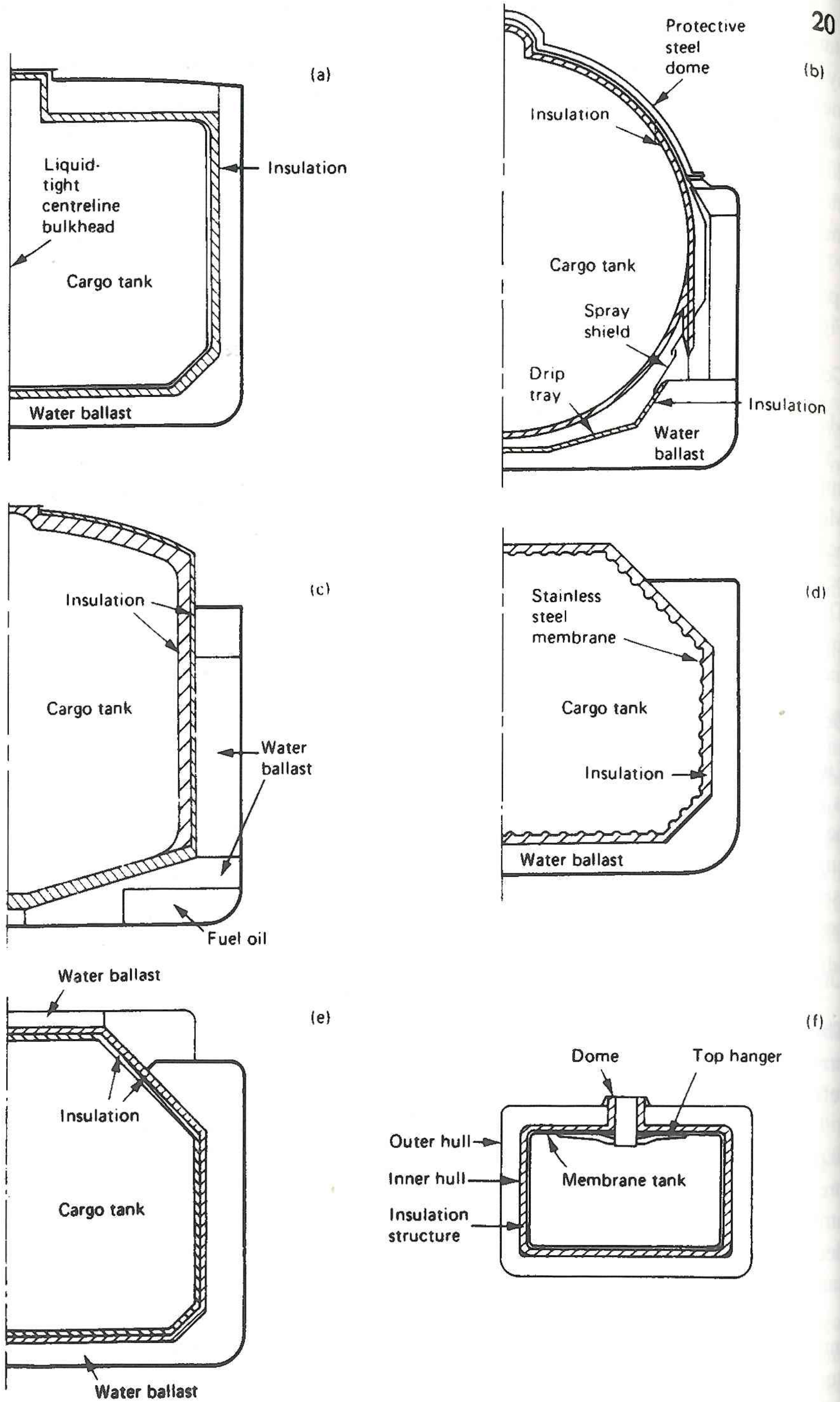


Figure 9.1 Tank arrangements for liquefied natural gas: (a) prismatic tank;

Fully refrigerated atmospheric pressure tank systems have service temperatures about -50°C and maximum working pressures of 0.28 bar. The tanks are insulated, self-supporting and prismatic in shape. The tank material must be ductile at low temperatures and is usually a fine-grain heat-treated steel such as Arctic D or a low alloy nickel steel. A secondary barrier capable of retaining the cargo in the event of main tank fracture is required by classification society rules. Three tank types are used with fully refrigerated LPG ships:

(1) A central trunk runs along the top for the length of the cargo tank. Wing ballast tanks are fitted, their inner surface acting as the secondary barrier (Figure 9.2).

(2) A large dome is situated aft at the top of the tank and wing ballast tanks are fitted (Figure 9.3). The inner surface of the wing tanks acts as the secondary barrier.

(3) A large dome is situated aft at the top of the tank but no wing ballast tanks are fitted (Figure 9.4). Hopper tanks are used for ballast when necessary. The hull itself acts as the secondary barrier and must be of low temperature carbon steel in way of the cargo tanks.

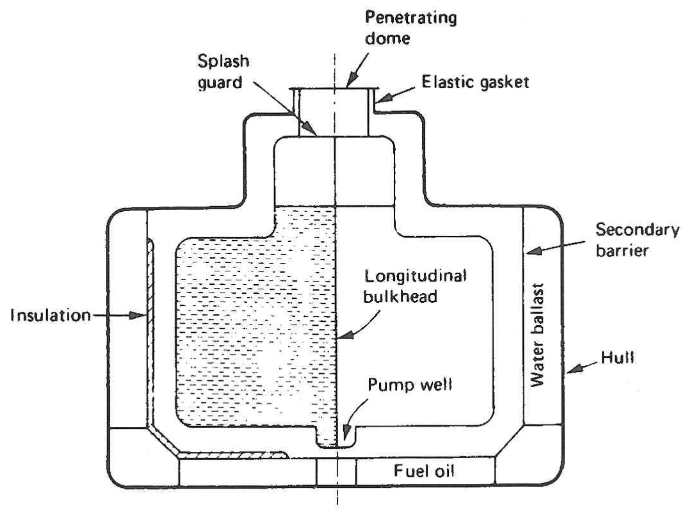


Figure 9.2 Cylindrical trunk tank arrangement

Comparison of tank types

The reduction in weight of tank material in a semi-pressurised tank design is offset by the need for refrigerating plant and insulation around the tank. The use of low pressure tanks does, however, permit better utilisation of the underdeck cubic capacity of the vessel. The fully pressurised tank has no need of insulation nor a secondary barrier.

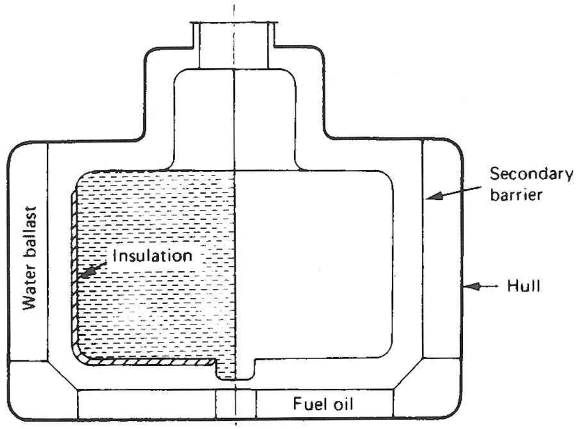


Figure 9.3 Aft dome tank arrangement

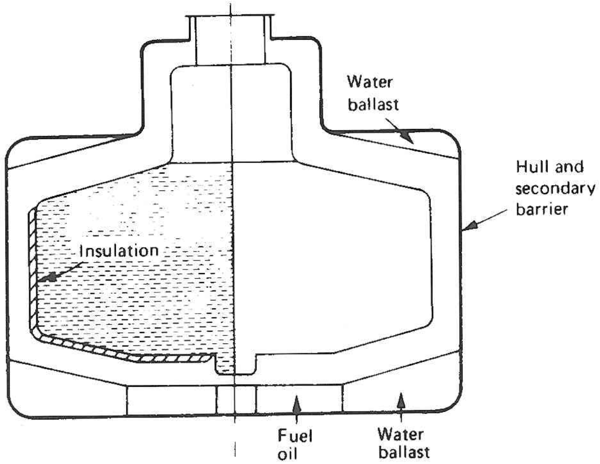


Figure 9.4 Tank arrangement with hull as secondary barrier

Construction aspects of LNG and LPG carriers

The various regulatory bodies have rules for the construction and classification of ships carrying liquid gases in bulk. These rules follow closely the IMO code for this type of vessel.

A complete or partial secondary barrier is required in all but pressure vessels operating at ambient temperatures down to -10°C. This secondary barrier is a liquid-resisting outer skin which will temporarily contain any leakage of the liquid cargo from the primary barrier or tank. The secondary barrier should also prevent the structure temperature from dropping and should not fail under the same circumstances as the primary barrier.

Bulkheads or cofferdam arrangements are necessary between cargo tanks, depending upon the temperature of the cargo carried.

Cargo-pumping pipework systems must have no interconnection with other systems. Where a cargo tank has no secondary barrier a suitable drainage system must be provided which does not enter the machinery space. Where secondary barriers are used drainage must be provided to deal with any leakage, again from outside the machinery space.

Special ship survival arrangements are required which limit the width of tanks in relation to the ship's breadth. Double-bottom tank heights are also stipulated. Arrangements of tank design or internal bulkheads where possible must be used to restrict cargo movement and the subsequent dynamic loading of structure. Membrane tanks, for instance, cannot have internal bulkheads and are tapered off in section towards the top.

Materials of construction and those used in piping systems are dealt with in considerable detail in the rules.

Chemical tankers

The hazardous nature of many, but not all, of the cargoes carried in chemical tankers has resulted in various rules and regulations relating to tanker construction in order to safeguard both the ships and the environment.

The International Maritime Organisation (IMO) has produced a 'Code for the Construction and Equipment of Ships carrying Dangerous Chemicals in Bulk'. This code provides a basis for all such vessel designs and an IMO Certificate of Fitness must be obtained from the flag state administration to indicate compliance.

This code was incorporated into the International Convention for the Safety of Life at Sea, 1974 (SOLAS 74), for chemical tankers built on or after 1 July 1986.

Annex II of the Marpol 73/78 Convention and Protocol is also now in force and applies to hazardous liquid substances carried in chemical tankers.

IMO ship types

The IMO Code sets out three ship types—I, II and III, which correspond to different classes of hazardous chemicals and the suitable location of the vessel's tanks. The length L and breadth B are defined in the International Convention on Load Lines 1966 and the configurations are given in Figure 9.5. Damage considerations following collision, stranding and minor ship side damage and also survival assumptions were the criteria considered in producing the tank configurations. Ship type I is designed to provide maximum preventive measures with respect to the escape of it's cargo under the assumed conditions. Ship type II requires significant preventive measures. Ship type III is for products of a sufficient hazard to require a moderate degree of containment.

Ship structure

The number of tanks, their volume and layout, will further be determined by the required frame spacing in the cargo space. The tanks must be designed to withstand the dynamic forces within partially filled tanks and also the high specific gravity of some cargoes.

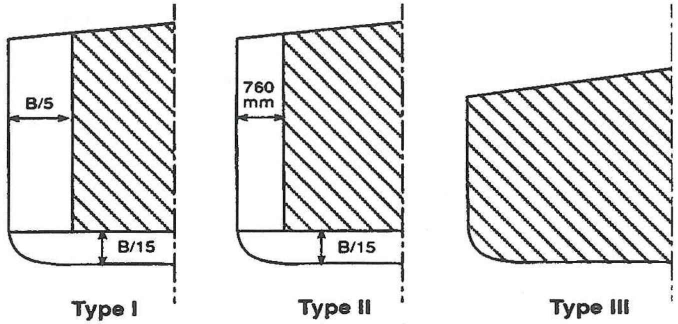


Figure 9.5 Chemical tankers IMO ship types

The bottom structure may be either single or double bottom throughout or a double bottom beneath the centre tanks and a single bottom beneath the wing tanks. The choice will be influenced by the fact that IMO types I and II must have a double bottom and double bottom ballast tank capacity is needed for trimming and heeling. Bulkheads may be either horizontally or vertically corrugated or plane with stiffeners on the outside of the tank to facilitate tank cleaning. Sandwich or double skin bulkheads have also been used to provide easily cleaned tank surfaces in both wing and centre tanks.

The hull structure may be single or double skin. IMO Type II cargoes require a double hull and cargoes requiring heating or cooling can benefit from the insulating effect of a double skin.

Deck structure can be conventional with stiffeners in the tank space or may use a double skin or cofferdam in order to provide plane surfaces within the tanks. Single decks with stiffeners outside the tank space have been used.

Cargo tank types

Cargo tanks may be 'integral' or 'independent'. An integral tank is built into and contributes to the strength of the hull structure. An independent tank is completely separated from the hull structure and does not contribute to the strength of the structure or the loads imposed upon it by the sea. Where an independent tank is designed to withstand an internal pressure in excess of 0.7 bar gauge, it is a pressure tank. Tanks which do not exceed this pressure are considered gravity tanks and can be either independent or integral. Small cargo parcels can be carried by fitting deck tanks, which are usually cylindrical gravity tanks, independent of the hull.

Cargo handling

The large numbers of tanks and the need to avoid contamination between different chemicals usually results in the use of deepwell pumps in each tank. The pump may also be used as the filling line for the tank.

Tank ventilation may use open or closed vent piping depending upon the type of cargo. The height of the main vent may be as low as 4 metres for less toxic and as high as B/3 for highly toxic cargoes. Pressure/vacuum valves are used to guard against overpressure in the tanks.

Heating coils may be provided in some or all of the tanks. Steam, heating oil or warm water can be used as the heating medium. Tank cleaning systems are also required and must include a slop tank system to comply with Marpol 73/78.

Tank coatings

Protection of the structural components is important and various types of coating are used in the cargo tanks. Tanks may be constructed of mild steel, clad steel or stainless steel. The choice of paint or other coating will depend upon the various cargoes to be carried and compatibility is essential. The main types of coatings used are epoxy, phenolics, zinc silicate and polyurethane. Rubber coatings are used in tanks carrying liquids such as hydrochloric acid.

NOT TO BE TAKEN AWAY WITHOUT PROPER AUTHORISATION

10 Ventilation

An ocean-going ship is required to operate in a variety of very different climates. Air temperatures may range from -15°C to 50°C and sea water temperatures from 0°C to 38°C. The moisture content of the air will vary considerably and solar radiation may affect one or more of the ship's exposed surfaces. All the various forms of good and bad weather will also be experienced. The air from the air-conditioning and ventilation plants is therefore required to provide an acceptable climate for the crew to live and work in, sufficient air for machinery use and to maintain temperature and humidity at acceptable levels to the cargo. All this must be achieved regardless of the conditions prevailing external to the ship. The design of suitable systems will therefore require information about the ship's trade routes, types of cargo and machinery installation.

Accommodation

Most ship's air-conditioning systems employ centrally situated units. These units are self-contained and supply the cabins and spaces within a particular area via trunking. The control possible in individual cabins or spaces depends upon the nature and complexity of the central unit. Three basic systems are in use—the single duct, the twin duct and the twin duct with reheat. In each case the central unit will supply warm or cool air, or clean, humidify or dehumidify the air supplied to the cabins.

The single duct system

In the single duct system the central unit mixes outside air with some returned or recycled air. This air is then filtered, heated and perhaps humidified or cooled. This conditioned air is then distributed along a single duct to the individual supply units in the different spaces. The amount of supply air can be controlled within the particular cabin or space. Figure 10.1 shows the arrangement of the single duct system.

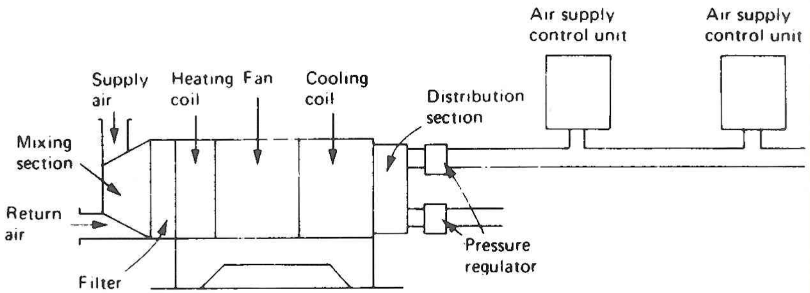


Figure 10.1 The single duct system

The twin duct system

Again, outside and returned air are mixed in the central units then filtered, preheated and perhaps humidified. Some of the air leaves the unit before it reaches the cooler, to be reheated; the amount is increased as the outside temperature falls. The conditions are passed through separate ducts to controlled mixing units in the individual spaces. The air temperature and condition can then be selected for the particular space. Figure 10.2 shows the arrangement of the twin duct system.

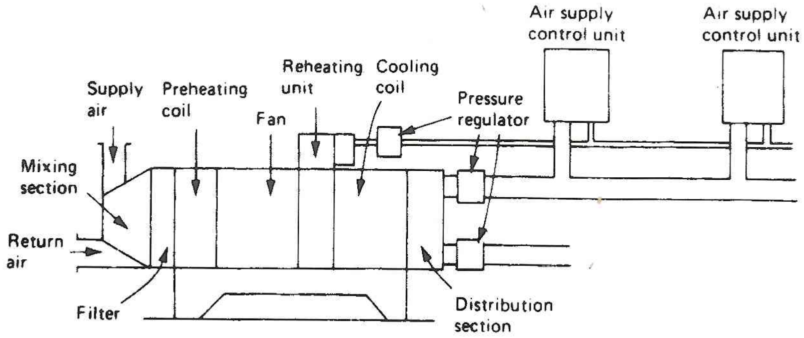


Figure 10.2 The twin duct system

The single duct with reheat system

The central unit mixes outside and return air, filters, preheats and humidifies or cools the air to the lowest required temperature of any part of the system. The air then passes along one duct to individual units in the spaces. Within these units is a controlled heater over which the air passes. Heating may be achieved by circulating hot water or an electric heater. The air supply and its temperature may therefore be regulated. Figure 10.3 shows the arrangement of the single duct with reheat system.

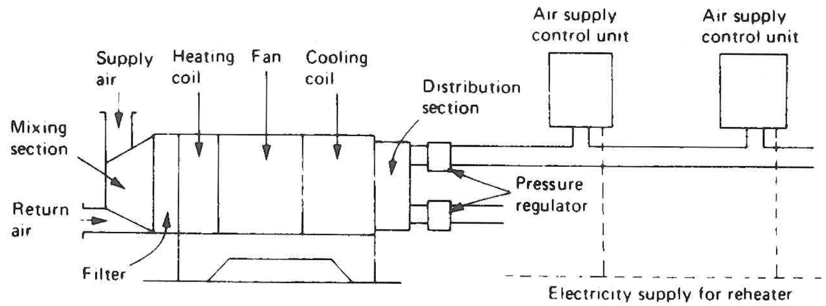


Figure 10.3 The single duct with reheat system

Cargo spaces

The primary function of ships is to transport goods from place to place. The cargo must be delivered in good condition and, in addition to careful loading and discharge, the storage and ventilation must be suitable and satisfactory. Inadequate, poor quality air supplied can seriously damage most cargoes. Fairly simple systems of cargo ventilation and attendant procedures can prevent such damage. Different cargoes react to the climate on board in as complex a manner as the human body, with often irreparable damage as the result.

Certain general cargoes, some fruit and vegetable cargoes and hygroscopic (water-absorbing or emitting) cargoes are carried in non-insulated holds. As a result they are exposed to all climatic changes which may cause condensation on the hull or cargo. Ventilation of the holds in which they are carried is therefore necessary. Refrigerated and frozen cargoes are carried in insulated holds but because of the living, gas-producing nature of the cargo they also require ventilation.

Ventilation of non-insulated cargo holds

The purpose of ventilation in non-insulated holds is to remove surplus heat and humidity, to prevent the condensing of moisture on cargo or hull and to remove gases produced in the ripening process of some fruit and vegetable cargoes. Natural and mechanical ventilation systems are used for this purpose.

Natural ventilation is accomplished by inlet and outlet pipes and trunking to each cargo space. These inlets and outlets consist of cowls or ventilators of various designs. Air is forced in by the action of the wind or drawn in as a result of an ejector type of exhaust drawing air out which is then replaced. Where the force of the wind is utilised the cowls must be manually positioned, and are large cumbersome fittings which must be well stayed to the deck. Figure 10.4 shows a natural ventilation arrangement for a tween deck or workshop. Most modern ships utilise mechanical ventilation for reliability, improved performance and the reduced size of cowls necessary.

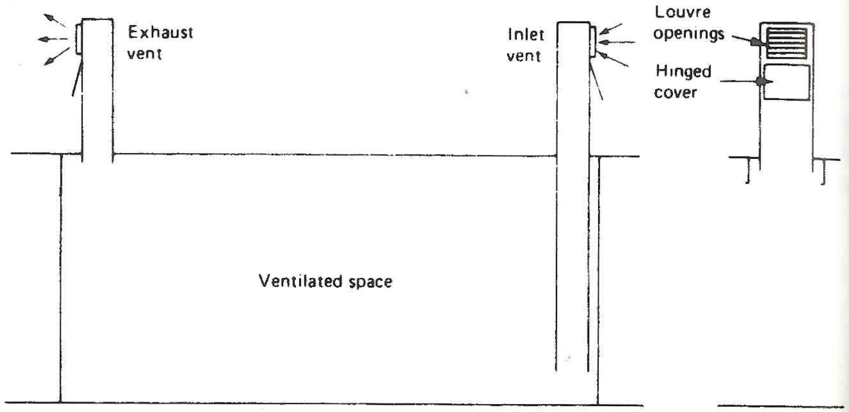


Figure 10.4 Natural ventilation of tween-deck space or workshop

Mechanical ventilation operates in two distinct systems—open or closed. The open system uses axial flow fans fitting in the inlet and exhaust trunks. The trunks may have separate cowls or be incorporated into samson posts or masts. The air is supplied along trunking and ducts to the bottom of the hold. The air is drawn from the top of the hold just below the decks. The exhaust fans can be reversed if condensation is likely near the deckheads, for example with a low outside air temperature. Figure 10.5 shows the arrangement of the open mechanical ventilation system.

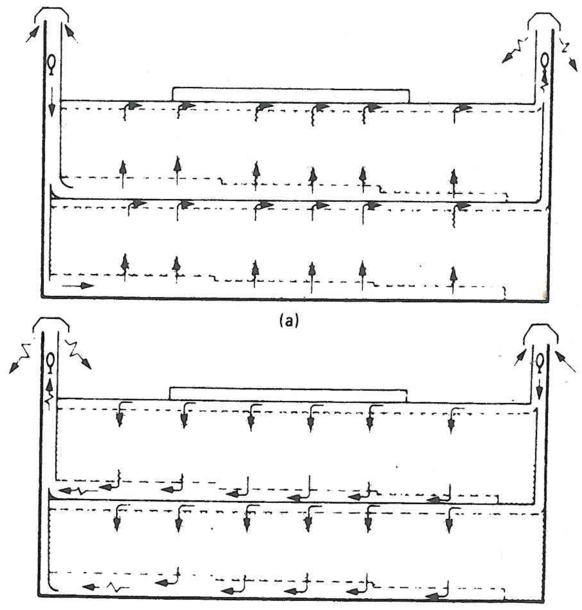


Figure 10.5 Open ventilation system: (a) normal circulation; (b) reversed circulation—to prevent underdeck circulation at low outside temperature

The closed system recirculates air and a controlled amount of fresh air can be admitted. The ventilating air is distributed around the hold and cargo, forming an insulating wall or curtain between the two. Exhaust air is drawn from the bottom of the hold. This system affords every possible mode of control and is widely used in somewhat varied forms. Figure 10.6 shows the closed ventilation system.

Ventilation of refrigerated cargo holds

Refrigerated cargo holds require a carefully controlled air-replacing system for each individual space. Cooled air is supplied to the refrigerated hold where it gains heat from ripening cargoes and entrains the gases produced. This air is then exhausted and a careful balance must be maintained between inlet and exhaust gas quantities, regardless of the outside climatic conditions.

One system achieves this by drawing outside air down to a bank of cooler tubes via a central unit. The dehumidified air then passes into the cargo holds. The exhaust gases are drawn from the hold through ducts back to the central unit and then returned to the outside atmosphere. The linking of inlet and outlet valves ensures a constant air supply at all times to the hold. Figure 10.7 shows the arrangement of such a system.

Particular types of ship have their associated cargo ventilation problems, e.g. 'roll-on, roll-off' ships, and the vehicle exhaust fumes during loading and discharging. Bulk carriers usually only require natural ventilation. The particular problems for each ship type must be considered early on at the design stage to ensure a suitable system is provided

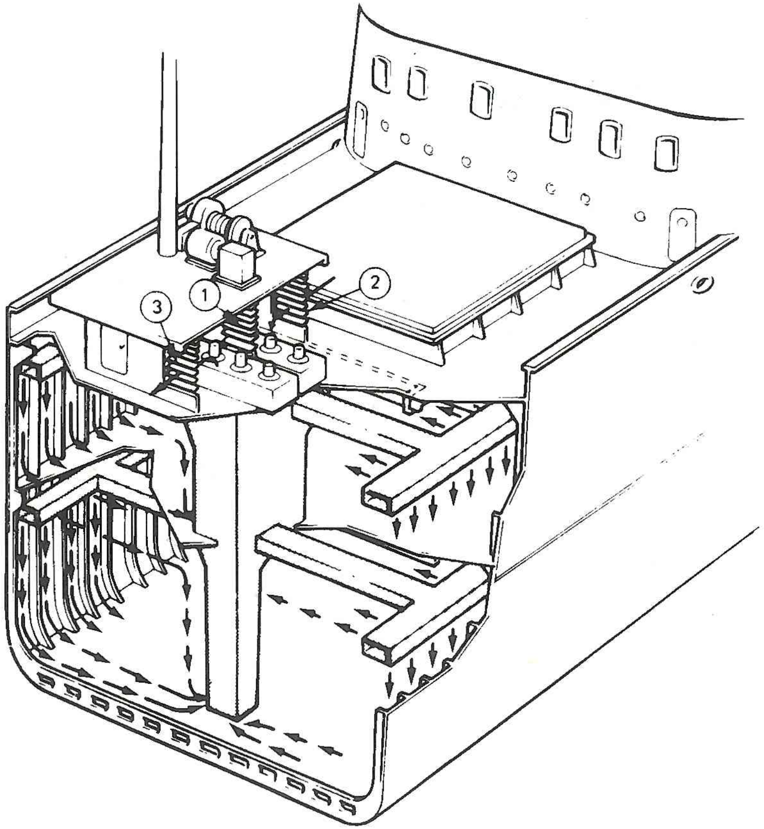


Figure 10.6 Closed ventilation system (1, recirculating damper; 2, inlet air damper; 3, exhaust air damper)

Controlled Atmosphere

Refrigerated cargo ships are making increased use of Controlled Atmosphere (CA), a technique which increases the storage life of fruit and vegetables. Oxygen and carbon dioxide levels and relative humidity are independently controlled to within close tolerances within a particular CA zone. This slows down the ripening of fruit and vegetables in transit. In a CA zone, oxygen levels may range from 1 to 12 per cent, carbon dioxide from 0 to 25 per cent and relative humidity should be kept within 40 to 90 per cent

The chamber or zone must be airtight, and any leakage of gas replaced by injecting the required volume into the zone. A low oxygen alarm and sampling points within the chamber protect cargo from suffocation, which would occur if the oxygen level was less than 0.5 per cent by volume.

The CA chamber will not support human life and rules exist for the use of CA, to ensure adequate safety precautions are taken prior to entry to such spaces. Locks and alarms are fitted to CA spaces and, if entry is required, complete aeration must take place. Ventilation outlets must be safely led out into the atmosphere, well away

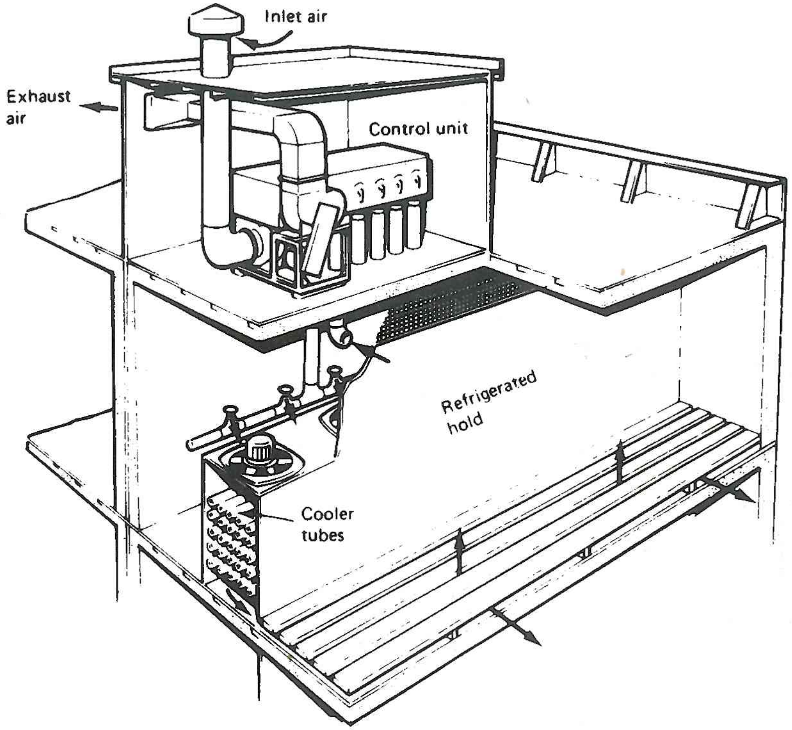


Figure 10.7 Balanced air renewal system for refrigerated cargo spaces

Machinery spaces

The machinery space requires an air supply for the operation of boilers, combustion engines, compressors, etc., and to maintain a satisfactory climate for the operating staff to work in.

Certain machinery consumes or requires air for its operation and sufficient air at as low a temperature as practically possible should be provided. Underpressure occurring in the machinery space will affect the efficiency and performance of internal combustion engines. Overpressure may lead to leakage of hot air into the accommodation. Ventilation is also necessary to remove the heat generated within the machinery space and thus provide a reasonable climate for staff to work in. This very difficult task is achieved by the provision of ducted supplies of filtered but uncooled air to as many regions as possible. Particular areas such as workshops and control rooms, being small, may be air conditioned and more readily provided with an acceptable working climate.

Various systems of air supply to the machinery spaces and casing are in use and are shown in Figures 10.8—10.10.

Figure 10.8 utilises a medium pressure axial flow fan supplying air down a trunking, which is proportionally released at the various platform levels and exhausts through the top of the casing. Figure 10.9 uses a low pressure axial flow air through ducts to outlets at the various platforms. Figure 10.10 uses medium pressure axial flow fans to provide a through trunking system to the various outlets at the various platforms. This method has proved to be the best. A diagrammatic arrangement of medium pressure axial flow fans and trunking in a machinery space is shown in Figure 10.11.

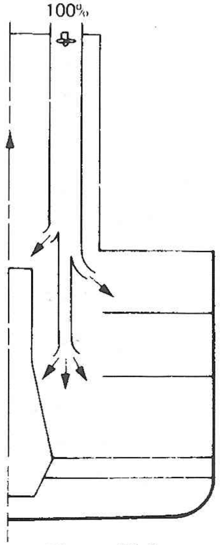


Figure 10.8

Machinery space ventilation using medium pressure axial flow fan

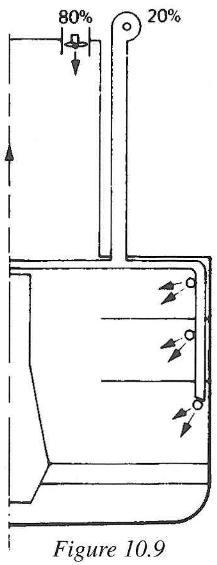


Figure 10.9

Machinery space ventilation using low pressure axial flow fan and high pressure centrifigal fan

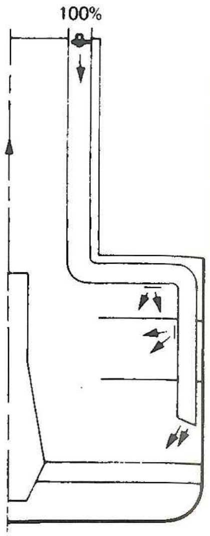
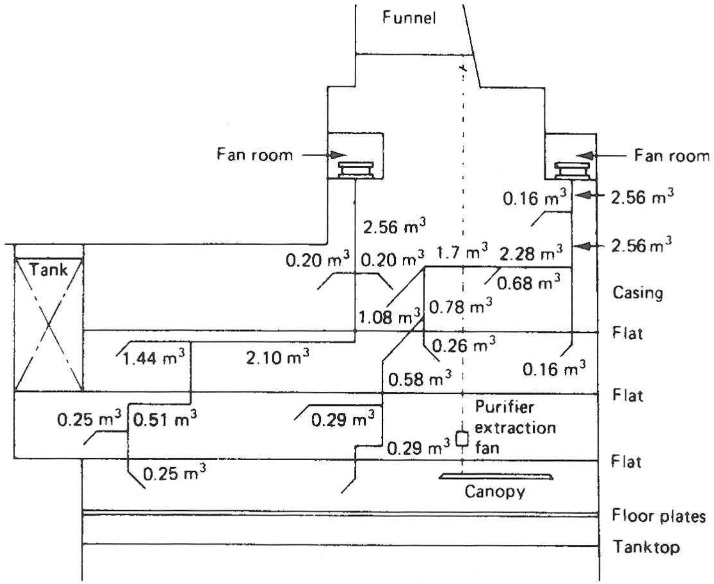


Figure 10.10

Machinery space ventilation using medium pressure axial flow fans and a through trunking system.



Ventilation

Control rooms

The provision of control rooms in most modern machinery spaces ensures close careful control of the climate in such spaces, often with the provision of air conditioning in addition to ventilation. This climate control provides the personnel with a comfortable working area isolated from the main machinery space. Also, delicate equipment in need of careful climatic control is able to receive it. The satisfactory operation and continuous performance of modern control equipment requires a carefully controlled environment which, by using a control room, can be achieved.

A separate ducted supply is led into the control room and, usually, through a filtering air-conditioning plant or unit which is set to function automatically with controls located in the control room. A matched exhaust will remove stale warm air from the control room. Figure 10.12 shows such an arrangement.

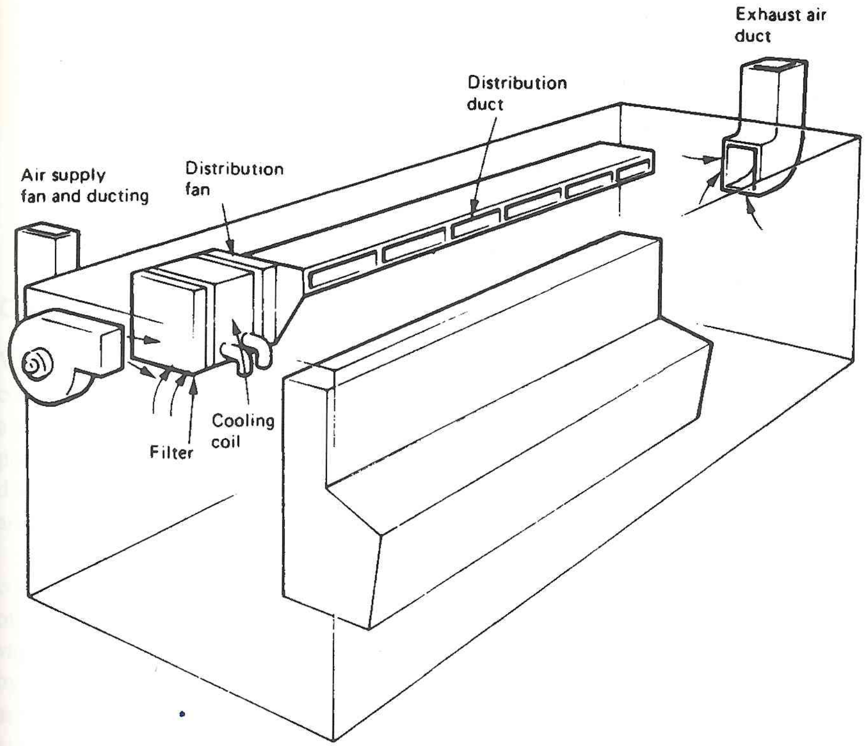


Figure 10.12 Control room ventilation

Pumprooms

Tanker pumprooms require ventilation to carry away poisonous cargo fumes resulting from leaking glands or pipe joints. The working climate in this space well below deck level must also be comfortable for any personnel present. Mechanical exhausting of air is achieved by the use of axial flow fans and trunking. The trunking draws from the pumproom floor and emergency intakes at a height of

2.15m from the working platform. These emergency intakes must be fitted with dampers which can be opened or closed from the weather deck or the working platform. The fan motors are located in the machinery space and drive the fans through gastight seals in the bulkhead. Supply is through cowls or louvres at the top of the pumproom. An arrangement is shown in Figure 10.13.

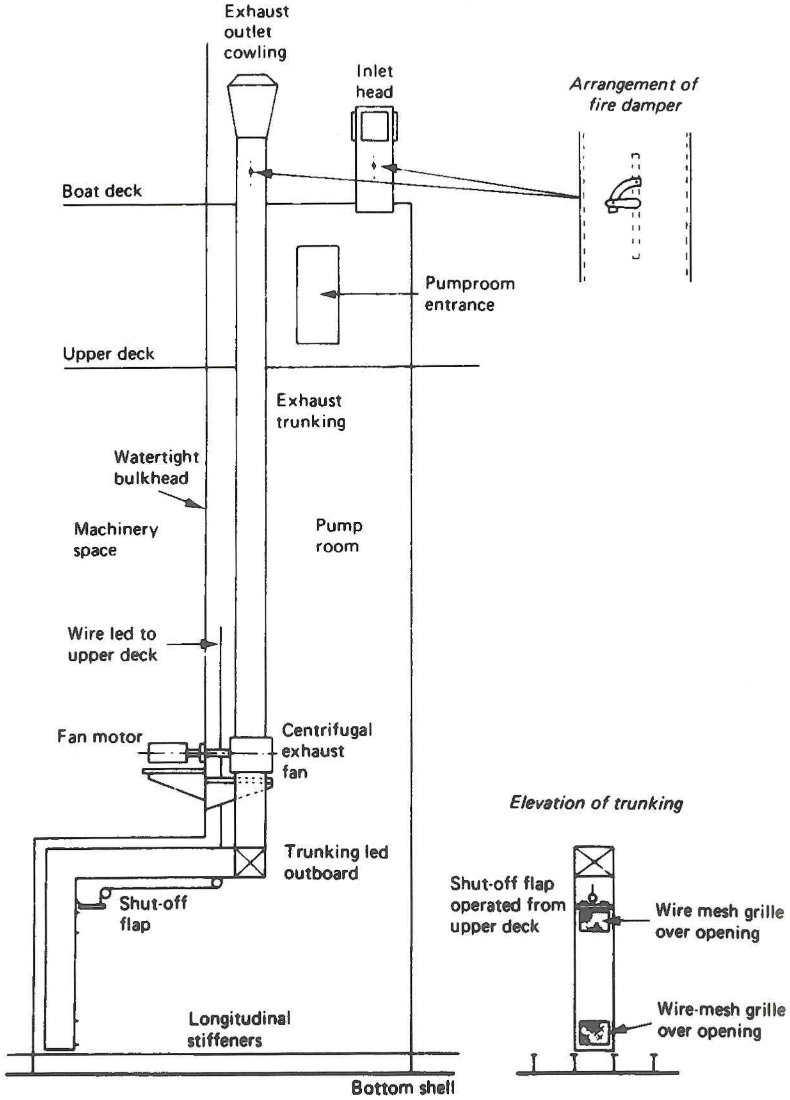


Figure 10.13 Pumproom ventilation

Double-bottom tanks

Ventilation of double-bottom tanks is provided by means of an air pipe situated remote from the filling pipe and usually at the highest point in the tank to avoid

patent type of head. Air pipes from fuel tanks are positioned in low risk areas and have flame screen gauzes fitted (Figure 10.14).

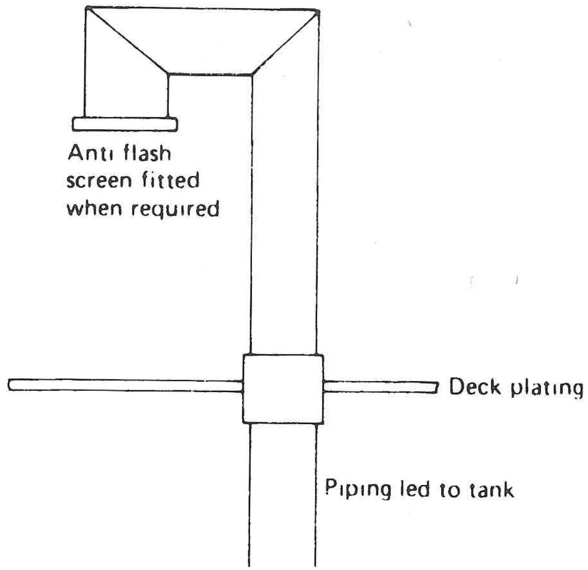


Figure 10.14 Air pipe head

Cargo tanks

Ventilation of cargo tanks avoids overpressure or partial pressure conditions which could occur during loading and unloading of cargo. Temperature fluctuations during a voyage could have a similar effect. Vapour pipelines from the cargo hatch are led to pressure/vacuum relief valves which are usually mounted on a standpipe some distance above the deck. Individual vent lines are fitted for each tank on large tankers and a common venting line is led up a mast or samson post on smaller vessels.

During loading and discharging of the cargo the ventilation requirements are considerable. Air must be drawn in or removed in quantities equivalent to the cargo oil discharged or loaded. In addition, during the loading operation the hydrocarbon vapours issuing from the tank must be dispersed well above the deck. This is achieved by the use of high velocity gas venting valves. One type is shown in Figure 10.15. The arrangement consists of a fixed cone around which is a movable orifice plate. A counterweight holds the orifice plate closed until sufficient gas pressure builds up to lift the plate. The gas is throttled through the orifice and issues at high velocity, dispersing into the atmosphere well above the deck. During discharge the cover is opened and a linkage from the cover holds the orifice plate in the fully open position.

Types of ventilator head

Various different types and arrangements of ventilator head are in use. Figure 10.16 shows a selection of the more common designs.

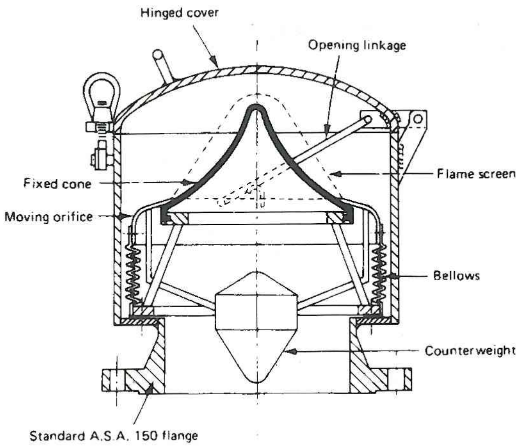


Figure 10.15 High velocity gas venting valve

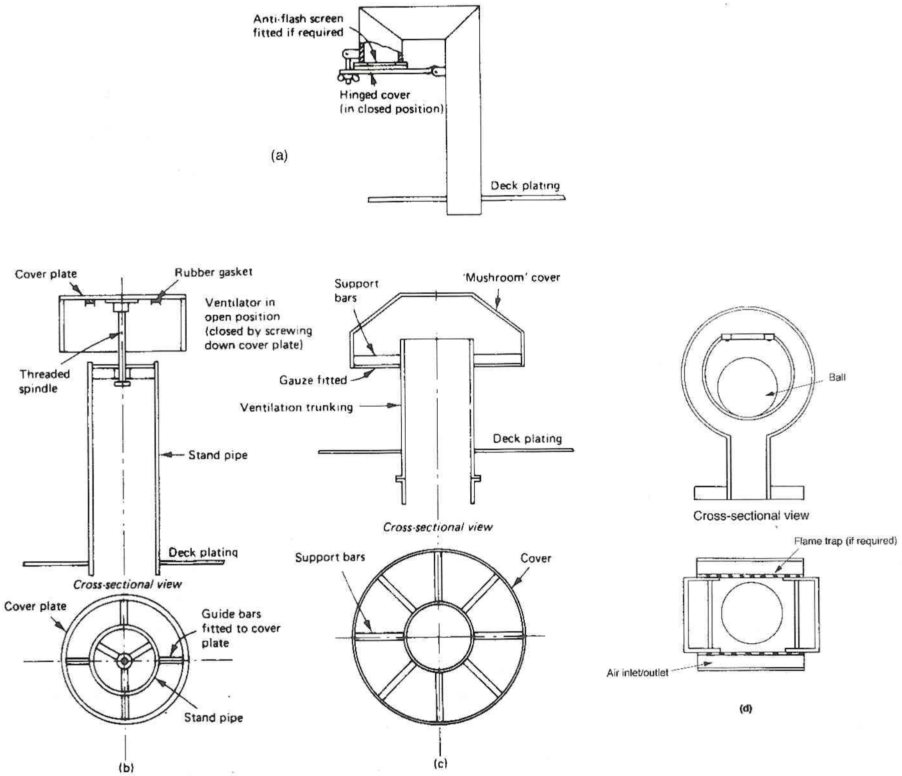


Figure 10.16 Ventilator heads: (a) gooseneck type; (b) mushroom type ;(c) fixed mushroom type; (d) autovent

11 Organisations and Regulations

The construction of merchant ships is considerably influenced and regulated by a number of organisations and their various requirements.

Classification societies, with their rules and regulations relating to classification, provide a set of standards for sound merchant ship construction which have developed over many years. These rules are based on experience, practical knowledge and considerable research and investigation.

A vast amount of legislation is applied to ships and is usually administered by the appropriate government department. The load line rules and tonnage measurement are two particular legislative requirements that are outlined in this chapter.

The International Maritime Organisation (IMO) is an international organisation which is attempting to develop high standards in every aspect of ship construction and operation. It is intended ultimately to apply these standards internationally to every ship at sea.

Classification societies

A classification society exists to classify or 'arrange in order of merit' such ships as are built according to its rules or are offered for classification. A classed ship is therefore considered to have a particular standard of seaworthiness. There are classification societies within most of the major maritime nations of the world and some are listed below.

Lloyd's Register of Shipping (UK)
American Bureau of Shipping (USA)
Bureau Veritas (France)
Det Norske Veritas (Norway)
Germanischer Lloyd (Germany)
Registro Italiano (Italy)
Register of Shipping (USSR)
Nippon Kaiji Kyokai (Japan)

Consultation between the societies takes place on matters of common interest through the International Association of Classification Societies (IACS).

The classification societies operate by publishing rules and regulations relating to the structural efficiency and the reliability of the propelling machinery and equipment. These rules are the result of years of experience, research and investigation into ship design and construction. They are in fact a set of standards. There is no compulsion on a shipowner to have his ship classified. However, the insurance premiums depend very much upon the class of a ship—the higher the standard the lower the premium. Also, by being classified a ship is shown to be of sound construction and a safe means of transport for cargo or passengers. There is no connection between the insurance companies and the classification societies.

The operation and organisation of Lloyd's Register of Shipping, the oldest to classification society rules are to those of Lloyd's Register of Shipping. This society is run by a general committee composed of members of the world community and the industry which it serves. National committees are formed in many countries for liaison purposes. A technical committee advises the general committee on technical problems connected with the society's business and any proposed alterations in the rules. The society publishes its 'Rules and Regulations for the Classification of Ships' in book form, which is updated as necessary, and also 'Extracts' from these rules and 'Guidance Notes' relating to more specific structures and equipment. The society employs surveyors who ensure compliance with the rules by attendance during construction, repairs and maintenance throughout the life of classed ships.

To be classed with Lloyd's, approval is necessary for the constructional plans, the materials used and the constructional methods and standards, as observed by the surveyor. The rules governing the scantlings of the ship's structure have been developed from theoretical and empirical considerations. Lloyd's collect information on the nature and cause of all ship casualties. Analysis of this information often results in modifications to the rules to produce a structure which is considered to be adequate. Much research and investigation is also carried out by the society, leading likewise to modifications and amendments to the rules.
The assigning of a class then follows acceptance by the general committee of the surveyor's report on the ship. The highest class awarded by Lloyd's is:

100 A1. This is made up as follows:

100 A	refers to the hull when built to the highest standards laid down in the rules.
✠1	refers to the equipment, such as the anchors and cables, being in good and efficient condition.
✠	indicates the vessel has been built under the supervision of the society's surveyors.

It is also usual to name the type of ship following the classification, e.g. ✠ 100 A1 Oil Tanker. Machinery is also surveyed and the notation LMC (Lloyd's Machinery Certificate) is used where the machinery has been built according to the society's rules and satisfactorily proved on sea trials. This information regarding the classification of a ship is entered in the Register of Ships. The Register of Ships is a book containing the names, classes and general information concerning the ships classed by Lloyd's Register of Shipping, and also particulars of all known ocean-going merchant ships in the world of 100 tons gross (a capacity measure) and upwards.

The maintaining of standards is ensured by the society in requiring all vessels to have annual surveys or examinations. Special surveys are also required every four years from the date of the first survey for classification. More detail with regard to these surveys is given in Chapter 13.

The society is also empowered to act as an assigning authority. This means that it acts as the agent for the government in administering certain of the mandatory requirements for shipping, e.g. the load line rules.

Governmental authorities

Legislation regarding the safety of ships is the responsibility of the government of the country concerned with registering the ship. In the UK this originally came under the Board of Trade and at the present time is the concern of the Department of Transport. This department is empowered to draw up rules by virtue of a number of Merchant Shipping Acts extending back more than a hundred years. The Department of Transport employ surveyors who examine ships to verify that they are built in accordance with the regulations. Some of the matters with which the Department of Transport is concerned are:

Load lines
Tonnage
Master and crew spaces
Watertight subdivision of passenger ships
Life-saving appliances
Carriage of grain cargoes
Dangerous cargoes

Some of these topics are now the subject of international regulations, e.g. load lines, tonnage and regulations relative to passenger ships. Load lines and tonnage will be considered in more detail as they have significant effects on ship design and construction.

IMO

The international nature of sea-borne trade has led finally to the organisation of an international body to provide intergovernmental co-operation on matters concerning ships, shipping and the sea. Under the auspices of the United Nations the International Maritime Organisation (IMO), formerly IMCO, was formed. Following its formal approval by 21 states, the first assembly met in London in 1959.

The governing body of IMO is the Assembly, which meets once every two years and consists of all the member states. IMO has one-hundred and fifty-five members and one associate member.

Some sixty non-governmental organisations have NGO status with IMO and can attend meetings, present papers and speak, but not vote. Up-to-date information on IMO can be found on their home page (http://www.imo.org).

In the period between the sessions of the Assembly a council exercises the functions of the Assembly in running the affairs of the organisation. At the moment the council consists of thirty-two member governments elected for two year terms by the Assembly. The organisation's technical work is carried out by a number of committees, the most senior of which is the Maritime Safety Committee (MSC). This has a number of sub-committees whose titles indicate the subjects with which they deal. They are the sub-committees on safety of navigation; radio communications; life-saving appliances; standards of training and watchkeeping; carriage of dangerous goods; ship design and equipment; fire protection; stability and load lines and fishing vessel safety; containers and cargoes; and bulk chemicals. The sub-committee on bulk chemicals is also a sub-committee of the Marine

Environment Protection Committee (MEPC), which deals with the organisation's anti-marine pollution activities. Because of the legal issues involved in much of its work the organisation also has a legal committee while the committee on technical co-operation coordinates and directs IMO's activities in this area. The facilitation committee, which deals with measures to simplify and minimise documentation in international maritime traffic, is a subsidiary body of the council.

In order to achieve its objectives IMO has, in the last thirty years, promoted the adoption of forty conventions and protocols. It has also adopted a larger number of codes and recommendations on various matters relating to maritime safety and the prevention of pollution. The initial work on a convention is normally done by a committee or sub-committee. A draft instrument is then produced which delegations from all states within the United Nations, including states which may not be IMO members, are invited to comment upon. The conference adopts a final text, which is submitted to governments for ratification.

An instrument so adopted comes into force after fulfilling certain requirements which usually include ratification by a specified number of countries. Generally speaking, the more important the convention, the more stringent are the requirements for entry into force. Observance of the requirements of a convention is mandatory for countries which are parties to it. Codes and recommendations, which are adopted by the IMO Assembly, are not so binding on governments. However, their contents can by just as important, and in most cases they are implemented by governments through incorporation into their legislation.

Conventions must be kept up-to-date by amendments, which are formally adopted at an IMO conference. The initial procedure for contracting government's acceptance was an explicit acceptance by a proportion, usually two-thirds. This process has proved too slow and now a 'tacit acceptance' procedure is used. Under this system, the amendment enters into force on a date selected by the conference or meeting at which it is adopted, unless it is rejected by a specified number of Contracting Parties, usually one-third.

Safety and the prevention of pollution are the two chief concerns of IMO and the work done in these two areas will now be considered in detail.

Safety

The first conference organised by IMO in 1960 was, appropriately enough, concerned with safety matters. In 1948 an 'International Convention on the Safety of Life at Sea' had been adopted at a conference convened by the United Kingdom, but developments during the intervening years had made it necessary to bring this up-to-date without delay.

The conference adopted a new 'International Convention on the Safety of Life at Sea', which came into force in 1965 and covered a wide range of measures designed to improve the safety of shipping. They include subdivision and stability; machinery and electrical installations; fire protection, detection and extinction; life-saving appliances; the carriage of grain; the carriage of dangerous goods; and nuclear ships.

The 'Safety of Life at Sea Convention' (SOLAS) became the basic international instrument dealing with matters of maritime safety and in response to new

adopt a new 'International Convention of the Safety of Life at Sea' which would incorporate the amendments adopted to the 1960 Convention as well as introduce other necessary improvements.

The 1974 Convention entered into force on 25 May 1980. In the meantime a considerable amount of work had been done on updating it. A protocol adopted in 1978 entered into force in May 1981 and the first of a series of important amendments was adopted in November 1981. The amendments entered into force in September 1984. A second set of amendments was adopted in June 1983 and entered into force on 1st July 1986. Further amendments have been made in 1991, 1992 and 1994 and are all now in force.

The various chapters of SOLAS 1974 deal with vessel construction in relation to subdivision, stability, machinery and electrical installations, fire protection, detection and extinction; lifesaving appliances and arrangements; radio communications; safety of navigation; carriage of various cargoes; nuclear ships; high speed craft and special measures to enhance maritime safety. Appendices deal with certificates and some amendments.

In 1966 a conference adopted the 'International Convention on Load Lines'. Limitations on the draught to which a ship may be loaded, in the form of freeboards, are an important contribution to its safety. An international convention on this subject had been adopted in 1930 and the new instrument brought this up to date and incorporated new and improved measures. It came into force in 1968.

Amendments were made in 1971, 1975, 1979 and 1983 relating to regulations and the form of record of conditions of assignment of load lines. A Protocol of 1988 contains modifications agreed at the International Conference on the Harmonized System of Survey and Certification.

The system of tonnage measurement of ships can also affect safety and this has been one of the most difficult problems in all maritime legislation. Tonnage is used for assessing dues and taxes and because of the way in which it is calculated it has proved possible to manipulate the design of ships in such a way as to reduce the ship tonnage while still allowing it to carry the same amount of cargo. But this has occasionally been at the expense of the vessel's stability and safety.

Several systems of tonnage measurement were developed over the years, but none of them was universally recognised. IMO began work on this subject soon after coming into being, and in 1969 the first ever international convention on the subject was adopted. It is an indication of the complexity of this aspect that the convention, which had a very high requirement for entry into force (twenty-five states with not less than 65 per cent of the world's gross tonnage of merchant shipping) did not receive the required number of acceptances until mid-1980. It entered into force on 18 July 1982.

The adoption of the conventions such as those described above is perhaps the most important of IMO's activities, but its work involves many other aspects. In addition to the conventions, whose requirements are mandatory for nations which ratify them, the organisation has also produced numerous codes, recommendations and other instruments dealing with safety. These do not have the same legal power as conventions, but can be used by individual governments as a basis for domestic legislation or as guidance.

Some of the most important of these deal with bulk cargoes, the carriage of dangerous goods; the carriage of bulk chemicals; liquefied gases; noise levels on board ships and special purpose ships. A number of Codes, such as the International Code of Safety for High Speed Craft (HSC Code), have been incorporated into Conventions as Amendments.

Prevention of pollution

The 1954 'Oil Pollution Convention' was the first major attempt by the maritime nations to curb the impact of oil pollution. The 1954 convention was amended in 1962, but it was the wreck of the Torrey Canyon in 1967 which fully alerted the world to the great dangers which the transport of oil posed to the marine environment. Following this disaster, IMO produced a whole series of conventions and other instruments and in 1969 the 1954 convention was again amended.

In 1971 the 1954 'Oil Pollution Convention' was further amended: one amendment was intended to limit the hypothetical outflow of oil resulting from an accident, while the other aimed at providing special protection for the Great Barrier Reef of Australia.

In 1973 a major conference was called to discuss the whole problem of marine pollution from ships and resulted in the adoption of the most ambitious anti-pollution convention ever drafted. The 'International Convention for the Prevention of Pollution from Ships' dealt not only with oil but other forms of pollution, including that from garbage, chemicals and other harmful substances.

The convention greatly reduces the amount of oil which can be discharged into the sea by ship, and bans such discharges completely in certain areas (such as the Black Sea, Red Sea and other regions). It gives statutory support for such operational procedures as 'load on top' (which greatly reduces the amount of mixtures which have to be disposed of after the tank cleaning) and segregated ballast tanks.

In practice certain technical problems meant that progress towards ratifying this convention was very slow, and a series of tanker accidents which occurred in the winter of 1976–77 led to demands for further action. The result was the 'Conference on Tanker Safety and Pollution Prevention' in February 1978.

This conference could well prove to be one of the most important ever held by IMO. Not only did it complete its work in a remarkably short time (barely ten months after the first call to IMO to convene the conference was made) but the measures adopted are already having a profound effect on tankers.

The measures include requirements for such operational techniques as crude oil washing (a development of the earlier 'load on top' system) and inert gas systems, but also include constructional requirements such as segregated ballast tanks for much smaller ships than stipulated in the 1973 convention. The most important of the new measures are incorporated in protocols to the 1974 'Convention on the Safety of Life at Sea' and the 1973 'Marine Pollution Convention'. The SOLAS protocol entered into force in May 1981 and the MARPOL protocol, which in effect absorbs the parent convention (the combined instrument is usually referred to as MARPOL 73/78) entered into force on 2nd October 1983.

Annexes II, III and IV of the MARPOL 73/78 Convention entered into force in 1987, 1992 and 1988 respectively. They relate to pollution by chemicals, harmful substances carried in packaged form, e.g. containers, and garbage. The Marine Environment Committee has adopted major amendments to the regulations governing the design and construction of both new and existing tankers which entered into force in July 1993.

Two amendments have been added to Annex I which relates to accidental pollution by oil. Oil tankers of 600 dwt and above must be fitted with double bottom tanks and the size of each tank is limited to 700 cubic metres, unless a double hull is fitted. Tankers of 5,000 dwt and above must be fitted with double bottoms and wing tanks extending the full depth of the ship's side. Mid-height deck tankers with double hulls are also permitted as an alternative.

Existing crude carriers of 20 000 dwt and above and product carriers of 30 000 dwt and above must comply with regulations which entered into force in July 1995. An enhanced programme of inspections is required, particularly for tankers which are over five years old. Tankers delivered after 1 June 1982 must comply with the double hull requirements not later than 30 years after their delivery date. Tankers built before the above dates must have side or bottom protection to cover at least 30 per cent of the cargo tank area, not later than 25 years after their delivery date.

A resolution, which came into force in 1994, designated the Antarctic area as a special area and a revised Annex III, which relates to harmful substances carried in packaged form, entered into force in the same year. A new Annex VI on air pollution from ships will be adopted as a protocol of 1997 to the MARPOL 73/78 convention. The main issue will probably be the limit on sulphur content of fuel oil.

Tanker construction and equipment

The construction and equipment of oil tankers will continue to be a source of much investigation since large quantities of oil have been, and are still being, discharged from damaged or foundered ships. Efforts are being made with the object of preventing or limiting pollution of the sea (and shore) by oil. Two particular avenues of approach are currently being adopted. The first deals with preventing the escape of the cargo oil in the event of a collision or grounding. The second approach is to attempt to limit sizes of centre tanks and wing tanks.

The first arrangement utilises segregated or clean ballast tanks (SBT or CBT). Proposals for the fitting of double-bottom tanks over the cargo tank length and wing ballast tanks have been put forward. These tanks are to be segregated, that is, for the carriage of clean water ballast only. The second method aims at restricting cargo tank sizes to 50 000 m^3 for centre tanks and 30 000 m^3 for wing tanks. This would limit the extent of pollution in the event of damage to a particular tank.

Other proposals following the 1973 Marine Pollution Convention which are now in force include:

(1) For new crude carriers over 20 000 deadweight tonnes, segregated ballast tanks (SBT), crude oil Washing (COW) and an inert gas system (IGS) will be required.

(2) For existing crude carriers over 40 000 deadweight tonnes, CBT, SBT, or COW will be required

(3) For existing crude carriers over 70 000 deadweight tonnes, IGS will be mandatory.

(4) For products carriers over 20 000 deadweight tones, IGS will be required.

(5) For products carriers over 30 000 deadweight tonnes, SBT will be required.

The fitting of double bottoms and wing tanks extending over the full depth of the ship's side is now compulsory for oil tankers over 5 000 dwt, as outlined in the previous section. Other structural or operational arrangements, such as hydrostatically balanced loading, may be accepted as long as they provide the same level of protection against pollution in the event of a collision or stranding.

Fire safety in ships

Fire at sea is an ever-present and much feared hazard. For passenger ships the recommendations, rules and regulations following the 1974 'International Convention on the Safety of Life at Sea' are extensive. They cover the many aspects of detection, restriction and extinguishing of fires. Cargo ships, particularly in the accommodation areas, must likewise have arrangements to deal with fires.

The arrangements for fire protection, by virtue of details of arrangement of construction, as detailed in the 1974 'International Conference on Safety of Life at Sea' and Lloyd's Rules, are applicable to passenger ships carrying more than 36 passengers and cargo ships of more than 4000 tons gross. The following principles are the basis of the regulations:

(1) The use of thermal and structural boundaries to divide the ship into main vertical zones.

(2) Thermal and structural boundaries are used to separate the accommodation spaces from the rest of the ship.

(3) The use of combustible materials is to be restricted.

(4) Any fire should be detected, contained and extinguished where it occurs.

(5) Access must be provided to enable fire fighting and a protected means of escape.

(6) Where inflammable cargo vapour exists the possibility of its ignition must be minimised.

Various definitions are given for the special terms used. Non-combustible material means a material which neither burns nor gives off inflammable vapours in a sufficient quantity to self-ignite when heated to 750°C in an approved test. Any other material is combustible. A standard fire test is when specimens of the relevant bulkheads or decks are exposed in a test furnace to a particular temperature for a certain period of time.

The 'A' class divisions are those divisions formed by bulkheads and decks which comply with the following:

(1) They shall be constructed of steel or other equivalent material.

(2) They shall be suitably stiffened.

(3) They shall be constructed to prevent the passage of smoke and flame for a one-hour standard fire test.

(4) They must be insulated such that the unexposed side will not rise more than 139°C or any point more than 180°C above the original temperature within times as follows: class A-60, 60 minutes; A-30, 30 minutes; A-15, 15 minutes; A-0, 0 minutes.

The 'B' class divisions are those divisions formed by bulkheads which are constructed to prevent the passage of flame for a half-hour standard fire test. They must be insulated so that the unexposed side will not rise more than 139°C, or any point 225°C, above the original temperature within times as follows: class B-15, 15 minutes and B-0, 0 minutes.

The 'C' divisions are made of non-combustible materials but meet no other requirements.

The main vertical zones are those sections into which the hull, superstructure and deckhouses are divided by 'A' class divisions, the mean length of which should not exceed 40 m.

The hull, superstructure, bulkheads, decks and deckhouses must be of steel or other material which has structural and fire integrity properties equivalent to steel. Pipe materials affected by heat must not be used for outlets near the waterline. The use of combustible materials should be kept to an absolute minimum. Paints, varnishes, etc., with a nitrocellulose base must not be used.

The hull, superstructure and deckhouses must be subdivided into main vertical fire zones of 40 m length or less. 'A' class fire-resisting divisions are to be used from deck to deck and shell or other boundaries. 'A' class boundary bulkheads above the bulkhead deck should, where possible, be in line with watertight bulkheads below.

Any openings in 'A' class bulkheads must be made good for fire-resisting purposes. Dampers must be fitted in vent trunks and ducts and should be operable from either side of the bulkhead; indicators should also be fitted. Doors in 'A' class bulkheads must be as fire resistant as the bulkhead and should be capable of being opened from either side by one person. Fire doors must be self-closing, and capable of being operated from a central control station, where a panel should be placed to indicate whether such doors are closed or open.

Other bulkheads in main vertical fire zones must be of 'B' class fire-retarding material. Boundary bulkheads and decks separating the accommodation from holds or cargo spaces or machinery spaces must be A-60 class fire-resisting divisions. Deck coverings within the accommodation spaces should be of non-ignitable material.

Stairways and lifts are to be steel-framed and within enclosures formed by 'A' class divisions. Self-closing doors with positive means of closure should be fitted at all openings, and be as effective as the bulkhead in which fitted, for fire containment. Control stations, such as the radio room, bridge, etc. must be surrounded by 'A' class divisions. Skylights in machinery spaces should have means of closing from outside the space and also steel shutters permanently attached.

Ventilation systems other than cargo and machinery spaces must have two independent control points where all machinery can be stopped in the event of a fire. Machinery space ventilation must be capable of being stopped from outside the space. All inlets and outlets must be able to be closed from outside the space. Air spaces in the accommodation behind ceilings, linings, etc. must be fitted with draught stops not more than 14 m apart.

The above arrangements are made to ensure that a fire on board ship will be contained within the zone in which it occurs. Attempts can then be made to extinguish the fire or, at worst, escape. Stairways and lift trunks act as chimneys which encourage the fire and 'A' class bulkheads are used here to ensure that this does not occur.

The load line rules—freeboard

Freeboard is the distance measured from the waterline to the upper edge of the deck plating at the side of the freeboard deck amidships. The load line rules set out the requirements for a minimum freeboard which must be indicated on the ship's side by a special load line mark. This minimum freeboard is a statutory requirement under the Merchant Shipping (Loadline) Rules of 1968. These rules are based on the 1966 International Loadline Convention called by IMO and ratified by each of the countries taking part.

A minimum freeboard is required principally to ensure that the ship is seaworthy when loaded. The minimum freeboard provides the ship with a reserve of buoyancy which enables it to rise as it passes through waves and thus remain largely dry on its decks. This reserve buoyancy also improves the vessel's stability and in the event of damage will enable it to remain afloat indefinitely, or at least for a time, to effect the escape of the crew.

The assigning of freeboard follows a calculation which considers the ship's length, breadth, depth and sheer, the density of the water and the amount of watertight superstructures and other features of the ship. Additional conditions of assignment are also made relating to certain openings and fittings. The ship is assigned a basic minimum freeboard on the assumption that it is correctly loaded, with adequate stability and strength. A number of terms and dimensions are used in the computation of freeboard.

Freeboard deck This is the uppermost continuous deck exposed to the weather and the sea which has permanent means for the watertight closure of all exposed openings on the deck and in the side shell below.

Deck line This is a horizontal line 300 mm long and 25 mm wide which is positioned amidships port and starboard. The upper edge of the line is located level with the upper surface of the freeboard deck plating on the outer shell.

Length The freeboard length is the greater of the following two measurements: (1) on a waterline at 85 per cent of the least moulded depth, 96 per cent of the length along the waterline; or (2) on the same waterline, the distance from the fore side of the stem to the axis of the rudder stock.

Breadth Measured at amidships, this is the maximum breadth to the moulded line.

Depth moulded This is the vertical distance between the upper edge of the keel and the upper edge of the freeboard deck beam measured at the ship's side.

Displacement This is the moulded displacement of the ship, excluding bossings, measured at 85 per cent of the least moulded depth.

Block coefficient This is determined using the values of displacement, length, breadth and a value of draught which is 85 per cent of the least moulded depth, i.e.:

$$\text{block coefficient, } C_b = \frac{\text{displacement}}{\text{length} \times \text{breadth} \times \text{draught}}$$

Superstructure This is a structure of adequate strength on the freeboard deck which extends transversely to at least within 0.04 times the breadth from the ship's side. The superstructure length, *S*, is taken as the mean length of that part of the superstructure within the freeboard length of the ship.

Freeboard categories

In order to assign freeboards, ships are divided into Types A and B. Type A ships are those designed specifically for the carriage of liquid cargoes in bulk. The cargo tanks have only small openings for access which are closed by watertight covers of adequate strength. Type B ships are all those which are not of Type A. The greater freeboard required for the Type B ship may be reduced in certain circumstances. In ships where steel hatch covers are fitted, special subdivision arrangements exist, improved water freeing arrangements are provided and better protection for the crew is given, and a reduced freeboard is permitted. This reduction can result in an almost equivalent value to that of a Type A ship. Where this value is almost equivalent the notation Type B-100 is used, indicating a 100 per cent reduction of the freeboard difference between Types A and B. The notation Type B-60 is used where a 60 per cent reduction of freeboard difference is obtained. Bulk carriers particularly benefit from this reduction in freeboard.

The freeboard is determined from a calculation where a tabular freeboard figure based on the ship's length and type is adjusted by several corrections. These corrections are to account for the variations between the actual ship and the standard ship on which the tabular freeboard is based.

Flush deck correction

A Type B ship of less than 100 m length having superstructures with an effective length, E, of up to 35 per cent of the freeboard length, L, may have its freeboard increased by:

$$7.5(100 - L)\left(0.35 - \frac{E}{L}\right)\text{millimetres}$$

Where E is the effective length of the superstructure, in metres. With the superstructure length, S, known the effective length, E, may be found from the load line rules.

Block coefficient correction

Where the actual block coefficient, C_b, of the ship exceeds 0.68, the freeboard amended by the flush deck correction, if relevant, is multiplied by the ratio:

$$\frac{C_b + 0.68}{1.36}$$

where C_b is obtained as defined earlier.

Depth correction

The formula for the freeboard depth, D, is given in the rules. Where D is greater than the freeboard length, L, divided by 15, the freeboard is increased by:

$$\left(D - \frac{L}{15}\right)R$$

where $R = L/0.48$ for ships less than 120 m in length, or 250 for ships greater than 120 m in length. If D is less than $L/15$ no deduction is made, except where there is an enclosed superstructure extending $0.6L$ at midships. This deduction would be determined as for the flush deck correction.

Superstructure correction

For an effective length of superstructure, E, equal to the freeboard length, L, the freeboard may be reduced by 350 mm for a 24 m ship length, 860 mm for an 85 m ship length and 1070 mm for all ship lengths greater than 122 m. Intermediate length deductions are obtained by interpolation; with effective lengths less than $1.0L$ the deduction is a percentage of the values given.

Sheer correction

The differences between the actual sheer profile and a standard sheer profile are determined. The correction is then the deficiency or excess multiplied by:

$$\left(0.75 - \frac{S}{2L}\right)$$

where S is the mean length of the superstructure.

For a deficiency of sheer, the correction is added to the freeboard. With an excess, a deduction is permitted where the superstructure covers $0.1L$ aft and $0.1L$ forward of midships. For lesser lengths of superstructure, the deduction is obtained by interpolation. A maximum deduction of 125 mm per 100 m of ship length is permitted.

With the tabular value amended by the corrections, the freeboard value will be that for the maximum summer draught in sea water. This value may be further amended if, for instance, the bow height is insufficient as defined in the rules, cargo ports or openings are fitted in the sides below the freeboard deck or the shipowner requests a freeboard corresponding to a draught less than the maximum permissible.

Load line markings

The maximum summer draught, as determined above, is indicated by a load line mark. This consists of a ring of 300 mm outside diameter and 25 mm wide, intersected by a horizontal line 450 mm long and 25 mm wide. The upper edge of this line passes through the centre of the ring. The ring is positioned at midships and at a distance below the upper edge of the deck line which corresponds to the assigned minimum summer freeboard. This value may not be less than 50 mm.

A series of load lines are situated forward of the load line mark and these denote the minimum freeboards within certain geographical zones or in fresh water. The summer load line is level with the centre of the ring and marked S. The tropical, T, and winter, W, load lines are found by deducting and adding, respectively, 1/48 of the summer moulded draught. For a ship of 100 m length or less a Winter North Atlantic (WNA) zone load line is permitted. This line is positioned at the winter freeboard plus 50 mm. The fresh water freeboards F and TF are found by deducting from the summer or tropical freeboard the value:

$$\frac{\text{displacement in salt water}}{4 \times TPC}\text{millimetres}$$

where TPC is the tonnes per centimetre immersion in salt water at the summer load waterline.

These markings are shown in Figure 11.1. In all cases, measurements are to the upper edge of the line.

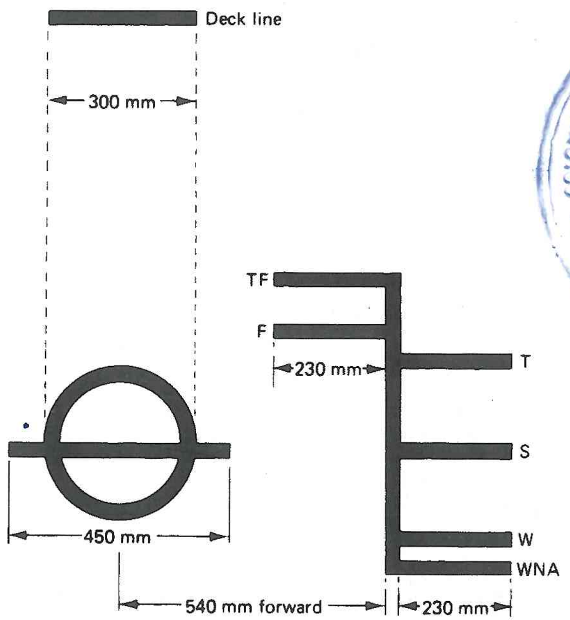


Figure 11.1 Load line marking (all lines 25mm thickness)

NOT TO BE TAKEN AWAY WITHOUT PROPER AUTHORISATION

Conditions of assignment

Mention was made earlier of the conditions of assignment relating to freeboard. These are certain requirements which must be met to ensure the watertightness of openings and the ability of the ship to rapidly free itself of water on its decks. Reference will be made to two particular positions which are now defined.

Position 1 Exposed freeboard, superstructure and raised quarter decks within one-quarter of the ship's length from the forward perpendicular.

Position 2 Exposed superstructure decks outside one-quarter of the ship's length from the forward perpendicular.

Structural strength and stability

The ship is required to have the necessary structural strength for the freeboard assigned. Certain criteria with regard to stability must be met and an inclining experiment must be carried out in order to ensure compliance.

Superstructure end bulkheads

Such bulkheads for enclosed superstructures must be adequately constructed. Any openings must have a minimum sill height of 380 mm above the deck.

Hatchways

Portable covers secured by tarpaulins

Substantial coamings of mild steel or equivalent material must be fitted to all hatchways. Minimum heights are 600 mm in position 1 and 450 mm in position 2. Requirements must be met in respect of thickness of covers, strength, loading of covers and beams, carriers or socket design, cleats, battens, wedges, number of tarpaulins and securing arrangements.

Watertight steel covers

There are similar requirements for coamings, but these may be reduced in height or dispensed with where the safety of the ship is not affected. Again requirements must be met in respect of cover strength, construction and watertight securing arrangements.

Machinery space openings

Machinery space openings in position 1 or 2 must be efficiently framed and plated for strength. Openings are to have watertight doors with sill heights of 600 mm in position 1 and 380 mm in position 2. All other openings are to have attached steel covers which can be secured weathertight if required.

Other openings in freeboard and superstructure decks

Manholes and scuttles (portholes) must have covers fitted to efficiently secure them. All doorways are to have a minimum sill height of 600 mm in position 1 and 380 mm in position 2. All openings other than hatchways, machinery space openings,

manholes and scuttles, where in an exposed position, must be enclosed by a structure of equivalent strength and watertightness to an enclosed superstructure.

Ventilators

Coamings on ventilators must be 900 mm above deck in position 1 and 760 mm in position 2. Where exposed to severe weather or in excess of 900 mm high, coamings are to be suitably bracketed to the surrounding structure or deck. Some means of permanent closure, either attached or close by, is required for all ventilators except those of height in excess of 4.5 m in position 1 or 2.3 m in position 2.

Air pipes

These pipes must be of efficient construction and have a permanently attached means of closing. The opening height must be a minimum of 760 mm on the freeboard deck and 450 mm on the superstructure decks.

Cargo ports and similar openings

Any cargo ports must be fitted with doors and frames which maintain the structural and watertight integrity of the ship. No door is to be fitted with any part of its opening below the load line decks.

Scupper, inlets and discharges

All discharges from above or below the freeboard deck from enclosed spaces are to have an efficient non-return arrangement fitted. Arrangements and their control are specified according to the discharge distance from the summer load waterline. Manned machinery space inlets and outlets are to have readily accessible controls and valve position indicators. Scuppers from open spaces may be led directly overboard.

Side scuttles (portholes)

Every side scuttle below the freeboard deck is to be fitted. Arrangements and their control are specified according to the discharge distance from the summer load waterline. Manned machinery space inlets and outlets are to have readily accessible controls and valve position indicators. Scuppers from open spaces may be led directly overboard.

Side scuttles (portholes)

Every side scuttle below the freeboard deck is to be fitted with a hinged cover-plate or deadlight which may be securely closed and made watertight. No side scuttles may be fitted below 2.5 per cent of the ship's breadth or 500 mm, whichever is the greater, above the load waterline.

Freeing ports

Where bulwarks on any exposed decks form wells they must be provided with efficient means for rapidly freeing the decks of water. Special formulae are given for the determination of the freeing area in relation to the length of the bulwark, its close to the deck as possible. Two-thirds of the freeing area should be located near the lowest point of the sheer curve where sheer exists on the deck. Openings are restricted in height to 230 mm by bars being placed across them. Where shutters or flaps are fitted to these openings they should be prevented from jamming.

Protection of the crew

All exposed freeboard and superstructure decks must have bulwarks or guard rails fitted at their perimeter with a minimum height of 1 m. Where rails are fitted the deck and lower rail spacing must not exceed 230 mm and other rails 380 mm. Effective protection and safety in the form of gangways, passages and other means of access required in the course of their work must be provided for the crew.

Special conditions of assignment for Type A ships

Machinery casings

An enclosed poop, bridge of standard height or a deckhouse of equivalent strength and height must protect the machinery casing. An exposed casing is allowed without doors or with a double-door arrangement, provided it is of weathertight construction.

Hatchways

All exposed hatchways are to have efficient watertight covers of steel or equivalent strength materials.

Freeing arrangements

Open rails must be fitted for at least half of the exposed length of the deck. The upper edge of the sheer strake should be kept as low as possible. Where a trunk connects parts of the superstructure, open rails should be fitted at the perimeter of the deck in way of the trunk.

Protection of the crew

Where separate superstructures exist they should be connected by a raised gangway at the level of the superstructure deck. An acceptable alternative would be a passageway below deck. With a single superstructure, adequate safe arrangements should exist for access to all work areas on the ship.

Tonnage

Tonnage, as discussed in this section, is a measure of cubic capacity where 1 ton represents 100 ft^3 or 2.83 m^3. Tonnage is a measure of the ship's internal capacity, with two values being used. The gross tonnage is the total internal capacity of the ship and the net tonnage is the revenue-earning capacity. Tonnage values are also used to determine port and canal dues, safety equipment and manning requirements and are a statistical basis for measuring the size of a country's merchant fleet. All ships prior to registry must be measured according to their country's tonnage regulations. The differences in the various measuring systems have led to ships

having several tonnage values and to unusual designs which exploited aspects of tonnage measurement. The 1969 IMO 'International Conference on Tonnage Measurement of Ships' led to an international review of the subject and a system has now been universally adopted. Reference will now be made to the British tonnage measurement system and also the 1969 convention measurement system.

British tonnage

The current regulations governing tonnage measurement are the Merchant Shipping (Tonnage) Regulations 1967(11). The measurement of tonnage follows from various specialist terms and values which will now be defined in turn.

Tonnage deck This is the second deck, except in single-deck ships.

Tonnage length An imaginary line is drawn across the ship at the stem and stern on the inside of the hold frames or sparring. The tonnage length is the distance between these lines measured along the ship's centreline on the tonnage deck.

Tonnage depth This is measured from the upper surface of the tanktop to the underside of the tonnage deck at the centreline, with a deduction of one-third of the camber. The height of flooring, double or single, is limited.

Tonnage breadth The breadth of the ship to the inside of the hold frames or sparring.

Underdeck tonnage This is the tonnage of the space below the tonnage deck. It is found by dividing the tonnage length into a specified number of parts. At each cross-section formed by this division, the tonnage depth is similarly divided up. The tonnage breadths at these points are then measured. The measured distances are then put through Simpson's rule to provide the underdeck volume which is converted into a tonnage value.

Gross tonnage

This is the total of the underdeck tonnage and the tonnage of the following spaces:

(1) Any tween-deck spaces between the second and upper decks.

(2) Any enclosed spaces above the upper deck.

(3) Any excess of hatchways over 0.5 per cent of the gross tonnage.

(4) At the shipowner's option and with the surveyor's approval, any engine light and air spaces on or above the upper deck.

The term gross register tonnage (GRT) is also used.

Exempted spaces

These are spaces which are not measured for the gross tonnage calculation. Such spaces may be above or below the tonnage deck and include:

(1) Wheelhouse, chartroom, radioroom and navigation aids room.

(2) Spaces fitted with and for the use of machinery or condensers.

(4) Stability tanks and machinery.

(5) Galley and bakery spaces.

(6) Skylights, domes and trunks.

(7) Washing and sanitary accommodation forming part of the crew accommodation.

Deducted spaces

The tonnage of these spaces must first be measured and may then be deducted from the gross tonnage of the ship to give the net tonnage. Examples of deducted spaces are:

(1) Master's accommodation.

(2) Crew accommodation and an allowance for provision stores.

(3) Chain locker, steering gear space, anchor gear and capstan space.

(4) Space for safety equipment and batteries below the upper deck.

(5) Workshops and storerooms for pumpmen, electricians, carpenter, and boatswain.

(6) Donkey engine and donkey boiler space, if outside the machinery space.

(7) Pumprooms, where these are outside the machinery space.

(8) Water ballast tanks, where they are for the exclusive carriage of water ballast; a maximum limit of 19 per cent of the gross tonnage is imposed.

(9) Propelling power allowance—this is the largest deduction and is determined according to certain criteria, as follows:

If the machinery space tonnage is between 13 per cent and 20 per cent of the gross tonnage, the propelling power allowance is 32 per cent of the gross tonnage. If the machinery space tonnage is less than 13 per cent of the gross tonnage then the propelling power allowance is the amount expressed as a proportion of 32 per cent of the gross tonnage. Where the machinery space tonnage is more than 20 per cent of the gross tonnage, the propelling power allowance is 13/4 times the machinery space tonnage. There is a maximum limit of 55 per cent of the gross tonnage for the propelling power allowance. If any part of the light and air space is included in the gross tonnage then it may also be included in the machinery space tonnage.

Net tonnage

This is the tonnage value obtained by deducting from the gross tonnage the total value of the deducted spaces. The net tonnage is considered to represent the earning capacity of the ship. The term net register tonnage (NRT) is also used.

Tonnage mark scheme

The tonnage mark scheme was devised to exempt from tonnage measurement the tween deck space between the uppermost complete deck and the second deck, provided a special tonnage draught mark was not submerged. The position of this mark on the ship's side was to generally correspond to the draught which would be obtained if the freeboard had been calculated for the second deck being the freeboard deck. A special mark is used and is shown in Figure 11.2. The position of the mark on the ship's side is given in the amendment to the load line rules dealing

When the tonnage mark is at or above the waterline the ship is considered to have a modified tonnage. When the tonnage mark is below the waterline the ship is considered to be at its full tonnage.

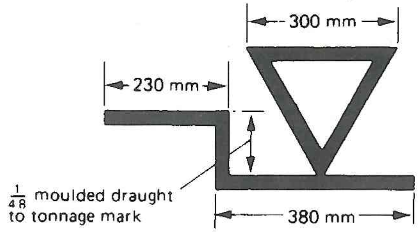


Figure 11.2 Tonnage mark
(all lines 25mm thickness)

The International Convention of Tonnage Measurement of Ships

This convention, which was the first successful attempt to create a universal tonnage measurement system, came into force on 18th July 1982. All aspects of the Convention became fully operative on 18th July 1994.

The shelter-deck concept and the tonnage mark scheme are abandoned. Gross and net tonnage are the only two parameters now used. Gross tonnage is determined in relation to the volume of all enclosed spaces. Net tonnage is the sum of the cargo space plus any volume of passenger spaces multiplied by a coefficient to bring the value close to existing tonnages. Each measurement is determined by a formula as follows:

$$\text{gross tonnage (GT)} = K_1 V \qquad \text{net tonnage (NT)} = K_2 V_c\left(\frac{4d}{3D}\right)^2 + K_3\left(N_1 + \frac{N_2}{10}\right)$$

where

V = total volume of all enclosed spaces of the ship in cubic metres
K_1 = $0.2 + 0.02 \log_{10} V$
V_c = total volume of cargo spaces in cubic metres
K_2 = $0.2 + 0.02 \log_{10} V_c$
K_3 = $1.25 \dfrac{GT + 10,000}{10,000}$
D = moulded depth amidships in metres
d = moulded draught amidships in metres
N_1 = number of passengers in cabins with not more than eight berths
N_2 = number of other passengers
$N_1 + N_2$ = total number of passengers the ship is permitted to carry as indicated on the ship's passenger certificate, when $N_1 + N_2$ is less than 13, N_1 and N_2 shall be taken as zero
GT = Gross tonnage of the ship.

In the above the factor $(4d/3D)^2$ is not to be taken as greater than unity and the term $K_2V_c(4d/3D)^2$ is not to be taken as less than 0.25GT.

The volumes referred to in these formulae are to be calculated to the inside of plating and include the volumes of appendages. Volumes of spaces open to the sea are excluded.

The main features of this convention can be summarised as follows:

(1) Measurements of gross and net tonnage are dimensionless numbers. The word ton will no longer be used.

(2) New ships are defined as ships whose keel is laid, or are at a similar stage of construction, on or after 18th July 1982.

(3) Existing ships may retain their current tonnages until 18th July 1994. After this date they may retain their existing tonnages only for the purpose of the application of international conventions.

(4) Excluded spaces are those which are open to the sea and therefore not suitable for the carriage of perishable cargoes.

(5) Cargo spaces are defined as compartments for the transport of cargo which is to be discharged from the ship. They are to be permanently marked with the letters CC.

(6) Alterations to the parameters of the net tonnage formula which would result in a reduction of net tonnage are restricted to once a year.

The application of this convention and the use of the above formulae will mean that open shelter-deck vessels and others with large exempted spaces will have larger gross tonnages. Roll-on roll-off ships and ferries will have significant increases in both their gross and net tonnages. Bulk carriers, ore carriers and other ships designed to carry high density cargoes will have their net tonnage values reduced.

Other tonnage systems

A ship will carry a tonnage certificate which indicates the values of tonnage for the vessel, calculated according to the relevant system. Other special tonnages exist which are calculated in a slightly different way and are shown on special certificates. These are used for ships passing through the Suez and Panama Canals. The charges levied for the use of these canals are based upon their particular canal tonnage.

12 Corrosion and its Prevention

The prevention of corrosion on board ship is an immense ongoing process demanding the attention and skills of considerable numbers of personnel. The ship because of its size, its physical environment and the materials used in its construction is subject to attack from the various forms of corrosion.

Corrosion

Corrosion is the wasting of metals by chemical or electrochemical reactions with their surroundings. Erosion is a term often associated with corrosion and refers to the destruction of a metal by abrasion. Erosion is therefore a mechanical wastage process that exposes bare metal which can then corrode.

Iron and steel corrode in an attempt to regain their oxide form which is in a balanced state with the earth's atmosphere. This oxidising, or rusting as it is commonly termed, will take place whenever steel is exposed to oxygen and moisture. The prevention of corrosion therefore deals with the isolation of steel from its environment in order to stop this oxidation taking place.

In addition, the presence of a ship almost constantly in sea water enables an electrochemical reaction to take place on unprotected steel surfaces. A corrosion cell is then said to have been formed. This is often referred to as a 'galvanic cell', since its current flow is a result of a potential difference between two metals (not necessarily different) in a solution such as sea water. This current flow results in metal being removed from the anode metal or positive electrode, while the cathodic metal or negative electrode is protected from corrosion. Most common metals can be arranged in what is known as a galvanic series, according to their electrical potential in sea water, as shown in Table 12.1.

A simple example of a corrosion cell would be a plate of copper and one of iron placed in a sea water solution and joined by a wire. Reference to Table 12.1 will show that copper will become the cathode or protected end and the steel will become anodic and corrode. This is shown in Figure 12.1. The chemical reaction taking place and the electron flow occurring will result in the anodic metal combining with dissolved oxygen to form its stable oxide form (rust).

Corrosion can also occur as a result of stress, either set up in the material during manufacture or as a result of its 'working' in the sea. The effects of stress and fatigue are to provide areas where cracking may occur, but even these sometimes minute cracks create conditions under which galvanic corrosion will proceed. The combined action of the two has a considerable effect on the material.

Corrosion prevention

The prevention of corrosion deals in the first place with the provision of an adequate protective coating for the ship's structural steel and its continued maintenance. Secondly, a means of preventing electrochemical wastage is required, which is known as cathodic protection. The two distinctly different types of corrosion prevention are usually complementary to one another in that both are normally fitted on modern ships. Finally, it should be noted that a knowledge of the processes of corrosion can ensure the reduction or prevention of corrosion on board ship, particularly on the internal structure, by the use of good design and arrangement of structural members.

↑	Platinum
	Gold
	Graphite
	Silver
	Passive stainless steels
	Passive high nickel alloys
	Passive nickel
	Silver solders
Cathodic or noble metals (protected material)	Copper-nickel alloys
	Bronzes
	Gunmetal
	Copper
	Brass (70/30)
	Active high nickel alloys
	Active nickel
	Mill scale
	Naval brass and brass (60/40)
	Tin
	Lead
Anodic or ignoble metals (corroding material)	Lead–tin solders
	Active stainless steels
	Cast iron
	Iron and steel
	Aluminium alloys
	Cadmium
	Aluminium
	Zinc
	Magnesium alloys
↓	Magnesium

Table 12.1 Galvanic series of metals and alloys in sea water

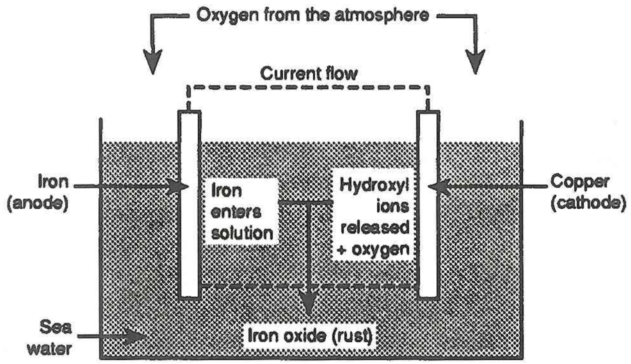


Figure 12.1 Corrosion cell

Paint

Protective coatings refer to the application of a suitable paint system. Paint is a mixture of three ingredients—the pigment, the binding agent or vehicle and the solvent. The pigment is responsible for the colour and covering capacity and may

also refer to certain additives, depending upon the properties required of the final product. The binding agent or vehicle, depending on its proportion in the paint, will decide the consistency and ease of application of the paint. The solvent or thinner is added to make the paint flow easily.

Most paints consist of solid pigments, usually in a finely divided form, suspended in a liquid binder or vehicle which, when spread thinly over a surface, will eventually dry out. A thin dry film is then left adhering to the surface. The 'drying' process associated with ships' paints is usually the evaporation of the solvent from the vehicle. Good ventilation is therefore essential and moisture-laden atmospheres are to be avoided during the drying process. The coating applied must also be thin to ensure that it dries out correctly. The appropriate solvent is essential to ensure the correct drying time; too quick and blistering can occur, too slow and the paint may end up immersed before it is dry. The common vehicles in use are:

(1) Bitumen or pitch—bitumen or pitch in a white spirit solvent, or blends of pitch with other materials.

(2) Oil based—vegetable drying oils, e.g. linseed oil, dehydrated castor oil.

(3) Oleo-resinous—natural or artificial resins mixed into drying oils.

(4) Alkyd-resin—a special type of (3).

(5) Chemical resistant—chlorinated rubber, epoxide resins and coal tar/epoxide are examples.

All the above vehicle types are suitable for above-water use. Only types 1 and 5 and certain types of 3 are suitable for underwater use, because of the need to resist alkaline deposits formed at the anodes of corrosion cells.

Anti-fouling paint

Fouling is the covering of a ship's underwater surface with marine organisms such as green slime, weeds and barnacles. Fouling occurs usually only when the ship is at rest and is dependent on water temperature, salinity, the season, the place, etc.

The slower speeds of the larger tankers and bulk carriers has resulted in increased fouling problems, since some marine organisms can survive and grow at speeds of 10–15 knots. The result of fouling is increased hull resistance and subsequent loss of the ship's speed or increased fuel consumption.

Anti-fouling paints function by slowly releasing a poison into the laminar sea water layer surrounding the ship. This sea water soluble poison is toxic to marine organisms which must pass through this laminar layer in order to attach themselves to the ship. The poison is released at a controlled rate, determined by the type of toxin and also the degree and rate of solubility of the binder.

Two basically different types of anti-fouling paint currently exist—non-polishing and self-polishing.

Non-polishing anti-fouling may have either a soluble or insoluble matrix. The soluble matrix consists mainly of rosin (colophony) which is slightly sea-water soluble. The bio-active materials (poisons) are released in sea water together with the binder. The insoluble matrix type uses a large proportion of polymeric binders which are insoluble in sea water. The bio-active materials are released together with other components which act as leaching aids. This leaves behind a released layer of insoluble binder. The release rate of the bio-active materials in each type will decrease with time in service of the vessel. The bio-active materials will include cuprous oxide and organotin compounds.

The amount or 'loading' of these materials is varied according to the vessel's requirements. Small amounts would be used for vessels trading in cold and temperate climates with short idle periods and long sailing times. Large amounts would be used for vessel trading world-wide in warm climates with short-to-medium idle time and varied sailing periods. Different strengths of binder result in the use of one- or two-coat systems to achieve a particular dry film thickness. The dry film thickness determines the quantity of bio-active materials available and the system life time. For any particular dry docking interval a suitable life time must be selected. It should be noted that the bio-active materials in the system are consumed faster during high speed sailing.

Self-polishing anti-fouling paint is designed to wear down smoothly while maintaining a bio-active interface between the coating and the water. One type of this paint uses a tributyltin copolymer binder and reinforcing bio-active compounds which produce a synergistic (assisting one another) effect with tributyltin anti-foulants. The tributyltin copolymer produces tributyltin oxide (TBTO) in a hydrated form by hydrolysis (ionic dissociation) with sea water. The reinforcing bio-active compounds comprise cuprous oxides and organotin compounds. They leach as the tributyltin copolymer releases its tributyltin content. The copolymer then becomes water soluble and is washed off. This renews and activates the next layer of tributyltin molecules.

The release of tributyltin (TBT) from anti-fouling paint has raised environmental concerns over possible damage to the marine ecology. Legislation has so far only been enacted against smaller vessels of less than 25 metres in length, but tighter controls are expected on dry dock discharges which may effectively stop the use of TBT anti-fouling paints. Paint manufacturers have therefore developed TBT-free anti-foulings in anticipation of possible legislation banning the use of TBT. Controlled depletion polymer (CDP) technology is used to ensure the controlled release of biocides. These TBT-free biocides are exposed as a series of physical and chemical reactions polish away the paint film to expose them.

The self-polishing rate is determined during paint manufacture by the nature of the copolymer binder. One manufacturer provides three self-polishing rates which, together with two possible degrees of fouling protection, results in six possible types of coating. The fouling protection may be either normal or severe. The three self-polishing rates relate to low-to-medium speed, medium-to-high speed and very high speed hulls. The degree of hull roughness acceptable increases in the same order and dry film thicknesses are 100 mm, 80 mm and 60 mm per coat minimum respectively. The self-polishing rate will increase with speed and average hull roughness.

Painting the ship

The paint used must be appropriate for the degree of protection required at the particular area or section of the ship. The principal areas requiring different forms of treatment are the underwater plating and boot topping region, the topsides, the superstructure and the weather decks (Figure 12.2).

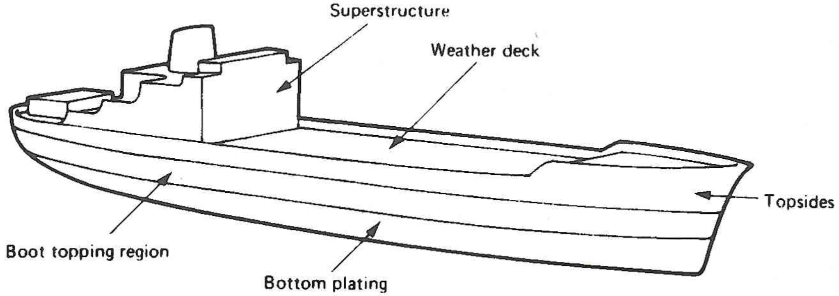


Figure 12.2 Principal painting areas

Preparation and priming

The surface preparation of the steel plate must be good in order to ensure the successful operation of the applied painting system. The steel plates used in ship construction are first shot blasted to remove all traces of rusting and mill scale, which may be present. The usual requirement is Swedish Standard Sa2.5. Where up to 12 months protection is needed for stored plates, high zinc content primers are applied. Greater productivity in shipyards and a faster flow of plates has meant less protection is necessary, but the high zinc content of such primers has also caused problems during welding processes. Shop primers are now available with lower zinc content to enable higher cutting and welding speeds, with fewer fumes emitted during these operations. Final painting will progress with the construction of the ship.

Underwater areas

The underwater and boot topping plating region will have paint types applied after consideration of the presence and type of cathodic protection applied to the hull and the degree of anti-corrosive and anti-fouling paint which is required. Highly alkaline conditions are to be found near the anodes of cathodic protection systems, and paints of an epoxide type are therefore required to resist these chemical conditions. Anti-fouling properties are also required for paints used in this region to emit poisons that will kill the marine organisms which tend to collect on ships' hulls. While fouling in the main increases ship resistance there are certain bacteria which reduced sulphates in sea water and release oxygen which can then take part in the corrosion process. The anti-fouling properties of a paint for the underwater regions are therefore important. The actual choice of paint type and its particular composition is usually made by the shipowner bearing the above factors in mind.

Modern practice makes little or no distinction between the paint used on the bottom shell and that used around the boot topping region. The boot topping region is, however, more likely to suffer damage due to mechanical abrasion (erosion) and the action of waves. Some suitable vehicle types of paint for this region would be bitumen or pitch, oleo-resinous epoxide, coal tar/epoxide resin and chlorinated rubber. A compatible primer would be applied first, then the particular paint type

Topsides and superstructures

Topsides and superstructures are usually adequately coated with primer, an undercoat and a finishing paint. Paint based on alkyd resins, modified alkyd resins and enamels are used in this region. Since appearance is of some importance, good colour- and gloss-retaining properties of the paints used on these parts is essential.

Weather decks

The paint for the weather deck area requires exceptionally good resistance to wear and abrasion and some non-slip quality. The deck coating should also be resistant to any oils or chemicals carried as cargo or fuel. Initial protective coatings topped by grit-reinforced oleo-resinous paints have been used successfully, as have primers and chlorinated rubber deck paints. Certain metallic final coats have been tried with considerable success, more particularly on naval vessels. The constant abrasion on weather decks from traffic, cargo handling and general ship operation makes long-term protection by paint alone almost impossible. Self-sealing coatings utilising epoxide resins have been used with some success on top of epoxide resin paint for a hard-wearing deck covering.

Tanks

Ballast, cargo and fresh water tanks require special coatings, depending upon the nature of their contents. Classification Societies and owners are now paying more attention to tank coatings, owing to structural failures on a number of tankers and bulk carriers, which have been attributed to tank coating failures and subsequent corrosion.

The splash zone or ullage space of a tank is most severely attacked due to the constant aeration of the liquid cargo. Such conditions are a particular problem in ballast tanks, which are alternately filled and emptied. The applied coating must protect the structure, which can rapidly deteriorate under such conditions. Conventional ballast tank coatings are usually zinc-rich primers, with epoxy or vinyl top coats. They act as a barrier by depositing high molecular weight polymers onto the steel surface as a result of solvent evaporation or chemical cross-linking. Filler combinations of silica, tar, vermiculite, mica and clay are used as barriers in a typical coal tar epoxy. As the paint cures the solvents evaporate to leave the solids behind as a dry impermeable membrane. A high-build polyamine coal tar epoxy may contain in excess of 70 per cent solids.

Coal tar epoxies, which combine the sea water resistance of coal tar pitch with the mechanical strength of epoxy resins, unfortunately present occupational health hazards and are being phased out in favour of tar-free epoxy types. Modern formulations of tar-free epoxies have a higher solid volume ratio, reduced volatile organic compounds and are surface tolerant when applied. Some paint formulations are now solvent-free.

Ballast tank coatings are now generally applied in two applications to provide a more uniform film thickness. This should be not so low that 'holidays' (uncoated areas), dry spray and insufficient film thickness diminish performance, nor so high that solvents are trapped or shrinkage or cracking occurs. Paint manufacturers now

creates stripes until the paint is properly mixed, a transparent appearance until at least 100 microns thickness has been applied, and different colours for two coat applications to ensure all surfaces are covered.

A typical coating standard for ballast tanks might require surfaces to be pre-treated to Sa 2.5 by steel shot, a primer of 15 microns dry film thickness, followed by one or two coats of paint of 200 microns dry film thickness. Strip coating of seams, ratholes, edges and corners may also be required.

Cargo tanks can be protected by paints formulated for ballast tanks, as long as they are resistant to crude oil and other mineral oil products, and have grain specification in the case of bulk carriers. Specific cargo tank coatings are formulated to protect against particular cargoes. Epoxy/amine coatings are recommended for use with crude oil, petroleum products and vegetable oils and a three coat application is usual. Epoxy/phenolic formulations will protect against some chemicals in addition to crude oil, petroleum products and vegetable oils and, again, a three coat application is usual. Modified epoxy and alkyl zinc silicate formulations can also be used for similar cargoes with only a single coating applied.

Fresh water tanks can be satisfactorily protected by bitumen or tar paints or more modern formulations of solvent-free epoxy. Drinking water tanks must have a non-taint coating such as artificial bitumen to BS 3416 Type 2.

Cathodic protection

When a metal is in contact with an electrolyte, e.g. the steel of a ship's hull in sea water, small corrosion cells may be set up due to slight variations in the electrical potential of the metal's surface. Electric currents flow between the high and low potential points, with the result that metal is corroded from the point where the current leaves the metal (the anode). At the point where the current re-enters the metal (the cathode) the metal is protected. Cathodic protection operates by providing a reverse current flow to that of the corrosive system. With current then entering the metal at every point, the whole metal surface becomes a cathode, and it is therefore cathodically protected.

When the potential over the immersed hull surface is 0.80–0.85 V more negative than a reference silver/silver chloride electrode in the water nearby, then the hull is adequately protected. Current density of the order of 20–100 mA/m^2 is usually sufficient on a painted hull to reverse any corrosion current and cease further metal corrosion. Current density necessarily increases for a poorly painted hull and therefore cathodic protection should be regarded as an additional protection to painting and by no means a substitute.

Two means of cathodic protection are in general use on ships—the sacrificial anode type and the impressed current type. The sacrificial anode type of cathodic protection uses metals such as aluminium and zinc which form the anode of a corrosion cell in preference to steel (see Table 12.1). As a consequence, these sacrificial anodes are gradually eaten away and require replacement after a period of time. The impressed current system provides the electrical potential difference from the ship's power supply through an anode of a long-life highly corrosion-resistant material such as platinised titanium.

Sacrificial anode system

Sacrificial anodes are, in practice, arranged as blocks and are securely bolted or welded to the ship's hull by their steel core to give a good electrical connection. Their metal composition is aluminium or zinc, usually in alloyed form. They are designed to ensure uniform wearing away and to provide a constant current to the protected steel. The amount of anode material should provide a protective current of 12–20 mA/m^2. Modern sacrificial anodes have a life of 3–4 years before requiring replacement.

Impressed current system

An impressed current system comprises several anodes, reference electrodes and a controller power unit. A typical installation for both large and small vessels is shown in Figure 12.3. The type and sizes of the various components and their position on the ship's hull will be decided according to design parmaters. These will include vessel size and the assumed fluctuation of the protection current during sea going service.

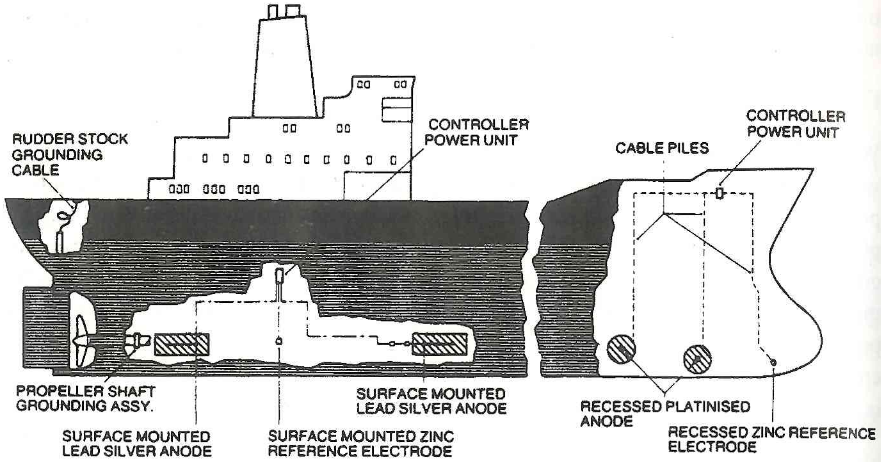


Figure 12.3 Typical location of impressed current system

The aft end system arrangement is used for all vessels, whereas the forward end system is only required on larger, longer vessels. Recessed anodes are fitted at the forward end in order to reduce drag and minimise damage. Where a bow thruster is fitted a separate immersed current system may be fitted to protect the housing tunnel and thruster components.

The propeller, exposed shafting and the rudder must also be protected in addition to the hull. The propeller and shafting are electrically grounded to the hull structure with a shaft slipring. A flexible cable is used to ground the rudder. When electrical continuity is established between these components and the hull, the impressed current system will protect them all.

Anodes used in the system may be of a lead/silver alloy or a platinised carrier metal, both of which are relatively inert. Vessels engaged in normal sea-going trades are usually fitted with lead/silver anodes which are encapsulated in glass reinforced

resin holders. The anodes are bolted to doubler plates which have been welded to the hull. The doubler plate is surrounded by a dielectric shield of glass reinforced resin which is bonded to it during manufacture (Figure 12.4).

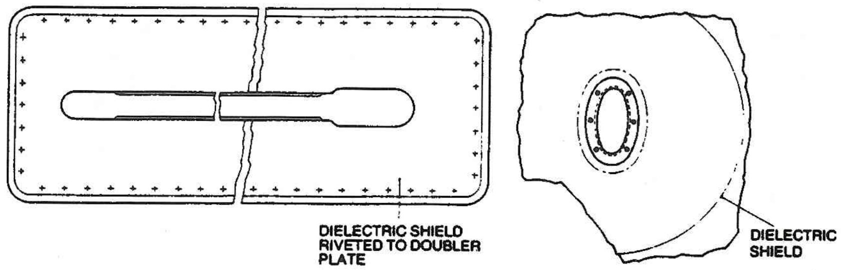


Figure 12.4 Surface mounted and recessed anodes. That on the left is lead/silver; on the right, a platinised anode

Platinised anodes have a platinum coating on a carrier metal plate which may be titanium or niobium. The anode is encapsulated in or mounted on a reinforced resin holder and may be surface mounted or recessed as required. Platinised anodes have their immediate surrounding area protected by a dielectric shield of an epoxy mastic material which has been applied to the shot blasted hull.

All anodes have a cofferdam with a double gland assembly to ensure a watertight hull penetration for the cable.

A minimum of two reference anodes are fitted which may be surface mounted or recessed (Figure 12.5). They are made of high purity zinc which is both robust and has stable electrochemical characteristics. The reference electrode will continuously monitor hull potential as a measure of the protection being provided. Signals from the electrodes are fed to the controller power unit which adjusts the current output as required.

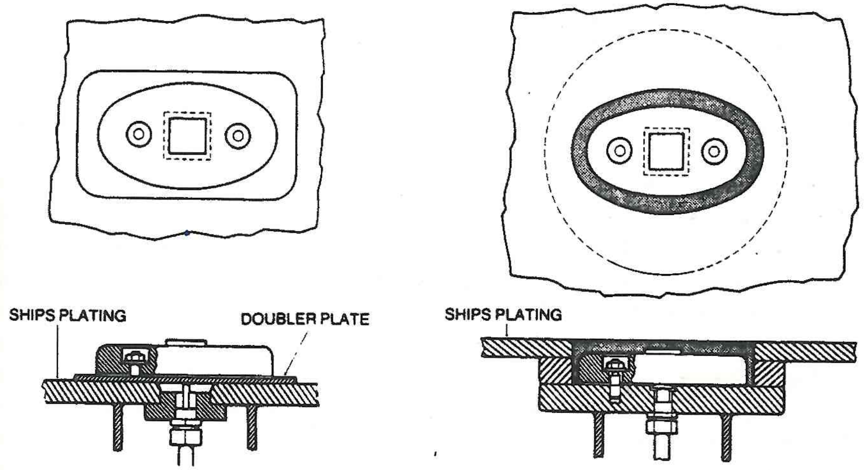


Figure 12.5 Surface mounted and recessed reference electrodes

The reference electrode is fitted into a glass reinforced resin holder and bolted to a doubler plate which is welded to the hull.

The recessed reference electrode is similarly mounted but in a recess. Again, cofferdam arrangements are used to ensure watertight hull penetration for the cable. The controller power unit is self contained in a cabinet which may be positioned in the machinery space or any other convenient location. The ship's a.c. mains supply is transformed and rectified in the controller power unit into the d.c. current which is used for cathodic protection. A graphic display can be provided for the recording of readings or a microprocessor unit can be provided to carry out self checking, monitoring and data output to computers and printers.

The propeller shaft slipring assembly ensures a good electrical contact between the propeller, shafting and the ship's hull. This will inhibit dezincification of bronze propellers and also protect propellers of other materials. The shaft bearings are also protected from corrosion. A silver inlaid copper band is clamped to the propeller shaft and a brush assembly of high silver content brushes runs on it to give electrical continuity to the hull (Figure 12.6).

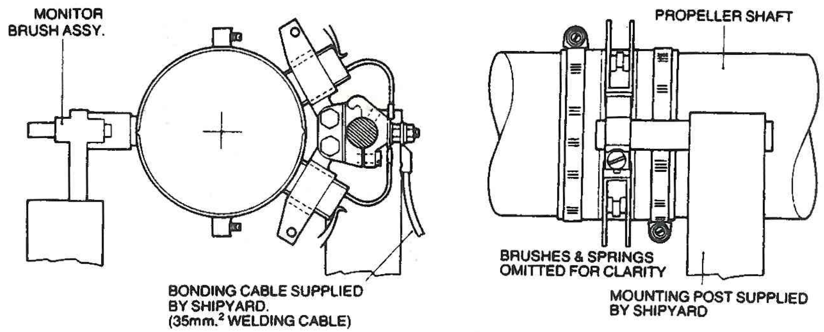


Figure 12.6 Propeller shaft slipring assembly

The rudder and rudder stock must also be bonded to give electrical continuity. a flexible cable is fitted between the rudder stock and the hull for this purpose.

Cathodic protection of tanks

The cathodic protection of ballast and cargo/ballast tanks is only ever of the sacrificial anode type using aluminium, magnesium or zinc anodes. The use of aluminium and magnesium anodes is restricted by height and energy limitations to reduce the possibility of sparks from falling anodes. Magnesium and aluminium anodes are not permitted at all in cargo oil tanks or tanks adjacent to cargo oil tanks. The anodes are arranged across the bottom of a tank and up the sides, and only those immersed in water will be active in providing protective current flow. Current density in tanks varies from 5 mA/m^2 for fully-coated surfaces to about 100 mA/m^2 for ballast-only tanks. Deckheads cannot be cathodically protected, since tanks are rarely full; they are therefore given adequate additional protective coatings of a suitable paint for the upper 1.5 m of the tank.

Sea water circulation systems

Corrosion and also marine growth can be controlled in sea water circulation systems by an impressed current arrangement. The different metals of pipes, valves and fittings will be affected by electrochemical corrosion, since sea water is an electrolyte. This corrosion is also accompanied by marine incrustation or the growth of marine plants and animals within the sea water system. Chemical methods, such as the introduction of hypochlorite, to release chlorine, have been used, but this can lead to metal pitting and possible environmental problems.

The impressed current cathodic protection principle can be used where direct current is applied to one or more copper anodes (Figure 12.7). Copper ions are then released at a controlled rate into the system and will create an environment in which primary forms of marine life cannot exist. Iron anodes can be used, in a similar way to protect a system with copper alloy piping.

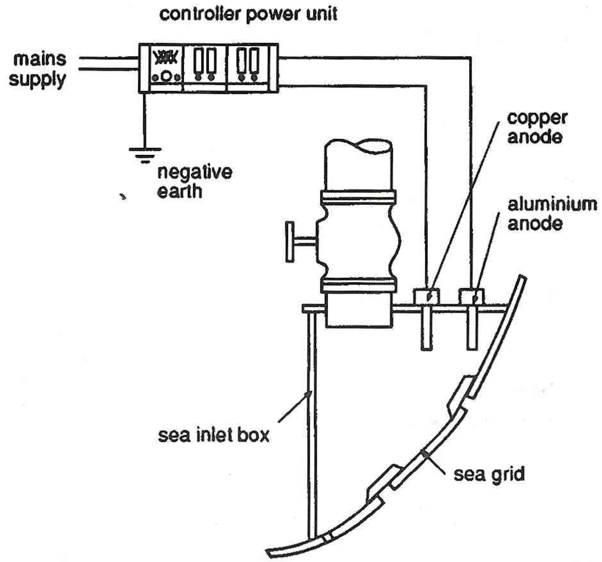


Figure 12.7 Corrosion protection of a sea water circulation system

A second aluminium anode releases a 'floc' or precipitate of aluminium hydroxide which collects the copper ions released from the copper anode and distributes them around the sea water system, in particular to low flow rate areas. The aluminium hydroxide precipitate also forms a fine coating over all the inner surfaces of the sea water circulation system. This coating acts as a current dispersing film to protect the system from the possible corrosive action that can occur due to copper ion deposition.

A controller power unit converts the a.c. mains supply to a suitable low voltage d.c. current. The sea water circulation system is connected to the negative terminal of the controller power unit and the protecting anodes to the positive terminal. All anodes have a cofferdam with a double gland assembly to ensure a watertight hull

Corrosion prevention by good design

The third method of corrosion prevention is by good design based on a knowledge of the corrosion processes. Good design, therefore, should avoid the trapping of corrosive agents or the setting up of corrosion cells in places which cannot be reached, are poorly ventilated, or rarely protected or maintained.

Small pockets, crevices, etc., where salt spray, water, etc., can collect will result ultimately in severe rusting. Since this involves an increase in volume of the material it will be followed by distortion or fracture of the structural members. Sealing of such crevices by welding or concrete, or their avoidance in the design stage, should be ensured. Dripping water as a result of poorly designed discharges or scuppers should be avoided. Condensed moisture on the underside of enclosed structures will cause corrosion and good design should ensure adequate ventilation of these areas. Steel decks covered by wood will corrode unless the steel is suitably protected and the wood is 'sealed' with a bitumen coating. All joints should be sealed by a suitable filler and any bolts through the wood should have washers under the nuts to prevent the entry of water. Paint, to be an effective protection, requires an adequate thickness over the metal surface. The surface should be made as accessible as possible to enable good coverage and a uniform dry paint thickness. Welding can be used to fill small crevices; however, any welded surface must be suitably prepared prior to painting to ensure protection against corrosion. Smooth rounded surfaces are always easier to paint and less liable to damage and subsequent corrosion.

The atmosphere of machinery spaces and boiler rooms, with the presence of heat, moisture, vibration and foul air, presents ideal conditions for the corrosive process to take place. Surfaces should therefore be kept water-free and as cool as possible by good drainage, insulation of steam pipes, etc., and good ventilation. Inaccessible places such as machinery seats should be well protected by painting before any machinery is fitted. Double-bottom tanks under boilers are sometimes left empty and specially coated with heat-resistant paint. All double-bottom tanks should be regularly inspected and maintained but only after adequate ventilation has been ensured. Maintenance should take the form of painting with bitumastic paint mixtures or in some cases cement wash. Any double-bottom tanks regularly used for oil will have little or no need for corrosion protection.

Two different metals in contact in the presence of an electrolyte such as rain, spray or condensation, can result in a corrosion cell. This can create problems in areas where light alloy members such as aluminium are in contact with steel, as in the superstructure of passenger ships. Modern practice with such joints is to use a transition plate as described in Chapter 4, but older vessels may have bolted joints with insulating ferrules, such as neoprene or some inert filler, between the metal surfaces. Problems do still arise where such joints are made by bolting or riveting, and regular maintenance and attention is required.

Where stainless steel is used in a marine environment the passive mode should be selected, since it is almost immune to electrochemical action.

13 Surveys and Maintenance

In common with all machinery a ship requires regular overhaul and maintenance. The particularly severe operating conditions for an almost all-steel structure necessitate constant attention to the steelwork. The operations of berthing, cargo loading and discharge, constant immersion in sea water and the variety of climatic extremes encountered all take their toll on the structure and its protective coatings. The classification societies have requirements for examination or survey of the ship at set periods throughout its life. The nature and extent of the survey increases as the ship becomes older.

Classification Societies have now introduced an Enhanced Survey Programme which expands and emphasises the existing survey requirements for annual, intermediate and special surveys, with particular attention being paid to the hull structure in the cargo hold region. One specific requirement is that ships must apply a protective coating to the structure in water ballast tanks, where they form part of the hull boundary, and side shell structure and transverse watertight bulkheads in holds. The condition of these coatings will be graded and recorded at the Special Survey, and the nature and extent of future annual and intermediate surveys will depend upon the protection provided to steelwork by these coatings.

Periodic surveys

New ships, which are to be classified, are built under Special Survey following the Classification Society approval of all constructional plans and particulars relevant to the hull, equipment and machinery. Throughout the building of the ship Surveyors will examine materials, workmanship and arrangements, to ensure they comply with the rules. Where defects are found, they must be rectified. The date of completion of the Special Survey during construction is the Date of Build entered in the Register Book and periodic surveys take place from this date.

All ships must have an Annual Survey within three months before or after the anniversary of completion. During an annual survey, the various closing appliances on all hatchways and the hull openings through which water may enter, must be checked to ensure they are in an efficient condition. Water clearing arrangements, such as scuppers and bulwark freeing ports, must also operate satisfactorily. The anchoring and mooring equipment are examined as far as is practicable, watertight doors are inspected and tested, guard rails, lifelines and gangways are examined, and various checks of the steering gear and ship's machinery are also undertaken. Fire protection, detection and extinction arrangements are verified by testing where possible and additional checks are made for specific ship types such as oil and chemical tankers and liquefied gas carriers.

Intermediate Surveys are held on ships instead of the second or third Annual Survey after completion or Special Survey. In addition to the requirements for Annual Survey, a general examination of salt water ballast tanks is undertaken for structural defects and to verify whether the coating condition is GOOD or FAIR. For ships over five years old the examinations become more rigorous, and where corrosion is found a Close-up Survey is carried out. Thickness measurements of structure will also be carried out at later surveys. Close-up surveys are where structural items are within reach of a Surveyor's hand. Additional checks are made for specific ship types such as oil and chemical tankers and liquefied gas carriers. Dry bulk cargo ships over five years old will have all cargo holds surveyed and Close-up Surveys conducted of shell frames, frame end connections and transverse bulkheads in a forward cargo hold and one other. Thickness measurements will also be taken.

Docking Surveys are required every 2.5 years and one in each five-year period should coincide with the Special Survey. The ship must be on blocks of a sufficient height to enable examination of the shell, all bottom and bow plating keel, stern, sternframe and rudder. The rudder may be lifted and measurements of wear in the rudder and propeller shaft bearings are made. In-water Surveys may be acceptable instead of the intermediate docking between Special Surveys, where the ship is coated with a suitable paint and an approved automatic impressed current cathodic protection system fitted. A diver-operated underwater survey vehicle is used to relay pictures of the hull to the Surveyor.

Special Surveys become due five years after completion and every five years after that. The requirements of an Annual Survey must be met together with additional examinations. A detailed examination of structure, removing covers and linings, can be made. Metal thicknesses at any area showing wastage may have to be checked. The double bottom and peak tanks must be tested by filling with water to the maximum service head. The decks, casings and superstructures, together with any areas of discontinuity, must be examined for cracks or signs of failure. All escape routes from occupied or working spaces must be checked. Emergency communications to the machinery space and the auxiliary steering position from the bridge must also be proved. Where the coating condition of salt water ballast tanks is considered POOR further examinations and thickness measurements may be required at Annual Surveys. Anchors must be examined and chain cables must be ranged (laid out for examination) on all ships over five years old.

Additional checks are made for oil tankers, including ore/oil and ore/bulk/oil ships, dry bulk cargo ships and chemical tankers which include Close-up Surveys and thickness measurements. The numbers and extent of structural members examined increases significantly as the vessel becomes older. Where coatings are found to be in GOOD condition the extent of Close-up Surveys may be specially considered.

Continuous Surveys may be permitted at the request of an Owner during which all compartments of the hull are opened for survey and examination in turn. An interval of five years is permitted between the examination of each part.

Liquefied gas tankers have requirements for annual surveys, as mentioned earlier, and several additional items. All tanks, cofferdams, pipes, etc., must be gas freed before survey. Where the maximum vapour pressure in the tanks is 0.7 bar or less the inner tank surfaces are to be examined. In addition, the tanks must be water tested by a head of 2.45 m above the top of the tank. All tank level devices, gas detectors, inerting arrangements, etc., must be proved to be operating satisfactorily. The special survey requirements are as previously stated, together with the examination internally and externally where possible of all tank areas. Tank mountings, supports, pipe connections and deck sealing arrangements must also be checked. Samples of insulation, where fitted, must be removed and the plating beneath examined. Pressure-relief and vacuum valves must be proved to be efficient. Refrigeration machinery, where fitted, must be examined.

All ships must be surveyed annually to ensure that they comply with the conditions of assignment (see Chapter 11) as stated in the Merchant Shipping (Load Line) Rules of 1968.

Protective coatings

Protective coatings of sea water ballast tanks have come in for special examination by Classification Societies and are generally considered to be hard paint coatings. When surveyed, their condition is assessed as either GOOD, FAIR or POOR. Lloyd's Rules and Regulations for the Classification of Ships gives the following definitions of these terms:

GOOD — Condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration, e.g. on a deck transverse, side transverse, on the total area of plating and stiffeners on the longitudinal structure between these components, etc.

FAIR — Condition with local breakdown at edges of stiffeners and weld connections and/or light rusting affecting 20 per cent or more of areas under consideration.

POOR — Condition with general breakdown of coating affecting 20 per cent or more of areas under consideration or hard scale affecting 10 per cent or more of area under consideration.

Hull surveys of very large crude carriers

The very size of these ships necessitates considerable planning and preparation prior to any survey. Large amounts of staging are necessary to provide access to the structure. Good lighting, safe access and some means of communication are also required. Surveys are often undertaken at sea, with the gas freeing of the tanks being one of the main problems. In-water surveys of the outer hull are also done. Some thought at the design stage of the ship should enable the stern bush, pintle and rudder bush clearances to be measured in the water. Provision should also exist for unshipping the propeller in the water. Anodes should be bolted to the shell and therefore easily replaced. Blanks for sealing off inlets should be carried by the ship, to enable the overhaul of shipside valves. The frame markings should be painted on the outside of the ship at the weather deck edge to assist in identifying frames and bulkheads. An in-water survey plan should be prepared by the shipbuilder. The hull plating surface must be clean prior to survey. This can be achieved by the use of rotary hand-held brushes which may be hydraulically or pneumatically powered. In-water cleaning of the hull is possible, with divers using these brushes or specially designed boats with long rotating brushes attached.

One particular system uses a 'Brush Kart'. This is a hydraulically-powered vehicle with three brushing heads. It is driven by a diver over the surface of the hull to clear the plating of all forms of marine fouling. The Brush Kart is shown in vehicle such as the 'Scan' unit shown in Figure 13.2. The various camera units enable close scrutiny of all the areas of the shell plating by the surveyor observing the monitoring units. The Scan unit is fully manoeuvrable over the hull surface.

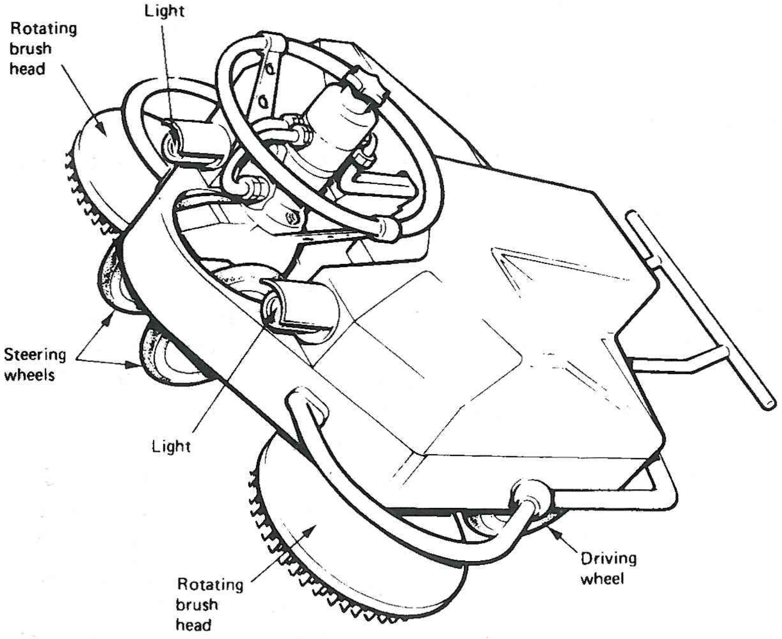


Figure 13.1 'Brush Kart' underwater cleaning vehicle

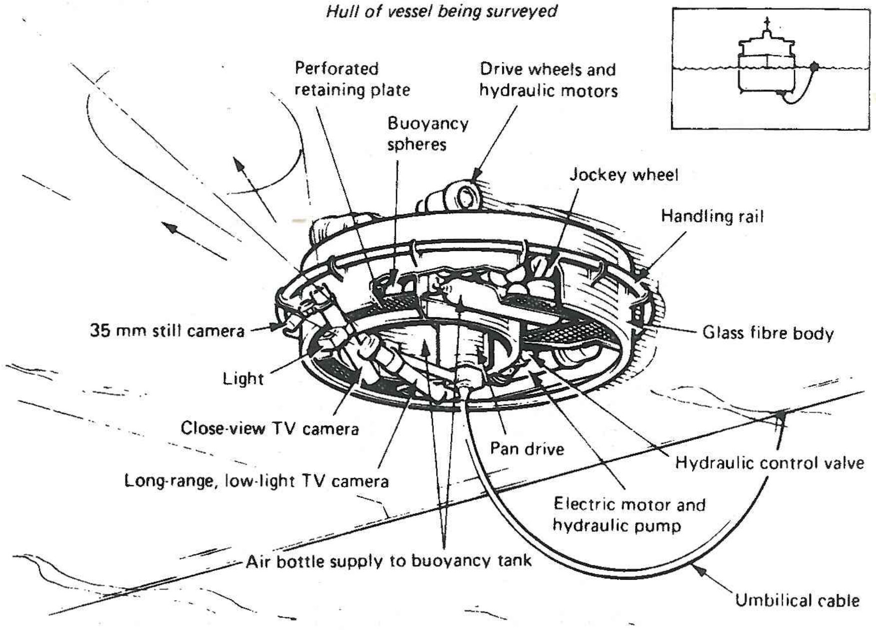


Figure 13.2 'Scan' underwater survey vehicle (from 'Wet docking of large ships', in

Bulk carrier surveys

Mechanical damage during cargo handling can lead to side shell failure. Cargoes such as iron ore and coal can bring about corrosion of the structure which can likewise bring about failure. High losses of this type of vessel in recent years have resulted in classification societies paying particular attention to problem areas during surveys.

Main side frames with end connections are prone to cracks beginning at the toe or root of the lower bracket connection to the hopper tank. These cracks may propagate during heavy weather movements of the ship and bring about separation and then similar action at the upper bracket connections. The unsupported shell plating then begins to crack and a major failure may follow.

The cross deck strips between hatches provide the upper support to vertically corrugated bulkheads. If this welded joint cracks the bulkhead may buckle, possibly upwards, causing the hatch covers to become detached. Corrosion may also occur where the bulkhead joins the deck or its stool or the stool joins the tank top. The bulkhead may then fail in shear due to excessive loading on one side.

Transition zones are particularly prone to cracking. The change in cross-section forward and aft of the cargo hold areas may be significant. It may be that these regions have been hand welded during the ship's construction making them further suspect. The ends of the upper and lower hopper tanks are also problem areas. Cracks may begin at the termination points against the transverse bulkheads. Water leaks may then occur causing corrosion which will hasten the failure.

Ballast tanks may corrode if the protective coatings fail or are not maintained. Where these ballast tanks act as support for other structural elements, they must be inspected very carefully. The various areas which should be examined are summarised in Figure 13.3.

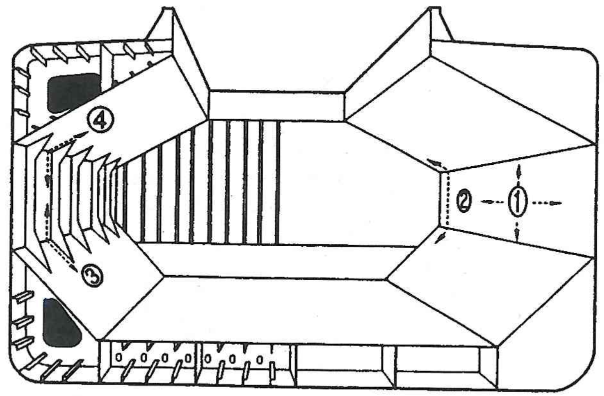


Figure 13.3 Bulk carrier survey points

1 Side shell plating.
2 Connection of bulkhead plating to side shell.
3 Connection of side shell frames and end brackets to shell plating and hopperside tank plating by close-up inspection.
4 Connection of side shell frames and end brackets to the shell

Examination in drydock

The drydocking of a ship provides a rare opportunity for examination of the underwater areas of a ship. Every opportunity should therefore be taken by the ship's staff, the shipowner and the classification society to examine the ship thoroughly. Some of the more important areas are now listed.

Shell plating

The shell plating must be thoroughly examined for any corrosion of welds, damage, distortion and cracks at openings or discontinuities. Any hull attachments such as lugs, bilge keels, etc., must be checked for corrosion, security of attachment and any damage. All openings for grids and sea boxes must also be examined.

Cathodic protection equipment

Sacrificial anodes should be checked for security of attachment to the hull and the degree of wastage that has taken place. With impressed current systems the anodes and reference anodes must be checked, again for security of attachment. The inert shields and paintwork near the anodes should be examined for any damage or deterioration.

Rudder

The plating and visible structure of the rudder should be examined for cracks and any distortion. The drain plugs should be removed to check for the entry of any water. Pintle or bearing weardown and clearances should be measured and the security of the rudder stock coupling bolts and any pintle nuts should be ensured.

Sternframe

The surface should be carefully checked for cracks, particularly in the areas where a change of section occurs or large bending moments are experienced.

Propeller

The cone should be checked for security of attachment and also the rope guard. The blades should be examined for corrosion and cavitation damage, and any cracks or damage to the blade tips. It is usual to examine any tailshaft seals and also measure the tailshaft weardown.

Anchors and cables

Cable should be laid out or 'ranged' in a drydock and the various lengths (shackles) transposed. The individual links should then be examined for wear and the joining shackles should be opened up and examined. Every link should be hammer tested to ensure it is sound. The chain locker should meanwhile be thoroughly cleaned out and the cable securing arrangement overhauled.

The anchor should be cleaned and examined, in particular to ensure the free movement of the head pivoting mechanism. The mechanism should be suitably greased after examination.

Paintwork

The shell plating should be examined for areas of paintwork which must be repaired. The whole surface of the shell will then be cleaned and prepared for recoating with paint. In some instances the hull may be cleaned down to the bare metal and completely recoated; most situations, however, will only require preparation of the surface for recoating.

Preparation

Several methods are used for cleaning the ship's hull prior to recoating. Some of the more common ones will now be discussed.

Manual wire brushing and scraping with steel scrapers usually takes place on the wet surface as the water level drops in the dock. The finish is poor, the operation slow and the effectiveness varies according to the skill and effort of the operatives involved.

Power discing or wire brushing uses either an electrically or pneumatically driven machine which is hand held. The method is slow but provides a relatively good finish.

High pressure water jetting is being increasingly used for hull cleaning. Water at pressures of 150–500 bar is directed on to the hull by a tubular steel lance. The lower pressure is sufficient to remove weak fouling growths, while the higher pressure will clean the hull down to the bare metal. The results from this method are excellent and very fast, although time is lost while waiting for the hull to dry. It is, however, a skilled operation requiring competent trained personnel for efficient safe performance.

Shot-blasting or abrasive-only cleaning utilises a jet of abrasive at 5–7 bar pressure fired from a nozzle on to the ship's hull. This method rapidly produces a clean dry surface ready for painting. The dusty, dirty nature of the work, however, stops any other activities in the area.

Abrasive and water-blasting combines in effect the foregoing two methods and claims the advantages of each. The method is fast, clean and effective, the abrasive speeding the cleaning and the water suppressing the dust. With this method and water jetting, corrosion inhibitors are added to the water to allow time between cleaning, drying and painting.

Painting

The successful application of paint requires the correct technique during painting and suitable conditions during which the application takes place.

Painting should take place in warm dry weather but not in direct sunlight. The presence of moisture in the air or on the metal surface may damage the paintwork or slow down its curing process. Where poor conditions are unavoidable, specially formulated paints for curing under these conditions should be used. The use of shelters or awnings perhaps supplied with warm air will greatly improve curing and adhesion of the paint. Any scuppers, discharges or overflows which may direct water on to the surface to be painted should be blocked or diverted before work is begun.

The principal methods of paint application are the airless spray, the air-assisted spray, the roller and the brush. Brush and roller application is employed where rough surfaces exist and small often inaccessible areas are to be covered. The method is slow, labour intensive and difficult with certain types of paints. Air-assisted spraying has been largely replaced by the airless spray technique for which most modern paints are formulated. Airless spray is the fastest and cleanest application method. High build materials are suitable for this method of application with dry film thicknesses up to 300mm possible in one application.

Throughout the preparation and painting of a ship the need for good safe, suitable means of access is paramount. Freedom of movement to maintain the appropriate distances for water jetting and paint spraying, for example, is essential. Free-standing scaffolding is used to some extent and also hydraulically operated mobile platforms.

A final mention on the subject of safety is required. Paints in their various forms can be poisonous, skin irritants and of a highly inflammable nature. Adequate protection and ventilation is therefore necessary. In addition, care is required in the location and operation of equipment to avoid the possibility of fires and explosions. Most manufacturers apply their own symbols to paint containers to indicate the various hazards, in addition to any mandatory requirements on labelling.

Computer-aided Survey and Maintenance

A number of computer-aided hull maintenance programmes have been developed to enable owners, classification societies and statutory authorities to monitor and record hull details enabling maintenance to be reliably programmed. The International Association of Classification Societies (IACS) and the International Maritime Organisation, have various requirements for enhanced detailed annual inspections of suspect areas on particular types of ships, and require maintenance planning procedures to be undertaken, up-dated and made available on-board. Most leading classification societies have developed computer-based systems to assist owners in the design, construction, safe operation and maintenance of their ships. Lloyd's Register have ShipRight, American Bureau of Shipping have the SafeNet module of the SafeHull system, Bureau Veritas have Veristar, and NKK have PrimeShip.

The Lloyd's ShipRight system offers Construction and Hull Monitoring procedures, where Structural Design and Fatigue Design Assessment procedures have been followed during the ship design stage. It is not proposed to discuss design aspects of this system, as they are outside the scope of this text. The Construction Monitoring procedure verifies construction tolerances at critical joints to ensure they are not exceeded and acts as quality assurance, to ensure satisfactory fatigue life.

The Hull Condition Monitoring procedure is a computer software system for modelling the ship to enable planning, inspection, maintenance and monitoring of structural condition. This procedure provides the required information on the ship's structure to meet the Unified Requirements of the International Association of Classification Societies (IACS) Enhanced Survey programme, which came into force for oil tankers and bulk carriers in July 1993. Use of the system also enables repairs to be scheduled and incorporated with the planned maintenance for the ship's structure.

The Hull Condition Monitoring procedure involves first modelling and then monitoring of the ship's hull. To model the hull, original structural plans of the vessel, imported directly from CAD/CAM format, are used to create a geometrical representation of the hull structure. Coding and numbering of every individual plate and stiffener is possible. Two dimensional views of an area, such as a tank, are first obtained and then the individual surface of interest, showing the geometrical properties of each item, is shown as a code with the original and any replacement thicknesses. The shell can be expanded from the hull form geometry and the plating, seams, butts, grades, thicknesses and longitudinals all defined. Zoom facilities enable a particular detail to be examined more closely.

The monitoring system enables planning of various inspections, documentation of thickness measurements, coating inspections and recording of fractures. Drawings of any tank or space can be selected and thickness readings pre-planned and subsequently recorded. Thickness loss can be calculated and suspect areas subsequently identified. Coating inspections can be similarly planned and recorded for coating ballast and cargo tanks with coatings then identified as 'good', 'fair' or 'poor' according to the IACS categories. Close-up inspections enable any fractures to be recorded and the type of repair needed to be determined.

A 'survey status' option provides details of all previous, and the next due, survey, together with the class requirements and critical area details. An 'executive hull summary' option gives details of previous special surveys as required by IACS. This will show which tanks have been surveyed, the extent of gaugings and close-up surveys done, a list of plates which have corrosion in excess of 75 per cent of the allowable margin, areas where coating breakdown is classed as poor, and a list of repairs undertaken.

Maintenance planning requires the appropriate sequencing of events, which is to plan the survey, enter survey data and then display and record all survey results. Operation of the system requires a minimum of computer experience, as a menu-driven system is used. Selected drawings can be used to plan surveys and enter any data obtained. The results can then be viewed and a summary of hull condition obtained.

These hull condition monitoring systems are considered to provide a powerful tool for planning and documenting surveys in accordance with new procedures for tankers and bulk carriers. They provide a continuity in the surveying process and maintain accurate records in what is a very flexible system.

14 Principal Ship Dimensions and Glossary of Terms

Principal ship dimensions

A ship is defined and described in size, shape and form by a number of particular terms, which are listed below and some of which are shown in Figure 14.1.

Forward perpendicular
An imaginary line drawn perpendicular to the waterline at the point where the forward edge of the stem intersects the summer load line.

After perpendicular
An imaginary line drawn perpendicular to the waterline, either (1) where the after edge of the rudder post meets the summer load line, or (2) in cases where no rudder post is fitted, the centreline of the rudder pintles is taken.

Length between perpendiculars (LBP)
The distance between the forward and after perpendiculars, measured along the summer load line.

Length overall (LOA)
The distance between the extreme points of the ship forward and aft.

Amidships
The point midway between the forward and after perpendiculars. A special symbol is used to represent this point (Figure 14.1).

Extreme breadth
Maximum breadth over the extreme points port and starboard of the ship.

Extreme draught
Distance from the waterline to the underside of the keel.

Extreme depth
Depth of the ship from the upper deck to the underside of the keel. Moulded dimensions are measured to the inside edges of the plating, i.e. they are the frame dimensions.

Base line
A horizontal line drawn along the top edge of the keel from midships.

Moulded breadth
The greatest breadth of the ship, measured to the inside edges of the shell plating.

Moulded draught
The distance from the summer load line to the base line, measured at the midship section.

Moulded depth
The depth of the ship from the upper deck to the base line, measured at the midship section.

Half-breadth
At any particular section half-breadth distances may be given since a ship is symmetrical about the longitudinal centreline.

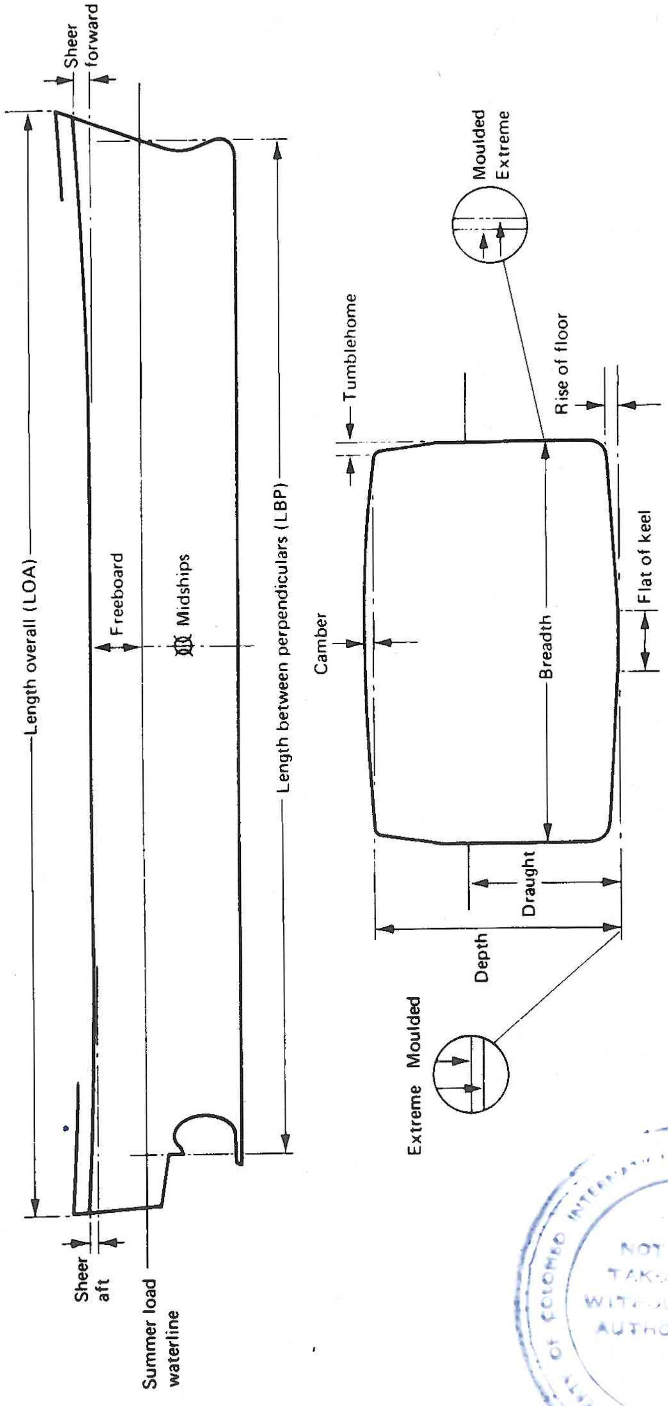


Figure 14.1 Ship terms and definition

NOT TO BE TAKEN AWAY WITHOUT PROPER AUTHORISATION

Freeboard
The vertical distance from the summer load waterline to the top of the freeboard deck plating, measured at the ship's side amidships. The upper most complete deck exposed to the weather and the sea is normally the freeboard deck. The freeboard deck must have permanent means of closure of all openings in it and below it.

Sheer
The curvature of the deck in a longitudinal direction. It is measured between the deck height at midships and the particular point on the deck.

Camber
The curvature of the deck in a transverse direction. Camber is measured between the deck height at the centre and the deck height at the side.

Rise of floor
The height of the bottom shell plating above the base line. Rise of floor is measured at the moulded beam line.

Bilge radius
The radius of the plating joining the side shell to the bottom shell. It is measured at midships.

Flat of keel
The width of the horizontal portion of the bottom shell, measured transversely.

Tumblehome
An inward curvature of the midship side shell in the region of the upper deck.

Flare
An outward curvature of the side shell at the forward end above the waterline.

Rake
A line inclined from the vertical or horizontal.

Parallel middle body
The ship's length for which the midship section is constant in area and shape.

Entrance
The immersed body of the ship forward of the parallel middle body.

Run
The immersed body of the ship aft of the parallel middle body.

Displacement
The weight of the ship and its contents, measured in tonnes. The value will vary according to the ship's draught.

Lightweight
The weight of the ship, in tonnes, complete and ready for sea but without crew, passengers, stores, fuel or cargo on board.

Deadweight
The difference between the displacement and the lightweight at any given draught, again measured in tonnes. Deadweight is the weight of cargo, fuel, stores, etc., that a ship can carry.

Tonnage
A measure of the internal capacity of a ship where 100 ft3 or 2.82 m3 represents 1 ton. Two values are currently in use—the gross tonnage and the net tonnage.

Glossary of terms

Aft
In the direction of, at, or near the stern.

Aft peak
A watertight compartment between the aftermost watertight bulkhead and the stern.

Athwartship
In a direction across the ship, at right-angles to the fore and aft centreline.

Ballast
A weight of liquid positioned in a ship to change the trim, increase the draught or improve the seaworthiness.

Bilge
Rounded region between the side and shell plating; the space where water collects after draining down from cargo holds, etc.

Bitter end
The end of the anchor cable which is secured in the chain locker by the clench pin.

Bollard
A pair of short metal columns on a rigid baseplate which are used to secure the mooring ropes or wires.

Bow
The forward end of a ship.

Bracket
A plate which is used to rigidly connect a number of structural parts; it is often triangular in shape.

Break
The point at which a side shell plating section drops to the deck below, such as the poop or forecastle.

Bulkhead, aft peak
The first major transverse watertight bulkhead forward of the sternframe.

Bulkhead, collision or forepeak
The foremost major watertight bulkhead.

Coaming
The vertical plate structure around a hatchway which supports the hatchcover. The height is dictated by the Merchant Shipping (Load line) Rules of 1968.

Cofferdam
A void or empty space between two bulkheads or floors which prevents leakage from one to the other.

Cowl
The shaped top of a natural ventilation trunk which may be rotated to draw air into or out of the ventilated space.

Deep tanks
Tanks which extend from the shell or double bottom up to or beyond the lowest deck. They are usually arranged for the carriage of fuel oil or water ballast but may be fitted with hatches and used for cargo.

Devil's claw
A stretching screw with two heavy hooks or claws. It is used to secure the anchor in the hawse pipe.

Dog
A small metal fastener or clip used to secure doors, hatch covers, etc.

Erection
The positioning and temporary fastening together of units or fabricated parts of a ship prior to welding.

Fabrication
The various processes which lead to the manufacture of structural parts for a ship.

Fair
To smoothly align the adjoining parts of a ship's structure or its design lines.

Fairlead
An item of mooring equipment used to maintain or change the direction of a rope or wire in order to provide a straight lead to a winch drum.

Flange
The portion of a plate or bracket bent at right-angles to the remainder; to bend over at right angles.

Flat
A minor section of internal deck often without sheer or camber, also known as a platform.

Forepeak
A watertight compartment between the foremost watertight bulkhead and the stem.

Forward
In the direction of, at, or near the stem.

Frame
A transverse structural member which acts as a stiffener to the shell and bottom plate.

Gasket
A joint, usually of flexible material, which is positioned between metal surfaces to prevent leakage.

Girder
A continuous stiffening member which runs fore and aft in a ship, usually to support the deck.

Gooseneck
A fitting on the end of a boom or derrick which connects it to the mast or post and permits a swivel motion.

Grommet
A ring of soft material positioned beneath a nut or bolthead to provide a watertight joint.

Gudgeon
A solid lug on the sternframe or rudder which is drilled to take the pintle.

Gussett plate
A bracket plate usually positioned in a horizontal or almost horizontal plane.

Holds
The lowest cargo stowage compartments in a ship.

Inboard
In a direction towards the centreline of the ship.

Intercostal
Composed of separate parts, non-continuous.

Offsets
The co-ordinates of a ship's form.

Outboard
In a direction away from the centreline of the ship.

Panting
The in and out movement of a ship's plating.

Pintle
The hinge pin on which certain types of rudder swing.

Port
The left-hand side of a ship when facing forward.

Samson post
A rigid vertical post used in place of a mast to support derricks.

Scantlings
The dimensions of the structural items of a ship, e.g. frames, girders, plating, etc.

Scuppers
Deck drains to remove sea water, rain water or condensation.

Seat
The structural support for an item of machinery or equipment.

Seaworthy
A term used to describe a ship which has adequate strength, free-board and stability in order to carry and deliver its cargo in good condition.

Spectacle frame
A large casting which projects outboard from the ship and supports the ends of the propeller shafts in a twin screw ship. The casting is plated into the surrounding shell.

Starboard
The right-hand side of a ship when facing forward.

Stays
Wires or ropes from the deck to the head of a mast, samson post or boom to provide support or prevent movement.

Stealer strake
A single wide plate which replaces two narrow plates in adjacent strakes.

Stern
The after end of a ship.

Stiffener
A flat bar, section or built-up section used to stiffen plating.

Tarpaulin
A tough waterproof canvas-type cloth cover used to cover non-watertight hatch covers.

Tiller
A casting or forging which is keyed to the rudder stock and used to turn the rudder.

Topping wire
A wire used to raise, lower or fix the position of a boom and to support it.

Transverse
A direction at right-angles to the centreline of the ship or an item of structure in this position.

Tripping bracket
A flat bar or plate fitted to a deck girder, stiffener, beam, etc., to reinforce the free edge.

Trunk
A passage extending through one or more decks to provide access or ventilation to a space.

Tunnel
A watertight access passage surrounding the propeller shaft which is fitted on a ship where the machinery space is positioned towards midships.

Tween decks
The upper cargo stowage compartments or the space between any two adjacent decks.

Uptake
A metal casing or large bore piping which carries exhaust gases up through the funnel to the atmosphere.

Web frame
A deep-section built-up frame which provides additional strength to the structure.

Well
A space into which bilge water drains.

Winch
A machine which utilises the winding or unwinding of rope or wire around a barrel for various cargo and mooring duties.

Windlass
A machine used for hoisting and lowering the anchor.

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