Rice contains a considerable amount of water and is liable to sweat. It must be well ventilated and not allowed to become moist or it will start to rot and give off a pungent smell which could affect other rice cargoes in the vicinity. It is also known to give off carbonic acid gas (a weak acid formed when carbon dioxide (CO_2) is dissolved in water).

Ventilators should generally be trimmed back to wind, although matured grain rice will require less ventilation than new grain rice. In any event, a void space between the deck head of the compartment and the surface of the stow should be left bearing in mind the possibility of cargo movement and the necessity to employ shifting boards. Surface ventilation should be ongoing to remove warm air currents rising from the bulk stow.

Prior to loading rice, the compartments should be thoroughly cleaned, bilges sweetened and made sift free. A lime coating is recommended, together with a cement wash. Their condition must be such to pass survey inspection. The hold ceiling should be stain free and covered by a tarpaulin or separation cloth. To this end an adequate supply of matting and separation cloths are to be recommended.

If compartments are only partly filled, then bagged rice with suitable separation cloths may be used to secure the stow. Bags for rice are usually of a breathable man-made, interwoven fabric. A ship loading rice would need a Certificate of Authorization, or alternatively the master would need to show that the vessel can comply with the carriage regulations to the satisfaction of an Maritime and Coastguard Agency (MCA) Surveyor.

Modern loading methods usually employ chutes, while pneumatic suction systems are often engaged for the discharge process. Working capacity of distribution and suction units is up to about 15 000 tonne/h (stowage factor for rice in bags = $1.39\,m^3$/tonne, or bulk stow = $1.20\,m^3$/tonnes). *Note*: See additional reference in Chapter 4.

Bale goods

Various types of goods are carried in bales, either in open stow or containerized. Bales in open stow are normally laid on thick single dunnage of at least 50 mm in depth. Bales are expected to be clean with all bands intact. Any stained or oil marked bales should be rejected at the time of loading. All bales should be protected against ships sweat and the upper level of cargo should be covered with matting or waterproof paper to prevent moisture from the deck head dripping onto the cargo surface.

Examples of bale cargoes:

Carpets – a valuable cargo which must be kept dry. Hooks should not be used. More commonly carried in containers these days.

Cotton/cotton waste – bales of cotton are highly inflammable and stringent fire precautions should be adopted when loading this cargo. A strict no-smoking policy should be observed. If the bales have been in contact with oil or are damp they are liable to the effects of spontaneous combustion. Generally, a dry stowage area is recommended.

Esparto grass – these and products like hay and straw bales are high risk to spontaneous combustion especially if wet and loosely packed. Poorly compressed bales should be rejected. If carried on deck these bales should be covered by tarpaulins, or other protective coverage.

Fibres – such as jute, hemp, sisal, coir, flax or kapok are all easily combustible. A strict no-smoking policy should be observed at all stages of contact. Bales must be kept away from oil and should not be stowed in the same compartment as coal or other inflammable substances or other cargoes liable to spontaneous combustion.

Oakum – this is hemp fibres impregnated with pine tar or pitch. It is highly inflammable and strict no-smoking procedures should be adopted. It is also liable to spontaneous combustion.

Rubber – if packed in bales these give an unstable platform on which to overstow other cargoes, other than more bales of rubber. Crêpe rubber tends to become compressed and sticks to adjacent bales and talcum powder should be dusted over the bales to prevent this stickiness between bales. Polythene sheeting with ventilation holes is also used and is now in more common use for the same purpose. Up-to-date methods tend to wrap the whole bales separately in polythene to eliminate the sticking element.

Tobacco – usually stowed in bales in open stow. It is liable to taint other cargoes and is also susceptible to taint from other cargoes in close proximity. The stowage compartment should be dry and kept well ventilated or there is a risk of mildew forming.

Wood pulp – must be kept dry. If it is allowed to get wet it will swell and could cause serious damage to the steel boundaries of the compartment. Notice metacentre (M) 1051 recommends that care should be taken to ensure that no water is allowed to enter the compartment. To this end all air pipes and ventilators should be sealed against the accidental ingress of water.

Wool – can be shipped in either scoured or unscoured condition. The two types should not be stowed together. Bales should be well dunnaged and provided with good ventilation. Slipe and pie wools are liable to spontaneous combustion and should, if possible, be stowed in accessible parts of the hold.

Loading, stowage and identification of cargo parcels

In order to ensure correct handling and stowage of goods, cargoes tend to be labelled and marked with instructions on the side of respective packages (Figure 3.7). Cargo is shipped all over the globe and not all countries of discharge are English speaking – to this end labels are of a pictorial display. Cargo Officers can monitor from the labelling that instructions are complied with and that stowage

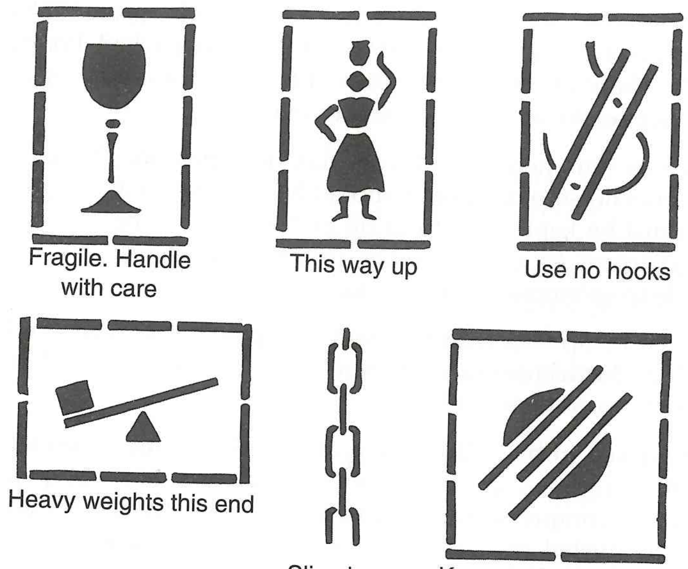


Fig. 3.7 Example labels provide instructions to stevedores for correct stowage practice.

Stowage of wine

Wine was often carried in barrels, and in some cases still is. However, bulk road tankers, and even designated wine carriers, are engaged in the shipment of large quantities of wine in bulk. Where barrels are transported they should be stowed on the side (bilge), with the 'bung' uppermost (Figure 3.8(a)). The stow should not be greater than eight (8) high and the first height level should be laid on a bed to keep the bilge free. 'Quoins', a type of wedge arrangement, are used to support the barrels and prevent them from moving (Figure 3.8(b)).

Barrels are heavy, with a capacity of 36 imperial gallons (164 l) and normally require two men to handle and stow in a fore and aft direction. Modern aluminium casks have, to some extent, replaced the old wooden barrels but some companies still use the old-fashioned wood barrels for their product.

Barrels are given underdeck stowage and would not generally be taken as deck cargo.

Where wine is not shipped in bulk-holding tanks or barrels the more popular method in this day and age is to pre-bottle the commodity and export in cartons usually in a container. Distinct advantages are associated with this method, in that pilferage is reduced with the bottled wine under lock and key. Containers are easily packed and sealed under customs controls. Mixed commodities, like spirits or beer, can also be packed into the same container. Once sealed, transport and shipping via a container terminal is usually trouble free.

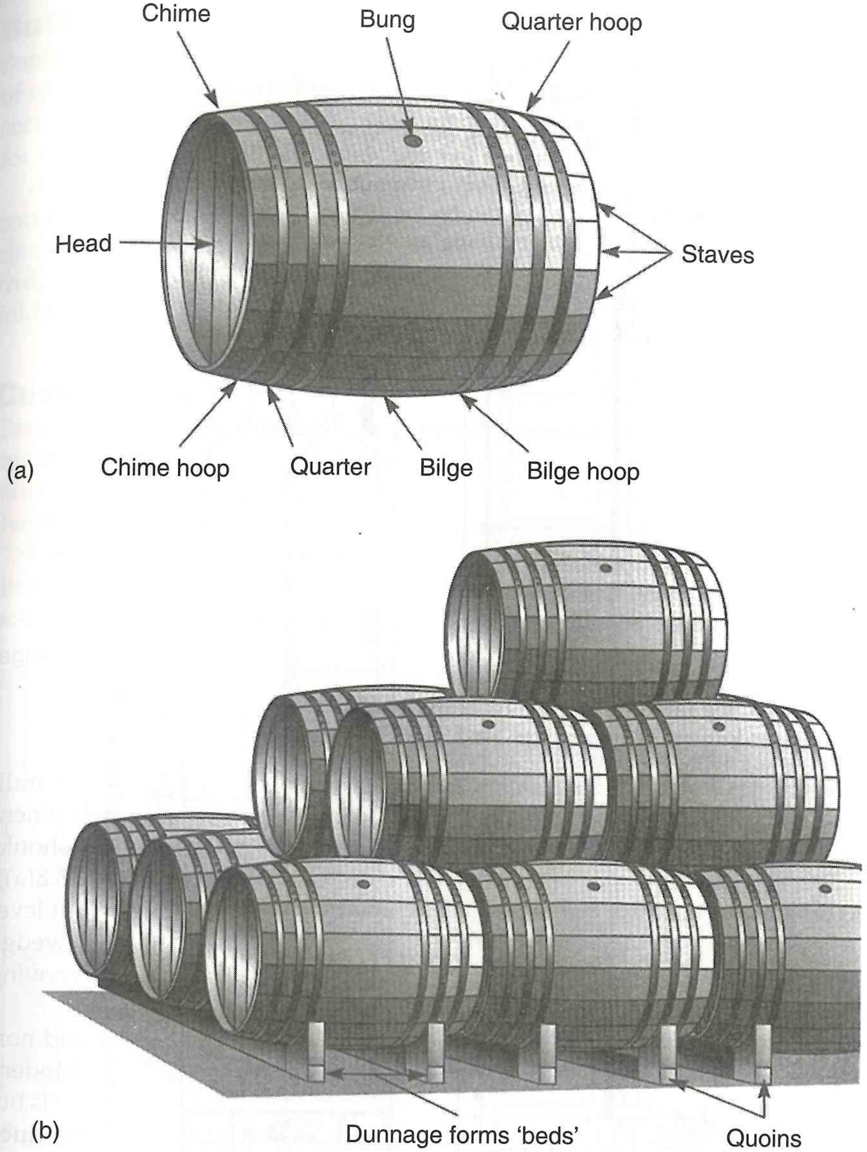


Fig. 3.8 Wine barrels.

Barrels are used more these days to allow wines to mature, rather than as transport vessels. They are awkward to handle and have difficulties in stowage. The art of the 'cooper' is also becoming scarce and if barrels are damaged in transit it becomes expensive to effect repairs.

Occasionally, barrels are still employed but with specialist commodities or shipped from one wine cellar to another where surplus casks are avail-

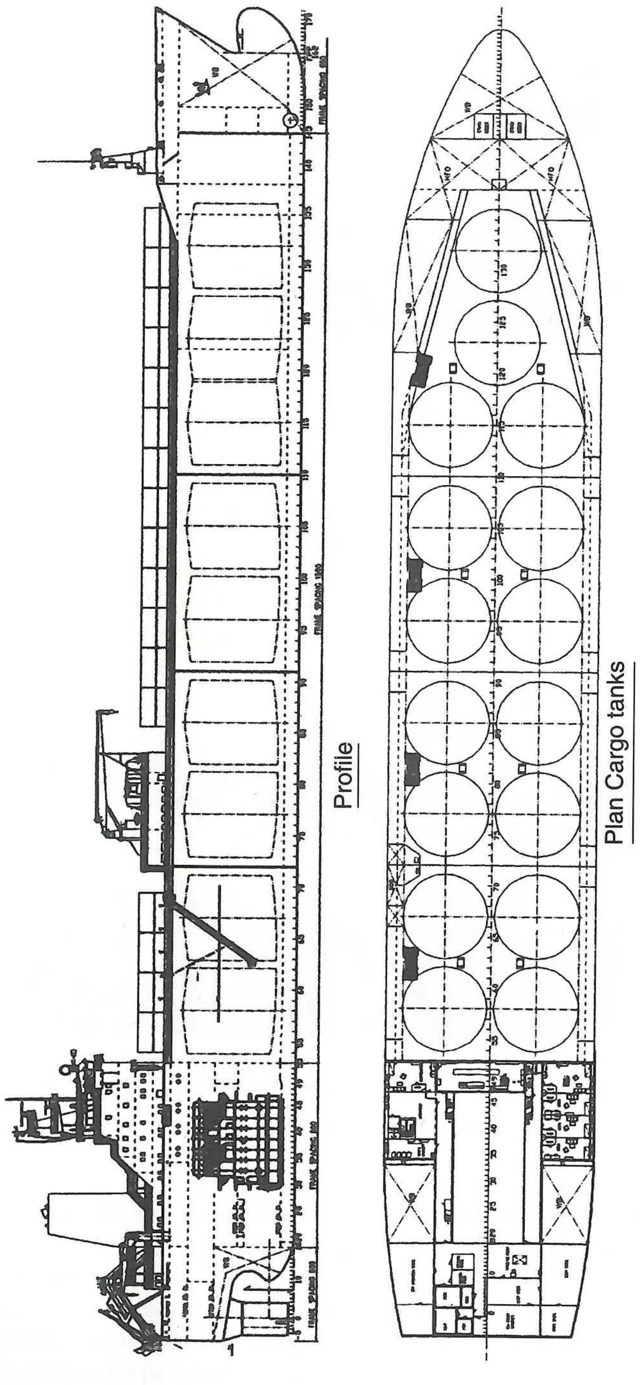


Fig. 3.9 Profile and tank disposition of 'Carlos Fischer'. Reproduced with kind permission from Motor Ship.

Bulk fluid products

Some products like wine and fruit juices have generated the construction of specialized transports, specifically for the carriage. An example of this is seen with the 'Carlos Fischer' fitted with free standing, stainless steel tanks for the purpose of shipping bulk 'orange juice' (Figure 3.9).

The ship is 42 500 dwt (deadweight tonnage), and is engaged in shipping concentrated orange juice from estates in Brazil. It is double hulled but not classed as a tanker, having four holds each with four vertical cylindrical fruit juice tanks. Cargo piping running through the holds is led to manifolds in lockers in the deckhouse.

Case goods

Case goods lend particularly to a general cargo open stow but can be containerized depending on size. Heavy cases should always be given bottom stow with the lighter cases on top. If the contents of the case are pilferable, then they should be loaded into a lock-up stow and tallied in and tallied out.

Slinging of case goods will be directly related to their weight and may be fitted with identified lifting points. Care should be taken that such lifting points are attached to the load and not just to the package (Figure 3.10).

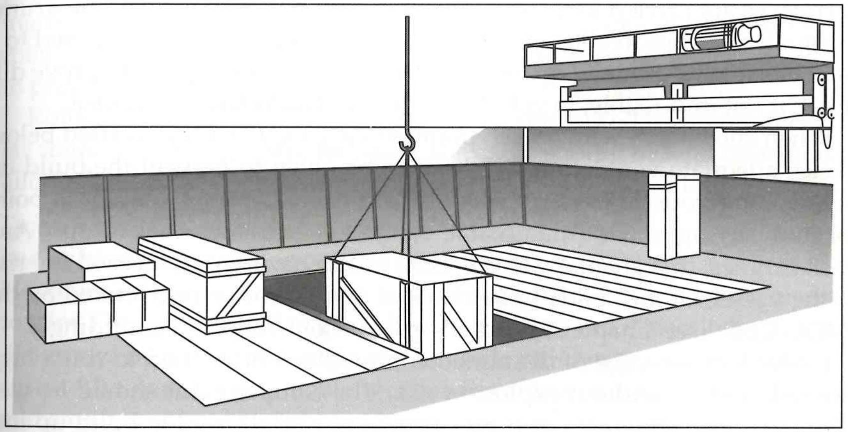


Fig. 3.10 Example of case goods/general cargo being loaded/discharged.

Specific case goods, i.e. glass, may have special stowage requirements. This would probably be marked as 'Fragile' or 'This way up' and require side, end on stowage. Crated cars or boats would expect to be loaded on level ground, and generally other crated goods would be treated as case goods depending on the nature of the contents.

Fork lift truck operations are often employed with the movement and stowage of heavy case goods both in the warehouse, on the quayside and aboard the vessel. However, the use of fork lift trucks inside the hold tends to be restrictive with case goods because they are so bulky. The fork lift truck needs open deck space to allow manoeuvring and as large cases quickly start to fill the manoeuvring space, landing becomes the only method to continue loading.

The loading and carriage of drums

Cargo in drums is not unusual and can be varied by way of chemicals, oils, paints, dyes, even sheep dip. Drums may differ in size, but a 50-gallon drum is probably the most common size for oils and is often used for own ship's stores of lubricating or diesel oil.

They are often taken as deck stow. In such an event, they would be protected by nets or a timber built compound to keep the stow tight, depending on the number of drums carried. Where upper decks are covered, this may necessitate a catwalk being built over the drums in order to provide accessibility to all parts of the vessel when at sea. In any event, drum cargoes are placed on single dunnage and are invariably secured by wire lashings, with or without nets, to prevent movement of the cargo when at sea.

Concern with such cargo may arise with the obvious problem of a leaking drum. If such an occurrence did take place, the action would depend on the contents of the drum, the associated effects on other cargoes, the potential fire risk and the ability to get at the affected drum(s). To this end, where corrosives are carried in large numbers, it may be better to stow the drums in smaller batches to allow accessibility to damaged units, as opposed to a total block stow of many drums together. Such a block stow may prove difficult, if not impossible, to get at the affected drums when in transit.

When substances with a flash point below 23°C (73°F) are carried below decks, adequate ventilation will have to be given to prevent the build up of any dangerous concentrations of inflammable vapours. Low flash point cargoes having a wide flammable range are extremely hazardous. Any such cargoes, that are likely to present a health hazard or increased fire risk to the vessel, should initially be checked against the advice offered by the IMDG Code (see Chapter 9) and any precautions followed accordingly.

Underdeck stowage of drummed commodities often tend to run a high fire risk with or without explosion risk. The compartment should be well ventilated and any gases or fumes should not be allowed to build up into dangerous concentrations. Prudent use of cargo hold fans should be exercised while on the voyage to ensure a continued safe atmosphere within the compartment and a no-smoking policy must be observed at all times.

Casks are manufactured in aluminium and are used extensively for 'beer'. They are comparatively light and may be full or empty. They require a compact stow and are often netted to prevent movement when in open stow.

A cargo of ingots – Copper, lead or tin ingots are all very heavy concentrated cargo parcels and require bottom stow, similar to the iron cargoes of castings, iron billets and long steelwork.

Lighter goods may be stowed on top of ingots but a secure separation

to work on top of the cargo without a dunnage floor. Ingots are often baled and banded, but are sometimes shipped as single-bar elements being floor stacked. Ingots can be considered a valuable cargo and are usually tallied in and tallied out at discharge.

Cable reels – large wooden reels with power cable rove around a central core are carried as general cargo. They are stowed in the upright position, on a firm deck and should be secured against any pitching or rolling of the vessel when in a seaway. They can be quite, large, 3–4 m in diameter, and consequently may be considered as a heavy load, especially if the cable contains a steel construction element.

Designated 'Cable Ships' with telegraph cable tend to load the cable directly into specially constructed cylindrical tanks in specialized cable holds. Such cables should not be confused with the Cable Reels discussed as general cargo.

Paper cargoes – paper may be carried in many forms from waste paper to newsprint. The compartment, in whatever form the paper is to be carried, must be in a dry condition and well ventilated. Newsprint is carried in rolls which are normally stowed on their ends to avoid distortion, preferably on double dunnage.

A ship's steelwork would normally be protected with waterproof paper to prevent ships sweat from damaging the rolls. Hooks should not be used during the loading or discharge periods. On occasions, like in tween decks, the rolls may be stowed on their sides. If this is done, they should be chocked off to prevent friction burns and movement when the vessel is at sea.

Rolls of paper should be sighted as being unmarked by oil or other similar stains on loading. Once on board, the cargo should be kept clean and not allowed to become contaminated by any form of oil or water.

Dried fruits – these include: apricots, currents, dates, figs, prunes, raisins and sultanas. May be shipped in cases, cartons, small boxes or even baskets. However carried, they must be stowed away from cargoes which are liable to taint. Dried fruits tend to give off a strong smell and generally may contain drugs and insects which could contaminate other cargoes, especially foodstuffs. The fruit itself is liable to taint from other strong odorous cargoes and stowage should be kept separate in cool well-ventilated compartments. Tween deck stowage is preferred, but if stowed in lower holds adequate ventilation must be available throughout the course of the voyage. If in open stow, good layers of dunnage are recommended to assist air flow and the cargo should not be overstowed.

Garlic and onions – shipped in bags, cases or crates and these give off a pungent odour and must be stowed clear of other cargoes liable to taint. It is essential that onions and garlic are provided with good ventilation, similar to fresh fruit. Considerable moisture will be given off onions and adequate drainage facilities would be expected.

Fresh fruit – apples, apricots, pears, peaches, grapefruit, grapes, lemons and the proviso being that adequate dunnage is used along with good ventilation. In the event that mechanical ventilation is not used then hatches should be opened (weather permitting). Fruit, especially green fruit, gives off a lot of gas and extreme care should be exercised before entering any compartment stowed with fresh fruit. Following the discharge of fruit the holds should be well aired and deodorized.

Cargo monitoring and tallying

Tallying – all cargoes are tallied on board the vessel and for monitoring the cargo parcels in this manner, specialized 'tally-clerks' are employed. These clerks tend to reflect the shipper's interest, while others so engaged by the ship may represent the owner's or ship's operator's interests. Cargo parcels are not only tallied into the ship but also tallied out at the port of discharge.

Tally counts are important, especially in the case of valuable effects, or short quantities being delivered to the ship. Cargo claims draw on tally information to substantiate quality and quantity as and when disputes evolve between the ship and the shipper, bearing in mind that the ship's personnel are there to protect the shipowner's or Charterer's interest.

Mate's Receipts tend to be the supporting document which denotes the quantity, marks, description and the apparent condition of goods received on board. It is usually signed by the Ship's Chief Officer, hence the name 'Mate's Receipt'.

CARGO shipped on Board "____________________"

In good condition excepting where otherwise stated

Port of Shipment________________ Date____________

Destination ____________ Hatch No________ ex________

NB Ships Tally Clerk to record all visible damage

MARKS	PACKAGES	SEPARATE NUMBERS	TOTAL

Ships tally Clerk

____

It is important that the details of the cargo are correctly stated on the Mate's Receipts as it is from these that the 'Bills of Lading' (B/L) could be prepared. The Bills of Lading are sent to the various consignees, who will in turn present them to the master before the cargo is handed over. The Bills of Lading are the consignee's title to the goods stated and he therefore can expect to receive those goods as described. In the event of the goods not being in the same condition as stated on the B/L, by way of quantity or quality, then the shipper could make a claim against the ship for any discrepancy.

Ship's Officers should bear in mind that they are temporary custodians of goods which belong to a third party. As such, they must endeavour to keep them in the same condition as that in which they were received aboard the vessel. As far as possible damaged cargo or damaged packages should be rejected for shipping.

Cargo sweat and ventilation

A great number of cargo claims are made for merchandise which has been damaged in transit. Much of this damage is caused by either 'ships sweat' or 'cargo sweat' and could be effectively reduced by prudent ventilation of cargo spaces.

Sweat is formed when water vapour in the air condenses out into water droplets once the air is cooled below its dew point. The water droplets may be deposited onto the ship's structure or onto the cargo. In the former, it is known as 'ships sweat' and this may run or subsequently drip onto the cargo. When the water droplets form on cargo this is known as 'cargo sweat' and will occur when the temperature of the cargo is cold and the incoming air is warm.

To avoid sweat and its damaging effects it is imperative that 'wet and dry' bulb temperatures of the air entering and the air contained within the cargo compartment, are taken at frequent intervals. If the temperatures of the external air is less than the dew point of the air already inside the space, sweating could well occur. Such conditions give rise to 'ships sweat' and is commonly found on voyages from warm climates towards colder destinations. Similarly, if the temperature of the air in the cargo compartment (or the cargo) is lower than the dew point of incoming air, sweating could again occur, giving rise to 'cargo sweat'. This would be expected on voyages from cold places towards destinations in warmer climates.

If cargo sweat is being experienced or likely to occur, ventilation from the outside air should be stopped until more favourable conditions are obtained. However, it should be noted that indiscriminate ventilation often does more harm than no ventilation whatsoever. It is also of concern that variation in the angles of ventilators away from the wind can cause very different rates of air flow within the compartment. The angle at which the ship's course makes with the wind also affects the general flow of air to cargo compartments. In general, the greatest air flow occurs when the lee ventilators are trimmed on the wind and the weather ventilators are trimmed away from the wind. This is known as through ventilation (Figure 3.12).

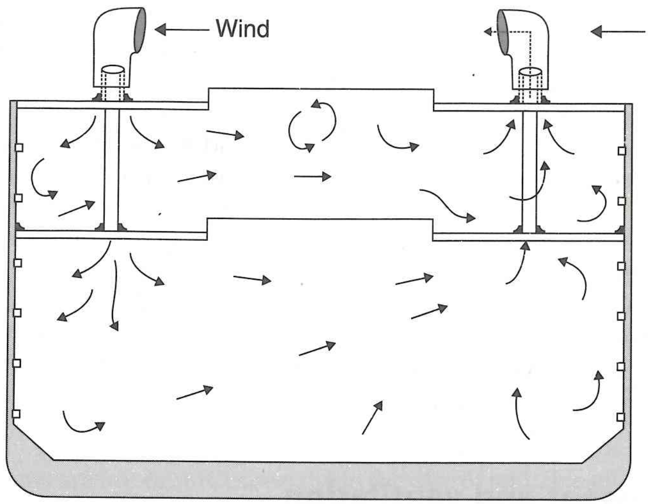


Fig. 3.12 Showing air circulation with lee ventilators on the wind and weather vents off. This is through ventilation.

Forced ventilation – if the dew point temperature in the cargo compartment can be retained below the temperature of the ships structure, i.e. decks, sides, bulkheads and the cargo, there would be no risk of sweat forming. Such a condition cannot always be achieved without some form of mechanical (forced) ventilation from fans or blowers.

There are several excellent systems on the commercial market which have the ability to circulate and dry the air inside the cargo holds. Systems vary but often employ 'baffle' plates fitted in the hold and tween decks so that air can be prevented from entering from the outside when conditions are unfavourable. Systems re-circulating the compartment's air can also operate in conjunction with dehumidifying equipment to achieve satisfactory conditions pertinent to relevant cargo.

Cargo battens (spar ceiling) – the purpose of the wooden cargo battens, which can be fitted horizontally or vertically, is to keep the cargo off the ship's inner steel hull. This arrangement produces an air gap of about 230 mm between the steelwork and the cargo surface, and subsequently reduces the risk of cargo sweat damaging cargo parcels. It is normal practice with some bulk cargoes, when carried in holds fitted with spar ceiling, to remove the wood battens to reduce the damage incurred to the wood, prior to loading, e.g. coal (Figure 3.13).

Dunnage – timber slats of a thickness of about 35/40 mm which are ordered in bundles by the Ship's Chief Officer. The purpose of dunnage, which can be laid either singularly or in a criss-cross double dunnage pattern, is to provide an air gap to the underside of the cargo. This allows ventilation around all sides of the cargo stow. This is again to effectively reduce the risk

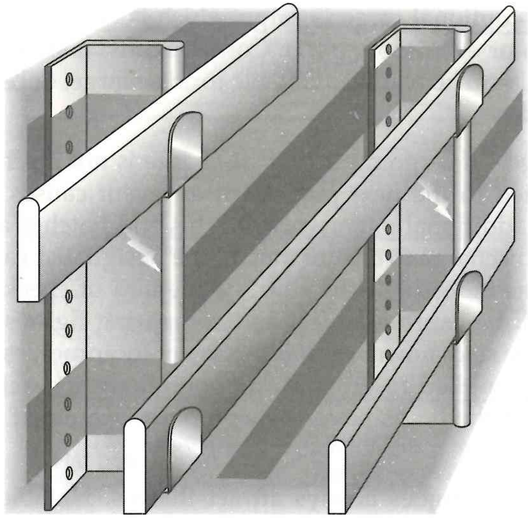


Fig. 3.13 Cargo battens fitted horizontally to allow separation of the cargo from the ship's inner steel hull.

of sweat damage to cargo. Dunnage should be in a clean condition and not oily or greasy as this could cause contamination to sensitive cargoes.

Tank top ceiling – a wood sheathing which covers the steelwork of the tank top, in way of the hatchway in the lower hold. This timber flooring not only protects the tank tops but also lends to a non-skid surface in the hold. It generally assists drainage of any moisture in the space and can be used in conjunction with a single-dunnage layer.

Contamination – cargoes which taint easily, e.g. tea, flour, tobacco, etc. should be kept well away from strong smelling cargoes. If a pungent cargo has been carried previously, i.e. cloves or cinnamon for example, the compartment should be deodorized before loading the next cargo.

Dirty cargoes should never be carried in the same compartment as clean cargoes. A general comparison of dirty cargoes would include such commodities as oils, paints or animal products, whereas clean cargoes would cover the likes of foodstuffs or fabrics. Obviously some notable exceptions in each of the two classes are to be found.

Separation of cargoes – it is often a requirement when separate parcels of the same cargo are carried together that a degree of separation between the units is essential. Depending on the type of goods being shipped will reflect the type of separation method employed. Examples of separation materials include colour wash, tarpaulins, burlap, paper sheeting, dunnage, chalk marks, rope yarns or polythene sheets.

The idea of separation is to ensure that the cargo parcels, although maybe looking the same, are not allowed to become inadvertently mixed.

Optional cargo – optional cargo is cargo which is destined for discharge at either one, two or even more ports. Consequently, it should be stowed in such a position as to be readily available for discharge, once the designated port is declared.

Overcarried cargo – if cargo meant for discharge is not discharged it is said to be overcarried to the next port. Such an event causes inconvenience, extra cost and additional paperwork. To this end hatches are searched on completion of discharge to ensure that all the designated cargo for the port of discharge has indeed left the ship – a method of checking against the cargo plan and the cargo manifest and comparing figures with the tally-clerks. It must be said, however, that this is not foolproof, especially if pressures are being applied to finish cargo operations and sail, and possibly departing before the holds have been properly examined for overcarried cargo pieces.

Pilferage – certain cargoes always attract thieves. Notable items include spirits, beer, tobacco or high value small items. To reduce losses such cargoes should be tallied in and tallied out. Lock-up stow should be provided throughout the voyage from the onset of loading to the time of discharge. Shore watchmen and security personnel should be used whenever it is practical and good watch-keeping practice should be the order of the day.

Deep tank use

Many vessels are fitted with 'deep tanks' – employed as ballast tanks or for the carriage of specialized liquid cargoes such as vegetable oils – i.e. coconut oil, bean oil, cotton seed oil, linseed oil, palm oil or mineral oils. Other cargoes include 'tallow' or bulk commodities like grain, molasses or latex.

The specialization of such cargoes often require rigid temperature control of the cargo and to this end most cargo deep tanks are fitted with 'heating coils' which may or may not be blanked off as the circumstances dictate (Figure 3.14).

> ***Note:*** *Some vessels with a shaft tunnel may be fitted with additional deep tanks aft, in a position either side of the shaft tunnel, but these are not common.*

Preparation of deep tanks

The need for absolute cleanliness with deep tanks is paramount and Cargo Officers are advised that they are virtually always subject to supervision and survey prior to loading example cargoes. Claims for contamination of these cargoes are high and meticulous cleaning of the tank itself and the pipelines employed for loading and discharging must be a matter of course.

> ***Note:*** *All precautions for the entry into an enclosed space must be taken prior to carrying out maintenance inside 'deep tanks' under a permit to work scheme.*

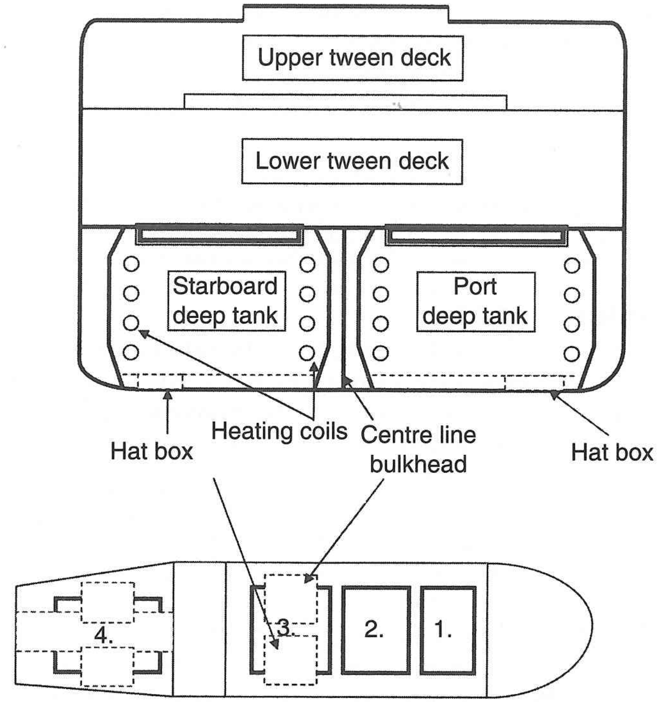


Fig. 3.14 Deep tank storage.

To enable the Classification Surveyor to certify that the tank has water-tight integrity and is clean, Chief Officers should, depending on the previous cargo, ensure that:

- After the carriage of a general cargo, the tank is swept down completely and any waste removed.
- In the event of a liquid cargo (assuming of a non-hazardous nature), puddle any residual fluids to the suction and allow the tank to dry.
- If the tank is uncoated (they are often coated in epoxy covering), the bulkhead's decks and deck head should be inspected for rust spots. These should be scraped and wire brushed, and all traces of corrosion removed.
- Heating coils should be rigged and tested. These coils may be 'side coils' or 'bottom coils', or a combination of both.
- Hat boxes should be cleaned out and the suctions should be tested.
- The tank should be filled with clean ballast and the tank lid pressure should be tested (tanks are to be tested to a head of water equal to the maximum to which the tank will be subjected but not less than 2.44 m above the crown of the tank).
- The tank should be emptied to just above the heating coils, a cleansing agent added and the residual water heated by means of the coils. A wash down using a hose and submersible pump then to be carried out.

- After cleaning, the heating element should be turned off and the tank sluiced down with fresh water, pumped dry and allowed to dry, with any residual puddles being mopped up.
- Finally, bilge suctions need to be cleaned and blanked off.

> ***Note:*** *Personnel so involved should be provided with protective clothing and footwear, together with goggle eye protection. Breathing apparatus may also be a requirement. A risk assessment would be carried out prior to commencing the above task.*

Deep tank cargoes

Vegetable oils – when shipped in bulk, the tank must be thoroughly cleaned and all traces of previous cargoes must be removed. Tank suctions will be blanked off, and the overall condition will be inspected by a Cargo Surveyor. The tank itself would be tested for oil tightness prior to loading. Heating coils will probably be in operation depending on the required shipping temperature. Some oils solidify at 0°C, others like palm oil or palm nut oil, solidify at between 32°C and 39°C, cotton seed oil and kapok seed oil solidify at about 10–13°C. Chief Officers could expect to be supplied with relevant shipping criteria for the oil.

Care must be taken that the heating is not too fierce or applied too quickly as the cargo could scorch. Such an occurrence would be noticeable by some discolouration of the oil, which could result in a cargo claim being filed.

Contamination is avoided by use of shoreside cargo pumps when discharging, while monitoring on passage is conducted by taking ullages and temperatures at least twice per day for oils kept in the liquid state.

Following discharge of the cargo, the tank would probably be steam cleaned and washed with a caustic soda type solution to ensure cleanliness.

Latex – is the 'sap' from rubber trees which rapidly solidifies when exposed to air. It is retained in liquid form by added chemicals, usually ammonia, and shipped in bulk. *Note*: Ammonia attacks brass and copper metalwork and latex tanks should not have such metals as part of their construction.

Prior to loading latex, the tank would be tested and inspected to be thoroughly clean. All steelwork would be coated with hot paraffin wax. The heating coils would be removed as they are not needed for the carriage. Ventilators, air pipes and sounding pipes are all sealed to prevent ammonia loss due to evaporation. Fire extinguishing pipes if fitted should also be plugged. Gas relief valves are fitted to ease any pressure build up inside the tank.

Discharge of the cargo is carried out by shoreside pumps and the tank would then be washed down with water to remove all traces of ammonia. The wax coating is often left in place unless the tank is to be used immediately for another cargo.

Molasses – a syrup obtained from the manufacturing process of sugar. Carried in deep tanks similar to vegetable oils, with heating coils operational to retain the cargo in a liquid state. It is discharged by shoreside pumps and the tanks would be scrubbed and washed down with plenty of water as soon

after discharge as is practical. Most contamination claims develop from dirty pipelines. *Note*: Specially designated vessels are employed for the carriage of molasses so the use of deep tanks has diminished with this type of cargo.

Rancidity

The possibility of products turning rancid is always present, especially with fatty oils and fats which contain strong flavours and odours. These elements become developed by being exposed to light, moisture and air, and move towards a condition we know as rancidity. A by-product following excessive exposure and subsequent chemical reaction is the production of fatty acids. These then decompose and form other compounds which are dramatically increased by temperature rise. Such action means that less refined, pure oil is recoverable.

> ***Note:*** *Fats are considered as products which are solid at ordinary temperatures, e.g. 15°C. Fatty oils are those which are liquid at that temperature. The difference between fats and fatty oils is that fatty oils are more chemically reactive than fats.*

Hides – may be shipped in either a wet or dry condition, either in bundles or in casks, or even loose. They are often carried in deep tanks, usually because there is not enough of them to fill a tween deck or lower hold space. Another factor that is against stowage in a tween deck is that wet hides require adequate drainage which would be difficult to achieve in exposed stow. Pickling and/or brine fluid can expect to find its way to the bilges which will necessitate pumping probably twice daily at the beginning of a voyage with hides in the cargo.

> ***Handling precautions*** – *Hides must only be handled with gloves as there is a high risk of contracting anthrax which could prove fatal. Neither should stevedores use hooks in the handling, because of damage to the product. In the case of dry hides these are often brittle and any person being scratched or cut should receive immediate hospital treatment.*

The stowage of hides must be away from dry goods and ironwork. They have a pungent odour and should be stowed well away from other goods that are liable to spoil. They should not be overstowed.

Ballasting and Ballast Management

As cargo is loaded it is general practice for most types of vessels to de-ballast. Some tanks are retained for the purpose of trimming the ship and adjusting the stability conditions, but overall if the ballast was kept on board, the ship could well be seen to be overloaded.

In future it is expected that participating governments to the International Maritime Organization (IMO) convention will have to restrict discharge of ballast water because of the impurities it may contain. To this end a Ballast Management (Record) Book would need to be kept, indicating which tanks are filled/emptied, the position of the Ballast Movement and details of quantities and any treatment, e.g. ultraviolet light which the water may be submitted to.

Stability

When loading/discharging the cargo, due regard must be taken of the ship's condition of stability at every stage and position of the voyage. A reasonable 'GM' must be appropriate throughout the passage and loadline zones must not be infringed. Most modern vessels would engage the flexibility of a 'loadicator' (computer program) for working relevant stability criteria. Associated software of this nature would also provide bending and shear force stresses incurred and take account of total weights of stores, bunkers, fresh water and ballast contents to provide example conditions.

> **Note:** *Free surface moments have a negative effect on the ship's GM, especially when loading or discharging heavy-lift cargoes which may cause the vessel to heel. To this end slack tanks should be avoided if at all possible, when working cargo (see also examples in Chapter 10).*

Loadlines

Ship's Cargo Officers must take care that the vessel is not overloaded beyond the appropriate loadline. Overloading endangers the safety of the vessel and would incur the risk of a heavy fine against the Ship's Master. When loading certain cargoes, especially bulk cargoes like bulk ore and oil the vessel is liable to become hogged or more probably adopt a sagged position. If the vessel is sagging the apparent mean draught will be less than the actual mean draught. This situation does not permit overloading.

The various loadlines (Figure 3.15) are shown and they are assigned to the vessel following a loadline survey by an Assigning Authority, e.g. Lloyds Register.

'S' The summer loadline mark is calculated from the loadline rules and is dependent on many factors including the ship's length, type of vessel and the number of superstructures, the amount of sheer, minimum bow height and so on.

'W' The Winter mark is 1/48th of the summer load draught below 'S'.

'T' The Tropical mark is 1/48th of the summer load draught above 'S'.

'F' The Fresh mark is an equal amount of $\Delta/4T$ millimetres above 'S' where Δ represents the displacement in metric tonnes at the summer load draught and T represents the metric tonnes per centimetre immersion at the above. In any case where the displacement cannot be ascertained, F is the same level as T.

TF The Tropical Fresh mark, relative to 'T' is found in the same manner as that of 'F' relative to 'S'.

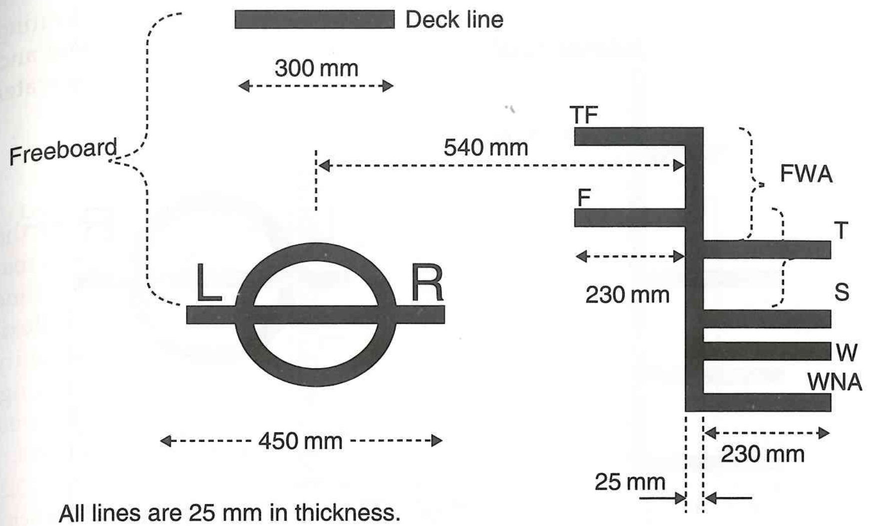


Fig. 3.15 Loadline marks. Should the ship carry a lumber loadline this would be positioned aft of the Plimsoll Mark and identity marks be prefixed with an 'L', e.g. LTF = Lumber Tropical Fresh. LR: Lloyds Register; TF: Tropical Fresh; T: tropical; F: Fresh; S: Summer; W: Winter; WNA: Winter North Atlantic; FWA: Fresh Water Allowance.

WNA The Winter North Atlantic mark is employed by vessels not exceeding 100 m in length when in certain areas of the North Atlantic Ocean, during the winter period. When it is assigned it is positioned 50 mm below the Winter 'W' mark.

Timber loadlines

Certain vessels are assigned Timber Freeboards when they meet certain additional conditions. One of these conditions must be that the vessel must have a forecastle of at least 0.07 extent of the ship's length and of not less than a standard height (1.8 m for a vessel 75 m long or less in length and 2.3 m for a vessel 125 m or more in length, with intermediate heights for intermediate lengths) (Figure 3.16). A poop deck or raised quarter deck is also required if the length of the vessel is less than 100 m. All lines are of 25 mm wide.

LS is derived from the appropriate tables contained in the loadline rules.

LW is one-thirty-sixth (1/36th) of the summer timber load draught below LS.

LT is one-forty-eighth (1/48th) of the summer timber load draught above LS.

LF and Lumber Tropical Fresh (LTF)are both calculated in a similar way to F and TF except that the displacement used in the formula is that of the vessel at her summer timber load draught. If this cannot be ascertained these marks will be one-forty-eighth (1/48th) of LS draught above LS and LT respectively. LWNA is at the same level as the WNA mark.

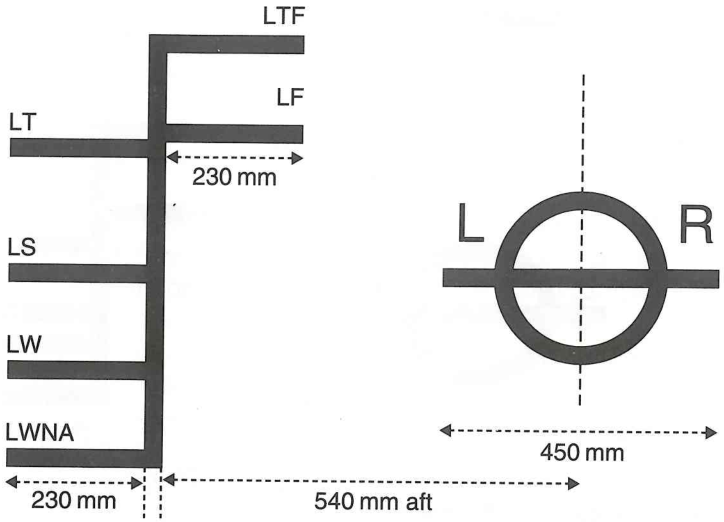


Fig. 3.16 Timber loadlines. The letters denoting the assigning authority LR should be approximately 115 mm in height and 75 mm in width.

> *Ships with timber loadlines and carrying timber deck cargo in accordance with the M.S. (Loadlines) (Deck Cargo) Regulations 1989 must observe the applicable loadline that she would use if she were not marked with timber loadlines, i.e. Lumber Summer (LS) in the Summer Zone. However, if the timber is not carried in accord with the regulations the ordinary loadlines should be employed.*
> ***Note:** The Dock Water Allowance (DWA) would be applied for vessels which are loading in waters other than sea water of 1.025.*

Deadweight scale

Once cargo has been loaded the ship's draughts would normally be ascertained and it would be the Chief Officer's practice to employ the deadweight scale (part of the ship's stability documentation) to ascertain the ship's final displacement. The known figures of fuel, stores and fresh water can then be applied to provide a check against total cargo loaded from the scaled deadweight figure (Figure 3.17).

Offence to overload

Cargo Officers should be aware that it is an offence to overload a vessel beyond her legal marks and attempt to proceed to sea. The owner, or master, will be liable on summary conviction to a fine not exceeding the Statutory maximum of (£5000) or on conviction on indictment, to an unlimited fine. The ship may also be detained until it has been surveyed and marked. The contravention will also carry, in addition to the stated fine, a further £1000 per centimetre of the amount of overload.

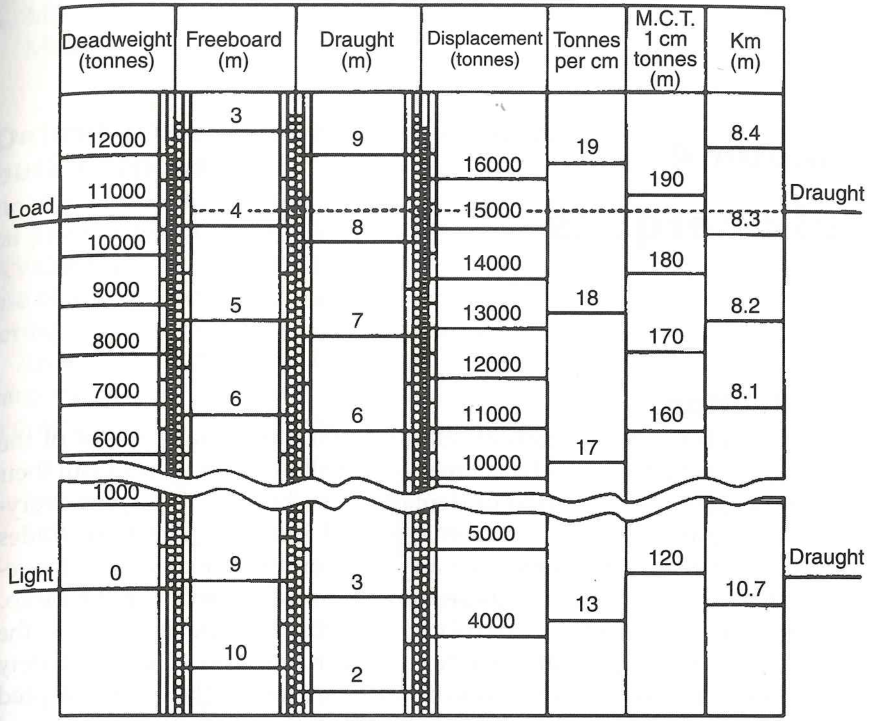


Fig. 3.17 Deadweight scales.

Restrictions to loading

The Loadline Regulations provide various zones around the world's ocean/sea areas. These zones reflect permanent and seasonal areas which are depicted on a chart which accompanies the regulations. There are three permanent zones, namely a *summer zone in each hemisphere* of the globe and a *tropical zone* across the equatorial belt – while the ship is passing through these zones the appropriate loadline would be used.

A ship cannot load deeper than her summer loadline in the summer zone, neither can a vessel load deeper than her tropical mark when in the tropical zone. There are five (5) 'Winter Seasonal Areas', usually found confined by land masses and include: the Black Sea, the Baltic Sea, the Mediterranean, the Sea of Japan and the special 'Winter' area in the North Atlantic, applicable for ships 100 m or less in length.

Cargo Officers will frequently find themselves loading in dock water of less density than sea water and such a situation would warrant use of the DWA formula which would permit a vessel to load beyond her marks, knowing that the vessel will rise to the permitted loadline once entering the sea water of the respective zone or seasonal area.

Chapter 4
Bulk cargoes

Introduction

The demand for raw materials continues to sustain a major sector of the shipping industry. Bulk products are shipped all over the world from their point of origin to that position of demand. The 'bulkers' transport everything from grain and coal to chemicals and iron ore. The bulk trades involve vast tonnage movement of any one commodity and such movement can present its own hazards and problems associated with the cargo.

Designs of ship's holds have evolved to maximize capacity while at the same time generating a safer method of carriage. The Maritime Safety Committee of the International Maritime Organization (IMO) has adopted amendments to Chapter XII Safety of Life at Sea (SOLAS) (Additional Safety Measures for Bulk Carriers) which came into force in July 2004, affecting all bulk carriers regardless of their date of construction. These amendments include the fitting of dry space, water level detectors and alarm monitors, as well as means of draining and pumping, and dry space bilges located forward of the 'collision bulkhead'.

Further recommendations for bulk carriers over 150 m in length to require 'double-hulls' has been agreed (but not yet ratified). Effectively, the double-hull, bulk carrier would seem to be the future for bulk cargoes. How these cargoes are loaded, managed and discharged in the types of vessels involved is as follows.

References for bulk cargoes

International Code for the Safe Carriage of Grain in Bulk.
International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (IBC Code).
Code of Practice for the Safe Loading and Unloading of Bulk Cargoes (BLU Code).
Code of Safe Practice for Solid Bulk Cargoes (BC Code).
Resolutions of the 1977 SOLAS Conference, regarding the Inspection and Surveys of Bulk Carrier vessels.
MSC/Circ. 908 (June 1999), Appendix C, Uniform Method of Measurement of the Density of Bulk Cargoes.

- MSC/Circ. 646 (June 1994) Recommendations for the Fitting of Hull Stress Monitoring Systems ((also MGN) 108 M).

Definitions and terminology employed with bulk cargoes

Angle of repose – the natural angle between the cone slope and the horizontal plane when bulk cargo is emptied onto this plane in ideal conditions. A value is quoted for specific types of cargoes, results being obtained from use of a 'tilting box'. The angle of repose value is used as a means of registering the likelihood of a cargo shift during the voyage.

An angle of repose of 35° is taken as being the dividing line for bulk cargoes of lesser or greater shifting hazard and cargoes having angles of repose of more or less than the figure are considered separately (Figure 4.1).

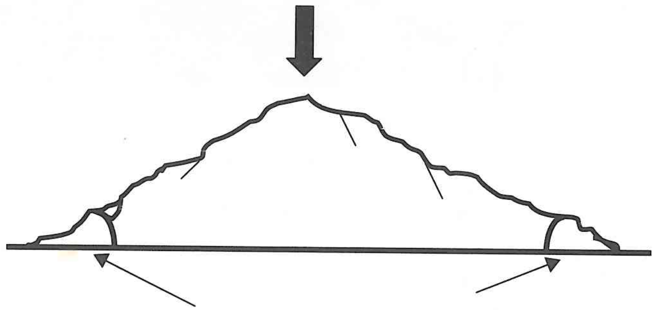


Fig. 4.1 Angle of repose.

Bulk density – is the weight of solids, air and water per unit volume. It includes the moisture of the cargo and the voids whether filled with air or water.

Cargoes which may liquefy – means cargoes which are subject to moisture migration and subsequent liquefaction if shipped with a moisture content in excess of the transportable moisture limit.

Combination carriers (OBO or O/O) – a ship whose design is similar to a conventional bulk carrier but is equipped with pipelines, pumps and inert gas plant so as to enable the carriage of oil cargoes in designated spaces.

Concentrates – these are the materials that have been derived from a natural ore by physical or chemical refinement, or purification processes. They are usually in small granular or powder form (Figure 4.2).

Conveyor system – means the entire system for delivering cargo from the shore stockpile or receiving point to the ship.

Flow moisture point – is that percentage of moisture content when a flow

Fig. 4.2 An overhead view of a general cargo vessel engaged in the discharge of concentrates by means of a free-standing crane using a mechanical grab. The ships own deck cranes are turned outboard to allow easy access for the shoreside crane operation.

Flow state – is a state which occurs when a mass of granular material is saturated with liquid to such an extent that it loses its internal shear strength and behaves as if the whole mass was in liquid form.

Incompatible materials – are those materials which may react dangerously when mixed and are subject to recommendations for segregation.

Moisture content – is that percentage proportion of the total mass which is water, ice or other liquid.

Moisture migration – is the movement of moisture contained in the bulk stow, when as a result of settling and consolidation, in conjunction with vibration and the ship's movement, water is progressively displaced. Part or all of the bulk cargo may develop a flow state.

Pour – means the quantity of cargo poured through one hatch opening as one step in the loading plan, i.e. from the time the spout is positioned over a hatch opening until it is moved to another hatch opening.

Transportable moisture limit – the maximum moisture content of a cargo that may liquefy at a level which is considered safe for carriage in ships other than those ships which, because of design features of specialized fittings, carry cargo with a moisture content over and above this limit.

Trimming – a manual or mechanically achieved adjustment to the surface level of the form/shape of a bulk stow in a cargo space. It may consist of altering the distribution or changing the surface angle to the point, perhaps of levelling some or all of the cargo, following loading.

Code of Safe Working Practice for Bulk Cargoes

(now known as the Bulk Cargo (BC) Code)

The IMO have produced several editions of the code since its conception in 1965. It is meant as a guide and recommendation to governments and shipowners for the carriage of bulk cargoes of various types.

Recommendations are made about the stowage of the cargoes and include suggested maximum weights to be allocated to lower holds as found from the formula:

$$0.9 \times LBD$$

where L represents the length of the lower hold; B represents the average breadth of the lower hold and D represents the ships summer load draught.

The height of the cargo pile peak should not exceed:

$$1.1 \times D \times SF\ (m^3/\text{tonnes})\ \text{metres}$$

where SF represents stowage factor.

Legislative, unified requirements (UR) for bulk carriers

Water ingress alarms – are required under SOLAS XII Regulation 12. Such alarms must be fitted to all cargo holds and be audible and visual alarms to the navigation bridge.

Existing bulk carriers are also required to have, in addition to the water level alarms stated above, permanent access for close-up inspection and the use of green sea loads on deck for the design of hatches and deck fittings. Such measures are expected to ensure that a well-maintained single-hull bulk carrier will remain satisfactory for the remainder of its lifetime.

> ***New bulk carriers** – The 2004 Design and Equipment meeting of the MSC confirmed the requirement that all bulk carriers would be of 'double-hull' construction (May 2004). **Note:** The distance between the inner and outer hulls being 1000 mm. (Consultation is still ongoing).*

They will probably also require: harmonized class notation and standard design-loading conditions together with 'double-side shell', water ingress alarms to cargo holds and forward spaces; increased strength and integrity for the foredeck fittings; free fall lifeboats and immersion suits for all crew members (Figures 4.4 and 4.5).

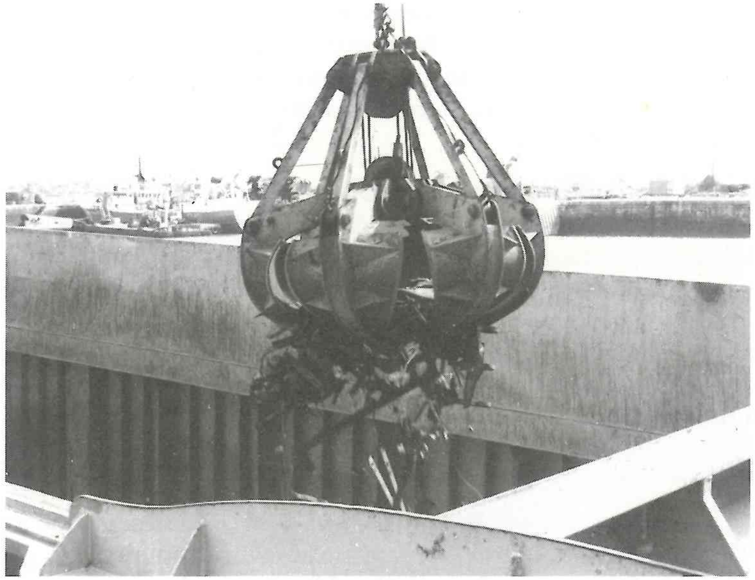


Fig. 4.3 Working bulk cargoes. Mechanical grabs discharging 'scrap metal' from the cargo hold of a small bulk carrier. The single hull construction shows the athwartships, side framing, positioned vertically below the hatch coaming.

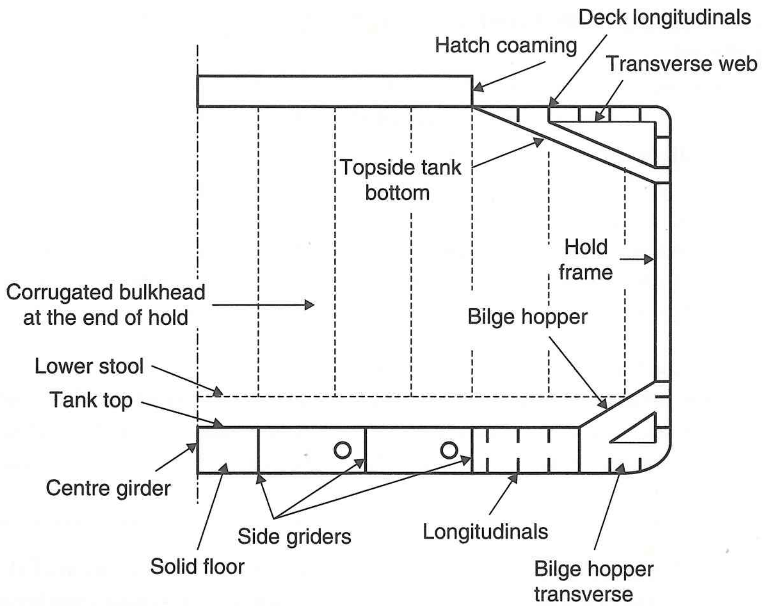


Fig. 4.4 Bulk carrier construction. *Note*: Framing on bulk carriers is designed as a longitudinal system in topside and double bottom tanks and as a transverse system at the cargo hold, side shell position.

Structural changes will also incorporate the permanent means of access for close-up inspection, an amendment to the loadline which will allow the building of stronger and more robust vessels but reduce deadweight capacity by approximate estimates of between 0.5% and 1.5%, depending on size.

Structural standards – as per SOLAS Chapter XII, applying to single-hull side skin bulk carriers, will also apply to new double-hull, bulk carriers.

Additional equipment

At the time of writing, drafted amendments to SOLAS, Chapter XII/II, propose that new bulk carriers over 150 m in length and below shall be fitted with loading instrumentation which provides information on the ship's stability.

Water ingress alarms – are required for vessels with a single cargo hold. The requirement to fit water level detectors in the lowest part of the cargo space is applicable to bulk carriers less than 80 m in length or 100 m in length if built before 1998, to take effect from the first renewal or intermediate survey after July 2004. The alarms will be audible and visual to the navigational bridge and will monitor cargo spaces and other spaces forward of the collision bulkhead. This regulation does not apply to vessels with double sides up to the freeboard deck.

Additional reference

S.I. 1999 M.S. (Additional Safety Measures for Bulk Carriers) Regulations 1999, and MGN 144 (M).

Future builds – double-hulls, bulk carrier construction

The double-hull types have inherent strength that allows flexible-loading patterns, which will increase the capacity for heavy load density cargoes like steel coils. The design dispenses with exposed side frames in the holds and presents a flush side and hold ceiling for cargoes. Such flush features have distinct advantages for hold cleaning and cargo working options with bulk commodities (Figures 4.5 and 4.6).

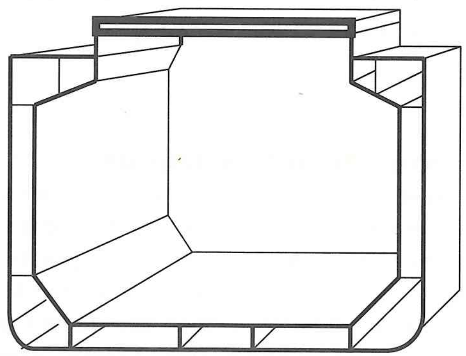


Fig. 4.5 Diamond 53 design – complete double hull in way of cargo holds.

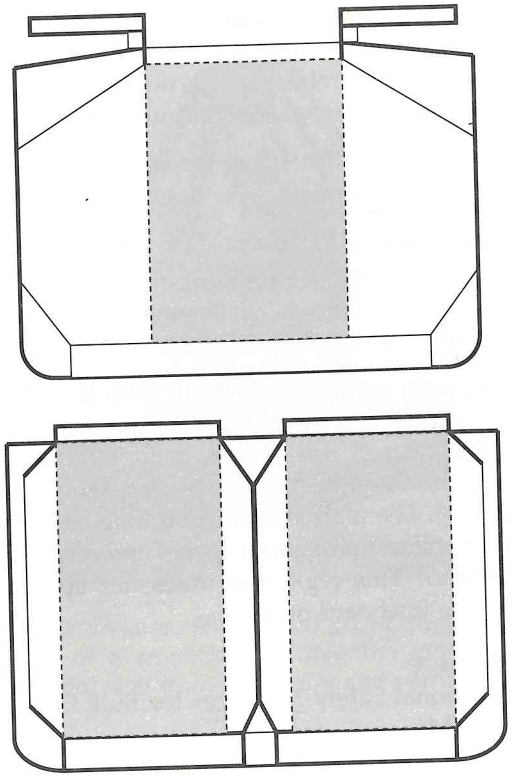


Fig. 4.6 Bulk carrier designs and hatch coverings. (a) Conventional design (twin side moving hatch covers). (b) OJ Libaek's Optimum 2000 (capesize) bulk carrier design (twin hatch covers).

The double design also provides a perceived safer protection against water ingress and is therefore seen as being more environmentally friendly in comparison with the single-hull types. Tank arrangements permit a large water ballast capacity, in both double bottoms and side tanks, eliminating the need to input ballast into cargo spaces, in the event of heavy weather.

Hold preparation for bulk cargoes

Bulk cargoes are generally loaded in designated 'bulk carrier' vessels, but they can be equally transported in general cargo ship's alongside other commodities. However, in such circumstances, specific stowage criteria and hold preparation would probably be a requirement. In virtually every case, except where perhaps the same commodity from the previous voyage is being carried, the cargo holds would need to be thoroughly cleaned and

Designated 'bulk carrier'

1. The holds would be swept down and cleared of any residuals from the previous cargo.
2. All rubbish and waste matter must be removed from the cargo space, before loading of the next cargo can commence.
3. The hold bilge system would need to be inspected and checked to ensure that:
   - the bilge suctions are operational;
   - the bilge bays are clean and smelling sweet (not liable to cause cargo taint).
4. All hold lighting arrangements, together with relevant fittings, would be inspected and seen to be in good order.
5. The space, depending on the nature of the previous cargo and the nature of the next cargo to be carried, would probably require to be washed down with a salt water wash.

> ***Note:*** *Following a wash down, the space would be expected to be allowed to dry out. Special commodities, like foodstuffs, may require the cargo spaces to be surveyed prior to permission being granted to load the ship's cargo.*

Bulk cargoes

Grain

Grain is defined in the IMO Grain Rules as: wheat, maize (corn), rye, oats, barley, rice, pulses or seeds, and whether processed or not, which, when carried in bulk, has a behaviour characteristic similar to grain in that it is liable to shift transversely across a cargo space of a ship, subject to the normal sea-going motion.

> **Applicable to the Grain Rules**
> The following terms mean:
>
> ***Filled*** *– when applied to a cargo space means that the space is filled and trimmed to feed as much grain into the space as possible, when trimming has taken place under the decks and hatch covers, etc.*
>
> ***Partly filled*** *– is taken to mean that level of bulk material which is less than 'filled'. The cargo would always be trimmed level with the ship in an upright condition. Note: A ship may be limited in the number of 'partly filled' spaces that it may be allowed.*

Grain must be carried in accordance with the requirements of the fore-mentioned Grain Rules which consist of three parts, namely 'A', 'B' and 'C'.

Part A Contains 13 rules which refer, among other items, to definitions, trimming, intact stability requirements, longitudinal divisions (shifting boards), securing and the grain-loading information which is to be supplied to the master. This information is to include sufficient data to allow the master to determine the heeling moments due to a grain shift. Thus, there are tables of grain heeling moments for every compartment, which is filled or partly filled, tables of maximum permissible heeling moments, details of scantlings of any temporary fittings, loading instructions in note form and a worked example for the master's guidance.

Part B Considers the effect on the ship's stability of a shift of grain. For the purpose of the rules, it is assumed that in a filled compartment (defined as a compartment in which, after loading and trimming as required by the rules, the bulk grain is at its highest level) the grain can shift into the void space which is always considered to exist at the side of hatchways and other longitudinal members of the structure or shifting boards, where the angle of repose of the grain is greater than 30°.

The average depth of these void spaces is given by the formula:

$$V_d = V_{d1} + 0.75(d - 600)\ \text{mm}$$

where V_d represents the average void depth in mm; V_{d1} is the standard void depth found from tables; d is the actual girder depth in mm.

The standard void depth depends on the distance from the hatch end or the hatch side to the boundary of the compartment (Figure 4.7).

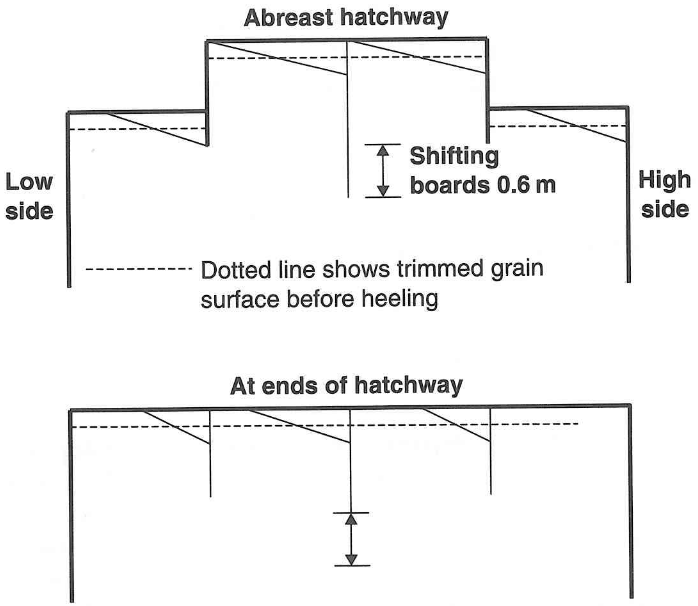


Fig. 4.7 Showing use of shifting boards and assumed formation of voids if heeled 15°

The assumed transverse heeling moment can now be calculated by taking the product of the length, breadth and half the depth of the void (if it is triangular over the full breadth) and the horizontal distance of the centroid of the void from the centroid of the 'filled' compartment:

The total heeling moment = 1.06 × calculated transverse heeling moment for a full compartment

or

= 1.12 × calculated transverse heeling moment in a partly filled compartment

It will have been noted that the above heeling moments are expressed in m^4 units and so it is also termed a volumetric heeling moment.

The reduction in GZ in the initial position (λ_0) is assumed to be:

$$\frac{\text{Total volumetric heeling moment due to grain shift}}{\text{Stowage factor of the grain} \times \text{displacement}}$$

The reduction in GZ at 40° (λ_{40}) = $0.8\lambda_0$.

Superimposing the above reductions in GZ on the vessel's curve of statical stability will give a 'heeling arm' curve (straight line). The angle at which the two curves cross is the angle of heel due to the shift of grain and this angle must not exceed 12°. Also, the initial metacentric height (GM) (after correction for free surface for liquid in tanks) must not be less than 0.30 m (Figure 4.8).

As can be seen in Figure 4.8, the residual area between the original curve of righting levers and the heeling arms up to 40°, or such smaller angle at which openings in the hull, superstructures or deckhouse cannot be closed watertight immersed (this is called 0_f – the angle of flooding – at which progressive flooding commences) must not be less than 0.075 metre-radians.

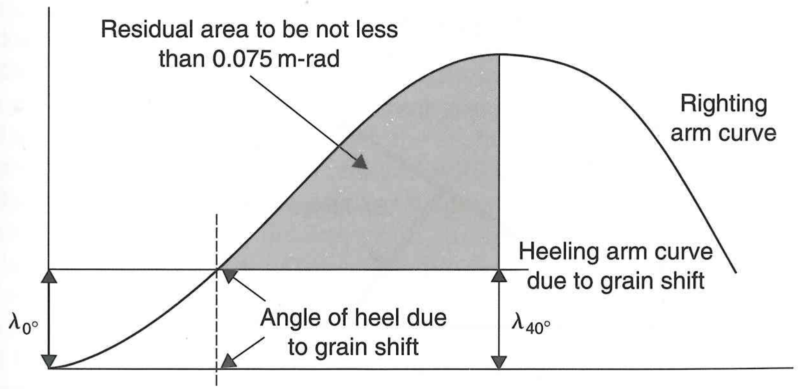


Fig. 4.8 Heeling arm curve

If the vessel has no Document of Authorization, from the contracting governments, she can still be permitted to load grain if all filled compartments are fitted with centre line divisions extending to the greater of one-eighth maximum breadth of the compartment or 2.4 m. The hatches of filled compartments must be closed with the covers in place. The grain surfaces in partly filled compartments must be trimmed level and secured, and she must have a GM which is to be the greater of 0.3 m or that found from the formula I of the rules.

Part C Concerned with the strength and fitting of shifting boards, shores, stays and the manner in which heeling moments may be reduced by the saucering of grain. The handling of bulk and the securing of hatches of filled compartments and the securing of grain in a partly filled compartment is also detailed.

When shifting boards are fitted in order to reduce the volumetric heeling moment, they are to be of a certain minimum strength with a 15 mm housing on bulkheads and are supported by uprights spaced according to the thickness of the shifting boards (e.g. 50 mm thick, shifting boards would require a maximum spacing of 2.5 m between uprights) (Figure 4.9). The shores will be heeled on the permanent structure of the ship and be as near horizontal as practical but in no case more than 45° to the horizontal. Steel wire rope stays set up horizontally may be fitted in place of wooden shores but the wire must be of a size to support a load in the stay support of 500 kg/m^2.

The shifting boards will extend from deck to deck in a filled tween deck compartment while in a filled hold they should extend to at least 0.6 m below the grain surface after it has been assumed to shift through an angle of 15°.

In a partly filled compartment the shifting boards can be expected to extend from at least one-eighth the maximum breadth of the compartment above the surface of the levelled grain to the same distance below.

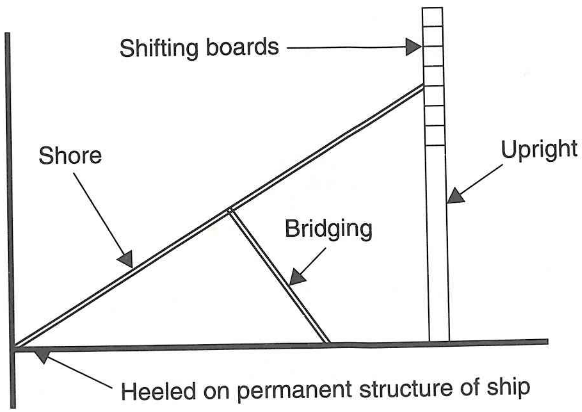


Fig. 4.10 The bulk carrier 'Alpha Afovos' lies port side to the grain silos in Barcelona. The grain elevators seen deployed into the ships hold effecting discharge.

A further method of reducing the heeling moment in a filled compartment is to 'saucer' the bulk in the square of the hatch and to fill the saucer with bagged grain or other suitable cargo laid on separation cloths spread over the bulk grain (Figure 4.12(b)). The depth of the saucer on a vessel over 18.3-moulded breadth will be not less than 1.8 m. Bulk grain may be used to fill a saucer provided that it is 'bundled' which is to say that after lining the saucer with acceptable material, athwartships lashings (75 mm polypropylene or equivalent are placed on the lining material not more than 2.4 m apart and of sufficient length to draw tight over the surface of the grain in the saucer. Dunnage 25 mm in thickness and between 150 and 300 mm wide is laid longitudinally over the lashings). The saucer is now filled with bulk grain and the lashing drawn tight over the top of the bulk in the saucer (Figure 4.11).

In a partly filled compartment, where account is not taken of adverse heeling moments due to grain shift, the surface of the bulk grain is to be trimmed level before being overstowed with bagged grain or other cargo exerting at least the same pressure to a height of not less than one-sixteenth the maximum breadth of the free grain surface or 1.2 m whichever is the greater. The bagged grain, or other suitable cargo, will be stowed on a separation cloth placed overt the bulk grain, or a platform constructed by 25 mm boards laid over wooden bearers not more than 1.2 m apart maybe used instead of separation cloths.

Lashings and bottle screw securings must be regularly inspected and reset taught during the voyage.

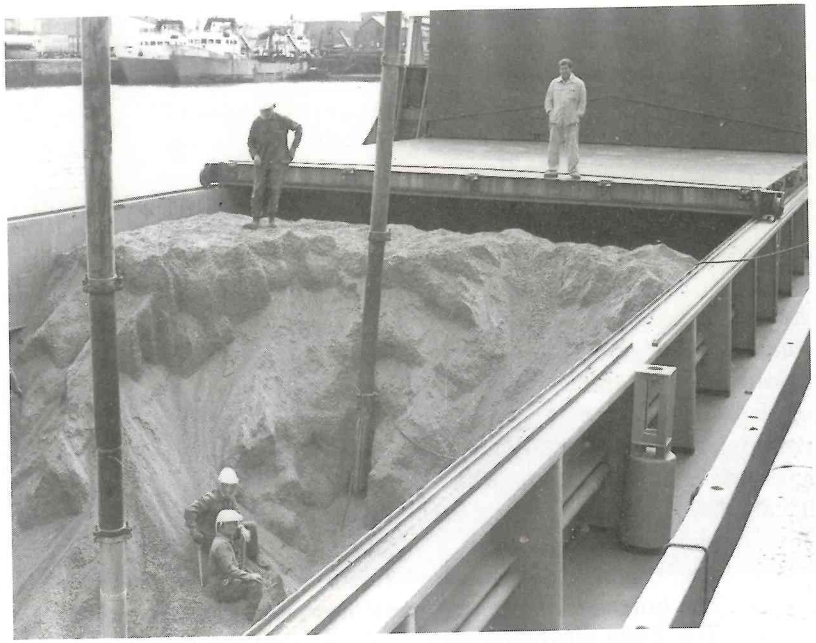


Fig. 4.11 Discharge of grain/cereals. The suckers from 'grain elevators' discharge cereals contained in a ships bulk cargo hold from under the rolled back steel hatch covers. Men in the hold actively use the heel ropes to drag the suctions into areas of cereal concentration.

Measures to reduce the volumetric heeling moment of 'filled' and 'partly filled' cargo compartments

- By use of longitudinal divisions – these are required to be grain tight and of an approved scantling.
- By means of a saucer and bundling bulk – a saucer shape is constructed of bulk bundles in the hatch square of a filled compartment. The depth of the saucer being established between 1.3 and 1.4 m depth dependent on the ships beam, below the deck line.
- By overstowing in a partly filled compartments – achieved by trimming the surface level flat and covering with a separation cloth then tightly stowing bagged grain to a depth of one-sixteenth the depth of the free grain stow.

To ensure adequate stability

- The angle of heeling of the vessel which arises from the assumed 'shift of grain' must not exceed 12°.
- When allowing for the assumed shift of grain, the dynamical stability remaining, that is the residual resistance to rolling on the listed side, must be adequate.
- The initial GM, making full allowance for the free surface effect of all partially filled tanks must be maintained at 0.3 m or more.

Document of Authorization

In order to load grain, a vessel must have a Document of Authorization or an appropriate 'Exemption Certificate'. The authorization means that the vessel has been surveyed and correct grain-loading information has been supplied to the ship for use by the Deck Officer responsible.

Grain awareness

When a grain cargo is loaded, compartments will contain void spaces below the crown of the hatch top. During the voyage the grain will 'settle' and these void spaces would be accentuated. In the event that the grain shifts, it will move into these void spaces to one side or another generating an adverse list to the vessel and directly affecting the stability of the ship by reducing the resistance to roll and adversely affecting the 'Range of Stability'.

Measures to reduce the possibility of the grain shifting include the rigging of longitudinal shifting boards (Figure 4.12(a)), and overstowing the bulk cargo with bagged grain (Figure 4.12(b)).

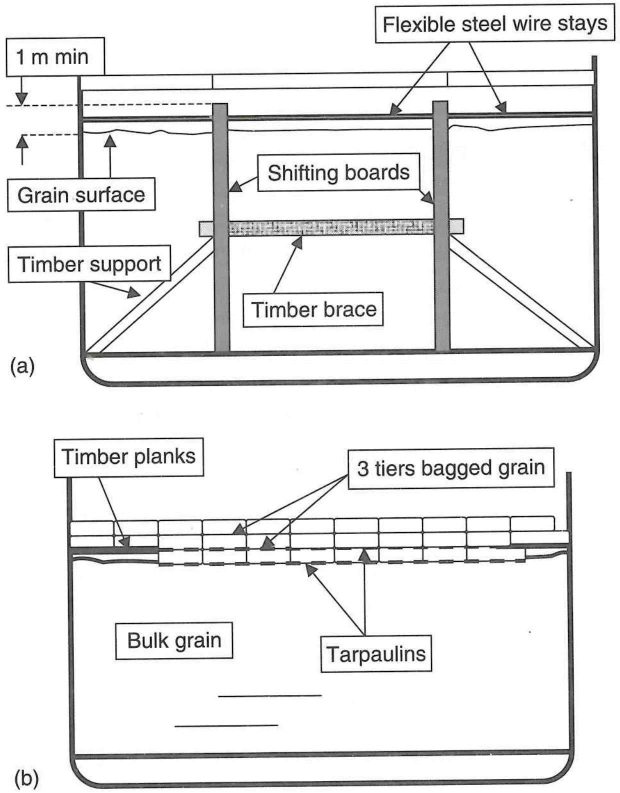


Fig. 4.12 Cargo hold. (a) Longitudinal separation and (b) overstowing bulk cargo with bagged cargo.

Fig. 4.13 A tractor is engaged in the tween deck of a vessel discharging cereals, to ensure that the suction of the grain elevator has access to all residuals of the cargo product.

Trimming of bulk cargoes

Many bulk cargoes are trimmed (levelled) at the loading port to provide a stable stowage for when the ship is at sea. However, trimming also takes place during the period of discharge to ensure that the total volume of cargo is landed (Figure 4.13).

Permissible grain heeling moment tables

The purpose of the tables is to allow the Ship's Master to ascertain whether or not a particular grain stowage condition will achieve the required stability criteria.

The obtained values can then be applied to acquire the approximate angle of heel which would result from a possible shift of the grain cargo.

$$\text{Actual grain heeling moment} = \frac{\text{Total volumetric heeling moment}}{\text{SF}}$$

$$\text{SF (bulk)} = 1.20/1.67\,\text{m}^3/\text{tonne}$$

$$\text{Approximate angle of heel} = 12° \times \frac{\text{Actual heeling moment}}{\text{Permissible heeling moment}}$$

For a ship to be authorized to carry grain, the surveyor will have made calculations for sample cargoes to show that adequate stability for the ship

exists. A *grain-loading information listing* should be made in which the surveyor would record all the dimensions of the carriage compartments and then these would be converted into potential heeling moments for when the space is filled or partly filled.

The Deck Officer would be expected to make his own calculations before the intended voyage to take account of the type of grain being carried and its stowage factor. Account must also be taken for the condition of the ship at all stages of the voyage to ensure adequate stability throughout.

Coal – loading, carriage and discharge

Categories of coal

Coal – any coal, including sized grades, small coal, coal duff, coal slurry or anthracite.
Coal duff – coal with an upper size of 7 mm.
Coal slurry – coal with particles generally under 1 mm in size.
Coke – solid residue from the distillation of coal or petroleum.
Small coal – sufficient particle material below 7 mm to exhibit a flow state when saturated with water.

The characteristics of coal

Coal cargoes are liable to spontaneous heating, especially when sufficient oxygen is available to generate combustion. The amount of heating that takes place will depend on the type of coal being carried, and the ability to disperse that heat with effective ventilation methods. Unfortunately, ventilation can work against the safe carriage because of supplying unwanted oxygen, while at the same time dispersing the heat concentrations. It is recommended that surface ventilation only is applied to coal cargoes. This can be applied by raising the hatch tops (weather permitting) to allow surface air and released gases to go to atmosphere and not be allowed to build up inside the cargo compartment.

Freshly mined coal absorbs oxygen which, with extrinsic moisture, forms peroxides. These in turn break down to form carbon monoxide and carbon dioxide. Heat is produced and this exothermic reaction causes further oxidation and further heat. If this heat is not dissipated, ignition will occur, e.g. spontaneous combustion.

Large coal gives a good ventilation path for air flow towards surface ventilation methods, while small coal tends to retain the oxygen content and is more likely to generate spontaneous combustion.

Preparation of the holds should include the overall cleaning of the hold prior to loading, the testing of the bilge suctions and sealing the bilge bays to prevent coal dust clogging bilge bays. Spar ceiling (cargo battens) should also be removed as these would have a tendency to harbour oxygen pockets deep into the heart of the stow. Hold thermometers should be rigged at three different levels, to ensure tight monitoring of the temperatures in the compartments loaded with coal. Critical temperatures in coal vary, but heating will be accelerated in some varieties of coal from as low as 38°C (100°F). Such temperatures would create a need to keep external hull and deck surfaces as cool as possible. In the tropics, it may be appropriate to cover decks to lessen the internal heating in the compartment.

Coal fires

Most coal fires occur at about the tween deck level which is an area that requires more attention to temperature monitoring and to ventilation.

Surface ventilation to holds should be concerned with the removal of gas for the first 5 days of the voyage, thereafter the ventilators to the lower holds should be plugged with an exception for about 6 h every 2 days. Gas from the holds or tween deck regions may find its way into trunk sections, shaft tunnels, chain lockers, peaks and casings unless bulkheads can be maintained in a gas-tight condition.

> **Note:** *A strict policy of no naked lights and no smoking should be followed and crew should not be engaged in chipping or painting below decks.*

The majority of coal fires are caused by spontaneous combustion. Poor hatch cleaning prior to loading and a lack of temperature monitoring are often directly linked to the cause. In the event of a coal fire at sea, it should be realized that these are extremely hot fires and if tackled with water would generate copious amounts of steam. Unless this can be vented, the compartments could become pressurized.

If tackled from sea, it is recommended that hatches are battened down and all ventilation to the compartment sealed with the view to starving the fire of oxygen. A Port of Refuge should be sort, where the authorities can be informed to receive the vessel and dig the fire out by grabs while fire-fighters are stood by to tackle the blaze once exposed.

Loading coal

Coal is loaded by either tipping or conveyor belt, bucket system. It is recommended that the first few truck loads are lowered to the holds, this reduces breakage as does a control rate of the chutes. Loading may take place from a single-loading dispenser and, as such, it may become necessary to shift the ship to permit all compartments to be loaded. A loading plan to prevent undue stresses and minimum ship movements would normally be devised. Coal will need to be trimmed as its 'angle of repose' is quite high, especially for large coal.

Small coal like 'mud coal', 'slurry' or 'duff' is liable to shift, but shifting is unlikely in large coal.

Reference should be made to the Code of Safe Working Practice (CSWP) for Bulk Cargoes prior to loading any of the coal types. Information on dry bulk cargoes is given under the heading of 'ores and similar cargoes' and information on wet bulk cargoes is given under the heading of 'ore concentrates'.

Coke

Coke and similar substances such as 'coalite' have had their gas and benzole removed and they do not heat spontaneously. No special precautions are necessary other than to ensure that the coke is cold before loading. If hot coke is loaded this may generate a fire.

The precautions of loading coal

The IMO divides coal into several categories:

Category A – no risk
Category B – flammable gas risk
Category C – spontaneous heating risk
Category D – both risks.

Although precautions are given to each category, the following general precautions are recommended.

1. Gas-tight bulkheads and decks.
2. Spar ceiling (cargo battens) removed.
3. Measures taken to prevent gas accumulating in adjacent compartments.
4. Intrinsically safe electrical equipment inside compartments.
5. Cargo stowed away from high temperature areas and machinery bulkheads.
6. Gas detection equipment on board.
7. Trim cargo level to gain maximum benefits from surface ventilation.
8. Cargo/hatch temperatures monitored at regular intervals.
9. No naked flame or sparking equipment in or around cargo hatches.
10. No welding, or smoking permitted in the area of cargo hatches.
11. Full precautions taken for entry into enclosed compartments carrying coal.
12. Suitable surface ventilation procedures adopted as and when weather permits.

> **Note:** *Certain coal cargoes of small particle content are liable to shift if wet, and experience liquefaction hazards. Reference to the IMO Code of Solid Bulk Cargoes should be made and appropriate precautions taken.*

Iron and steel cargoes

Steelwork is carried in various forms, notably as pig iron, steel billets, round bars, pipes, castings, railway iron, 'H' girders, steel coils, scrap metal or iron and steel swarf

It is without doubt one of the most dangerous of cargoes worked and carried at sea. Recommendations for stowage have been made by various Merchant Shipping Notice (MSNs) and Marine Guidance Notice (MGNs) in the past and yet it is still prone to 'shifting' in a rough sea condition.

Pig iron – if pig iron or billets are taken, they should be levelled and large quantities should not be carried in tween deck spaces. A preferred stow is to level in lower hold spaces and overstow by other suitable cargoes.

If it has to be carried in tween deck spaces the maximum height to which it can be stowed should not exceed 0.22 × the height of the tween deck space.

Pig iron should be trimmed and stowed level in both tween deck and hold spaces in either a side to side or fore and aft stow. If it is not effectively overstowed it should be stowed in robust 'bins', with suitable shifting boards to prevent cargo movement. It is recommended that gloss finished pig iron is always stowed on wood ceiling or dunnage, to reduce steel-to-steel friction.

Round bars and pipes – should preferably be stowed in the lower hold compartments and levelled off. Securing should be in the form of strong cross wires over the top of the stow and secure 'toms' at the sides. Suitable cargoes can overstow this type of steelwork.

Railway iron, 'H' girders, long steel on the round – should be stowed in a fore and aft direction, and packed as solidly as possible. If left exposed and not overstowed, chain lashings should be secured to prevent cargo shift.

Iron and steel swarf – this may heat to dangerous levels while in transit, if the swarf is wet and contaminated with cutting oils. The carriage of 'swarf' requires that surface temperatures of the cargo are monitored at regular intervals during the loading process and whilst on the voyage. If, during loading, the temperature of an area is noted as 48°C (120°F), loading should be temporarily suspended until a distinct fall is observed. In the event that a temperature of 38°C is observed on passage, gentle raking the swarf surface area in the region of the high temperature, to a depth of about 0.3 m should cause the temperature to lower. If a temperature of 65°C is noted, the ship is recommended to make for the nearest port.

Scrap metal – similar problems to other steel cargoes in that it is very heavy. It is generally loaded by elevator/conveyor or grabs and usually discharged by mechanical grabs. When loading, the first few loads are often lowered into the hold to prevent the possibility of excessive damage to ship's structures.

Scrap metal tends to come in all shapes and sizes. As such, where mechanical grabs are engaged, metal pieces frequently become dislodged from the grab when in transit from the hold to the shore, while discharging or loading. Deck Officers should ensure that the working area is cordoned off and personnel on the deck area should wear hard hats and observe cargo operations from a safe distance.

Steel coils – steel coils are stowed on the round and are frequently carried in the cargo holds of 'bulk carriers' (see Chapter 3). The overall stow is secured by steel wire and bottle screw lashings. The sides of the stow are generally chocked tight, against the ship's side, if broken stowage is a feature of the cargo.

Steel coils are classed as a heavy cargo, and would be levelled to no more than two tiers in height. Individually, a coil may weigh up to 10 tonnes, and they are frequently treated as 'heavy lifts'. They are prone to shifting, being stowed on the round, if the vessel encountered rough weather. Passage plans should bear this in mind and chart a 'Port of Refuge' in case such a contingency is required.

Ores – mostly of a low stowage factor, which means that when a full cargo of ore is loaded, there will be a large volume of the hold left unused. A low stowage factor also lends itself to a 'stiff ship', unless some of the cargo can be loaded in the higher regions of the vessel.

Ore should be trimmed if possible and, at the very least, the top of the heap should be knocked off. Modern bulk carrier hold design compensates in some way towards a cargo which is likely to shift. Other vessel designs have been developed as designated ore carriers, and have effective upper ballast compartments to raise the vessel's centre of gravity, when carrying dedicated heavy ore cargoes. In the event that an ore cargo is only a 'part cargo' it should be realized that some ores have a high moisture content which does not always lend to overstowing.

Example ore cargoes: bauxite, chrome, iron, lead and manganese.

Use of mechanical grabs

Many types of bulk cargoes are discharged by means of 'mechanical grabs', of which there are several variations. The handling of grabs is always precarious – especially the larger 5 tonne plus, capacity grabs – because they are not exactly controlled and may incur structural damage to the vessel.

Cargoes tend to be loaded by chute, tipping or pouring, especially the grain type cargoes, ores and coals. However, discharging of ores, bulk solids and the coal cargoes tend to employ grabs for discharge purpose. Bucket grabs coming in various sizes ranging from 2 to 10 tonnes, but the more popular range being in the 4–5 tonne bucket (manual labour for bulk commodity discharge has all but died out) (Figure 4.14).

Cargo Officers are advised that working with heavy grabs requires designated concentration by the crane drivers and even then ship damage is not unusual. A close check on the operation of grabs throughout load/discharge operations is advised and any damage to the ship's structure by contact of the grabs should be reported to the Chief Officer of the vessel. Subsequent damage claims can then be made against the stevedores for relevant repair costs. Bearing in mind that damage to hatch coamings may render the vessel unseaworthy if the damage prevents the closure of hatches and cannot be repaired, before the time of sailing.

Fig. 4.14 Bucket mechanical grab seen in the open position on the quayside. The crane is configured so that the controlling crane driver can open and shut the grab by means of an operational wire to open and close the bucket arrangement.

General information on the loading/discharge of steel cargoes

Steel cargoes in any form are probably one of, if not, the most dangerous cargoes. Steel comes in many forms, from railway lines to ingots, from bulk scrap to bulldozers, etc. It is invariably always heavy and very often difficult to control because of its size. It is a regular cargo for many ships and has been known to cause many problems by way of stability, or adverse effects to the magnetic compass. If steel shifts at sea, due to bad weather, it is unlikely that the crew would have the skills or the facilities to rectify the situation and the vessel would probably need to seek a 'Port of Refuge' with the view to corrective stowage, e.g. steel coils, on the round are particularly notorious for moving in bad weather.

During the loading period, an active Cargo Officer can ensure that correct stowage is achieved and even more important that correct securing is put in place. Relevant numbers of chain lashings and strong timber bearers go well with steel loads, but are often required before the load becomes overstowed by light goods.

Masters should monitor progress during loading periods without being

be given to the use of rigging gangs being employed as and when required. An awareness of the needs of industrial relations without sacrificing the safety requirements can be a delicate balance when a load needs 20 securings and dock labour only wants to secure with 10.

Damage to the vessel when loading or discharging heavy steelwork is not unusual. Heavy lifts by way of bulldozers or locomotives require advance planning and a slow operation. They are awkward to manoeuvre because of either width, length or both. Heavy rig lifting gear operated by ship or shore authorities, even when taking all precautions, very often results in damaged hatch coamings or buckled deck plates. The possibility of damage to the cargo itself is also a likely occurrence.

'H' or 'T' section steel girders are difficult to control because of length and are normally loaded on the diagonal into a hatchway. Slinging is normally by long-leg chains but high winds when loading can cause excessive oscillations of the load, especially with deep sections. Steadying lines of adequate size should be employed before lifting. High winds also pose problems for the lighter steel boilers. These are large but comparatively light, being hollow. Size and shape coupled with strong winds tend to cause slewing on the load in way of the hatch coaming.

Steel in any form will always be shipped and it is in the interests of all concerned to ensure safe handling and stowage. Masters tend to be wary of the stability needs and load in lower holds rather than tween decks depending on circumstances and the needs of other cargoes. However, the need for vigilance when securing remains a high priority towards voyage safety.

Bulk cargo examples

Concentrates – are partially washed or concentrated ores. These cargoes are usually powdery in form and liable to have a high moisture content, and subsequently, under certain conditions, have a tendency to behave almost as a liquid. Special stowage conditions prevail, and sampling must take place to ascertain the transportable moisture limit as provided by the CSWP for Bulk Cargoes.

They are extremely liable to shifting, and care should be taken when loading. Some cargoes may appear to be in a relatively dry condition when loading, but at the same time, contain sufficient moisture to become fluid with the movement and vibrations of the vessel when at sea.

Nitrates – are considered dangerous cargoes. Before stowing, the International Maritime Dangerous Goods (IMDG) Code on dangerous goods should be consulted.

Phosphates – readily absorb water and should be kept dry. A variety of these is Guano which is collected from islands in the Pacific. Phosphates should be kept clear of foodstuffs.

Sulphur – is a highly inflammable cargo and all anti-fire precautions should be taken

It is also very dusty and highly corrosive. The risk of dust explosions when clearing holds after carriage is of concern. Fires occurring in sulphur cargoes are smothered by use of more sulphur. Personnel should be issued with personnel protection equipment when loading or discharging a sulphur cargo, i.e. masks and goggles.

Nuts – tend to have a high oil content and they are liable to heat and deterioration. They should be kept dry. Precautions should be taken to prevent shifting, as per the grain rules.

Copra – is dried coconut flesh mainly from Malaysia. It is liable to spontaneous heating and is highly inflammable. It is suggested that cargo thermometers are rigged to monitor temperatures in the bulk. Tight anti-fire regulations should prevail around the cargo spaces, to include spark arrester gauze in place on ventilator apertures. The cargo should be kept dry and kept clear of surfaces that are liable to 'sweat'. Matting is recommended to cover the ship's steelwork for this purpose.

Salt – has a high moisture content which is likely to evaporate and dry goods should not be stowed in close proximity. Prior to loading, the spaces should be clean and dry. The steelwork may be whitewashed and separation cloths may be used to keep salt off the ship's structures.

Sugar – vessels have been specifically built for the bulk sugar trade. They are of a similar construction to those of the bulk ore carrier. This is not to say that bulk sugar cannot be carried in any other general type cargo vessel. In any event the compartments should be thoroughly cleaned out and the bilge bays made sugar tight. Bulk sugar must be kept dry. If water is allowed to enter by any means it would solidify the cargo and result in the product being condemned.

Main hazards of loading/shipping/discharging bulk cargoes

Dry shift of cargo – is caused by a low angle of repose and can be avoided by trimming level or the use of shifting boards.

Wet shift of cargo – is caused by liquefaction of the cargo possibly due to moisture migration causing the cargo to act like a liquid, the moisture content of the product probably being below the transportable moisture limit.

Oxidation – the removal of oxygen from the cargo compartment by the type and nature of the cargo, ventilation being required before entry into the compartment.

Flammable/explosive gas/dust – the nature of the cargo has a high risk and may be of a highly inflammable nature, or give off explosive gases. Dusty cargoes also run the risk of a dust explosion of the atmosphere inside the compartment.

Toxic gas or dust – identified toxic effects from products may well require personnel to wear protective clothing and masking/breathing equipment when in proximity of the product.

Corrosive elements (e.g. sulphur) – personnel will require protective clothing, and eye protective wear. High fire risk.

Spontaneous combustion – a self-heating cargo which needs to be monitored by the use of cargo and hatch thermometers throughout the period of the voyage. It should be stowed clear of machinery space bulkheads and provided with recommended ventilation where appropriate (e.g. coal surface ventilation).

Reaction cargoes – products that may react with other cargoes, and as such may require separate stowage compartments.

High density cargoes – may cause structural damage to the vessel and pose stability problems from the position of stow. Could well affect bending and shear force stress effects on the hull.

Infectious cargoes (e.g. Guano) – exposed personnel would require personal protection inclusive of respirators.

Structural damage – through excessive bending and shear forces caused by poor distribution of and/or inadequate trimming of certain cargoes, or sailing with partly filled holds or empty holds.

MARINE GUIDANCE NOTE
MGN 108 (M)

Hull Stress Monitoring Systems

Notice to Shipowners, Ship Operators, Charterers and Managers; Ships' Masters, Ships' Officers, Engineers, Surveyors and Manufacturers of Hull Stress Monitoring Systems.

Summary

- Recommendation for the fitting of hull stress monitoring systems on bulk carriers of 20 000 dwt and above.
- Arrangements for type approval of hull stress monitoring systems.

1. The International Maritime Organization (IMO) recommends the fitting of hull stress monitoring systems to facilitate the safe operation of ships carrying dry cargo in bulk. Use of the system will provide the Masters and Officers of the Ship with real-time information on the motions and global stress the ship experiences while navigating, and during loading and unloading operations. The IMO recommendations are published in the Maritime Safety Committee Circular, MSC/Circ. 646, which is annexed to this Marine Guidance Note.

2. The Maritime and Coastguard Agency (MCA) supports the IMO's recommendations, and invites owners to fit hull stress monitoring systems on bulk carriers of 20 000 dwt and above. Consideration should also be given to fitting such systems to other types of ship.

3. The MCA requests all parties to return information on the reliability of hull stress monitoring systems, their performance relative to the actual and predicted stress levels, their application to other types and sizes of ships and any other relevant experience gained in the use of such systems. Such information should be returned to the Ship Construction Division Section quoting reference MS070/014/0007. This information will be used to inform future deliberations at the IMO, which may include the development of performance standards.

4. The IMO's recommendations call for the hardware and software of the hull stress monitoring system to be approved by the administration. In this respect, the MCA will accept type approval certification of compliance with MSC/Circ. 646, which has been issued by one of the Nominated Bodies, listed in Table A of the Annex to MSN No. M.1645 "Type Approval of Marine Equipment", who are authorized to examine, test and certify equipment. The terms of M.1645 shall apply. The type approval of hull stress monitoring systems will be included in the next revision of M.1645.

5. Since the adoption of MSC/Circ. 646 in 1994, the design of hull stress monitoring systems has developed and some of the Nominated Bodies are developing standards for such systems. Such development is beneficial and to be encouraged. Consequently, the MCA will accept type approval certification which has been issued by one of the Nominated Bodies in accordance with its published standards or rules, provided that any deviation from MSC/Circ. 646 is recorded on the certificate and notified to the MCA.

6. In designing hull stress monitoring systems, consideration should be given to the IMO Performance Standards for Shipborne Voyage Data Recorders (VDRs), published as Resolution A.861 (2O). Paragraph 5.4.14 of this standard states:

   '5.4.14 Accelerations and hull stresses
   Where a ship is fitted with hull stress and response monitoring equipment, all the data items that have been pre-selected within that equipment should be recorded'

   Owners are invited to ensure that hull stress monitoring equipment is compatible with the VDR fitted and that all monitored data can be transmitted to the VDR.

7. Approval of the hardware and software of the hull stress monitoring system is the first stage but it is essential that the assigning authority for the International Loadline Certificate be consulted regarding the installation of the hull stress monitoring system and the determination of maximum permissible stresses and accelerations. They will also need to be consulted over the frequency of system verification, taking account of the manufacturer's recommendations.

8. Further information on this note may be obtained from:

   Maritime and Coastguard Agency, Spring Place, 105, Commercial Road, SOUTHAMPTON, UK, SO15 IEG. 01703329100 (Tel), 01703 329204 (Fax)

Additional reading and references for bulk cargoes

MGN 144 (M) The Merchant Shipping (Additional Safety Measures for Bulk Carriers), Regulations 1999.

S.I. 1999, No. 336, The Merchant Shipping (Carriage of Cargoes), Regulations 1999

Chapter 5

Tanker cargoes

Introduction

At the present time modern civilization is largely dependent on oil and its by-products. Vast quantities of liquid products are transported by tankers throughout the world and, as such they have a high profile in the eyes of the general public. However, it should be realized from the outset that not all tankers are in the oil trade. Many transport wine or liquid chemicals, or liquid natural gas (LNG), but generally the tanker vessel is synonymous with the carriage of bulk oil or oil-based products.

Concern for the environment, associated with tanker traffic, has become a number one priority in the anti-pollution campaign and rightly so (Figure 5.1). The marine industry must respect the environment and the well-being of the planet in which we all exist. To this end the Maritime Pollution (MARPOL) convention has gone some way to establishing standards of oil operations around the globe.

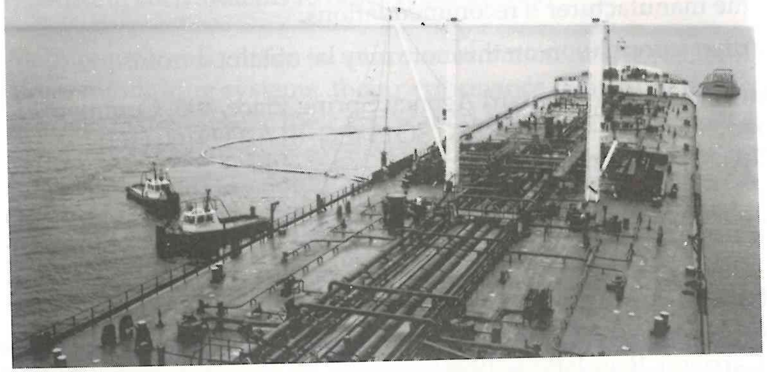


Fig. 5.1 A tanker approaches a single buoy mooring (SBM) and prepares to pick up the floating oil pipe with the assistance of local tenders.

The main concern with the demands of a modern society has always been the costs of pollution scaled against societies' needs for oil. Those countries that have it need to go to market to strengthen national economy. While those that are without oil need to import to strengthen their economy. Clearly, an endless circle of world economics. Unfortunately, the tanker accident is not unheard of, e.g. the 'Amoco Cadiz', the 'Torrey Canyon', the 'Exxon Valdez' and the 'Sea Empress' are hard examples to live with.

Our seafarers must be educated – not only to the public outrage that accompanies poor seamanship which generates most modern-day accidents, but also to the ways that prevent such catastrophes happening in the first place. The training of all our seafarers, especially tanker, personnel is an aspect of the marine industry which must take precedence within an industry which continues to drill for oil in the deepest and most remote quarters of the earth.

Definitions for use

(within the understanding of MARPOL) and tanker operations (gas and chemical)

Administration – the Government of the State under whose authority the ship is operating.

Associated piping – the pipeline from the suction point in a cargo tank to the shore connection used for unloading the cargo and includes all the ship's piping, pumps and filters which are in open connection with the cargo unloading line.

Bulk Chemical Code – the Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (ships must have a Certificate of Fitness for the carriage of dangerous chemicals).

Cargo area – that part of a ship which contains cargo spaces, slop tanks and pump rooms, cofferdams, ballast and void spaces adjacent to cargo tanks and also deck areas throughout the length and breadth of the part of the ship over such spaces.

Centre tank – any tank inboard of a longitudinal bulkhead.

Chemical tanker – a ship constructed or adapted primarily to carry a cargo of noxious liquid substances (NLS) in bulk and includes an oil tanker as defined by Annex 1 of MARPOL, when carrying a cargo or part cargo of NLS in bulk (see also Tanker).

Clean ballast – ballast carried in a tank which, since it was last used to carry cargo containing a substance in Category A, B, C or D, has been thoroughly cleaned and the residues resulting therefrom have been discharged and the tank emptied in accord with Annex II, of MARPOL.

Cofferdam – an isolating space between two adjacent steel bulkheads or decks. This space may be a void space or a ballast space.

Combination carrier – a ship designed to carry either oil or solid cargoes in bulk

Continuous feeding – defined as the process whereby waste is fed into a combustion chamber without human assistance while the incinerator is in normal operating condition with the combustion chamber operative temperature between 850°C and 1200°C.

Critical structural areas – locations which have been identified from calculations to require monitoring or from service history of the subject ship or from similar or sister ships to be sensitive to cracking, buckling or corrosion, which would impair the structural integrity of the ship.

Crude oil – any liquid hydrocarbon mixture occurring naturally in the earth whether or not treated to render it suitable for transportation and includes: (a) crude oil from which certain distillate fractions may have been removed and (b) crude oil to which certain distillate fractions may have been added.

Dedicated ship – a ship built or converted and specifically fitted and certified for the carriage of: (a) one named product and (b) a restricted number of products each in a tank or group of tanks such that each tank or group of tanks is certified for one named product only or compatible products not requiring cargo tank washing for change of cargo.

Domestic trade – a trade solely between ports or terminals within the flag state of which the ship is entitled to fly, without entering into the territorial waters of other states.

Discharge – in relation to harmful substances or effluent containing such substances means any release howsoever caused from a ship and includes any escape, disposal, spilling, leaking, pumping, emitting or emptying.

Emission – any release of substance subject to control by the Annex VI, from ships into the atmosphere or sea.

Flammability limits – the conditions defining the state of fuel oxidant mixture at which application of an adequately strong external ignition source is only just capable of producing flammability in a given test apparatus.

Flammable products – are those identified by an 'F' in column 'F' of the table in Chapter 19 of the International Gas Code for ships carrying liquefied gases in bulk (IGC).

Flash point (of an oil) – this is the lowest temperature at which the oil will give off vapour in quantities that, when mixed with air in certain proportions, are sufficient to create an explosive gas.

Garbage – all kinds of victual, domestic and operational waste, excluding fresh fish and parts thereof, generated during the normal operation of the ship and liable to be disposed of continuously or periodically, except those substances that are defined or listed in other Annexes to the present convention.

Gas carrier – is a cargo ship constructed or adapted and used for the carriage in bulk of any liquefied gas or other products listed in the table of Chapter 19 of the IGC Code.

Harmful substance – any substance that, if introduced into the sea, is liable to create hazards to human health, to harm living resources and marine life, to damage amenities or to interfere with legitimate use of the sea, and includes any substance subject to control by the present convention.

Hold space – is the space enclosed by the ship's structure in which a cargo containment system is situated.

Holding tank – a tank used for the collection and storage of sewage.

IBC Code Certificate – refers to an International Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk, which certifies compliance with the requirements of the International Bulk Cargo (IBC) Code.

IGC Code – refers to the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk.

Ignition point (of an oil) – this is defined by the temperature to which an oil must be raised before its surface layers will ignite and continue to burn.

Incident – any event involving the actual or probable discharge into the sea of harmful substance, or effluents containing such a substance.

Instantaneous rate of discharge of oil content – the rate of discharge of oil in litres per hour at any instant divided by the speed of the ship in knots at the same instant.

International trade – a trade which is not a domestic trade as defined above.

Liquid substances – are those having a vapour pressure not exceeding 2.8 kPa/cm^2 when at a temperature of 37.8°C.

MARVS – is the maximum allowable relief valve setting of a cargo tank.

Miscible – soluble with water in all proportions at wash water temperatures.

NLS Certificate – an international Pollution Prevention Certificate for the Carriage of Noxious Liquid Substances in Bulk, which certifies compliance with Annex II, MARPOL.

Noxious liquid substance – any substance referred to in Appendix II of Annex II of MARPOL. Or, provisionally, assessed under the provisions of Regulation 3(4) as falling into Category A, B, C or D.

NO_x Technical Code – the Technical Code on Control of Emission of Nitrogen Oxides from Marine Diesel Engines, adopted by the Conference, Resolution 2 as may be amended by the Organization.

Oil – petroleum in any form, including crude oil, fuel oil, sludge oil refuse and refined products (other than petrochemicals which are subject to the provisions of Annex II).

Oil fuel unit – is the equipment used for the preparation of oil fuel for delivery to an oil fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine and includes any oil pressure pumps, filters and heaters with oil at a pressure of not more than 1.8 bar gauge.

Oily mixture – a mixture with any oil content.

Oil tanker – a ship constructed or adapted primarily to carry oil in bulk in its cargo spaces and includes combination carriers and any 'chemical tanker' as defined by Annex II, when it is carrying a cargo or part cargo of oil in bulk (Figure 5.2).

Fig. 5.2 Tanker structure. The 'Jahre Viking' at 564 000 dwt is the largest man-made transport in the world. It is seen manoeuvring with tugs off the Dubai Dry Dock. The size and sophistication of the modern tanker has changed considerably over the decades. World economics have influenced the capacity, while legislation has changed all future construction into the double-hull category. This vessel has recently been converted to a floating oil storage unit to prolong its active life.

Organization – the Inter-Governmental Maritime Consultative Organization. The International Maritime Organization (IMO).

Permissible exposure limit – an exposure limit which is published and enforced by the Occupational Safety and Health Administration (OSHA) as a legal standard. It may be either time weighted average (TWA) exposure limit (8 h) or a 15-min short-term exposure limit (STEL), or a ceiling (C).

Primary barrier – is the inner element designed to contain the cargo when the cargo containment system includes two boundaries.

Product carrier – an oil tanker engaged in the trade of carrying oil, other than crude oil.

Residue – any NLS which remains for disposal.

Residue/water mixture – residue in which water has been added for any purpose (e.g. tank cleaning, ballasting and bilge slops).

Secondary barrier – the liquid resisting outer element of a cargo containment

leakage of liquid cargo through the primary barrier and to prevent the lowering of temperature of the ship's structure to an unsafe level.

Segregated ballast – that ballast water introduced into a tank which is completely separated from the cargo oil and fuel oil system and which is permanently allocated to the carriage of ballast or to the carriage of ballast or cargoes other than oil or noxious substances.

Sewage – (a) drainage and other wastes from any form of toilet, urinals and WC scuppers; (b) drainage from medical premises (dispensary, sick bay, etc.) via wash basins, wash tubs and scuppers located in such premises; (c) drainage from spaces containing living animals and (d) other waste waters when mixed with drainage as listed above.

Ship – a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air cushion vehicles, submersibles, floating craft and fixed or floating platforms (Figure 5.3).

Fig. 5.3 Tanker approaches a floating storage unit (FSU). The pipeline-bearing boom of the FSU is seen in the vertical ready to be deployed once the tanker vessel has moored and connected to the stern of the FSU.

Shipboard incinerator – a shipboard facility designed for the primary purpose of incineration.

Slop tank – a tank specifically designated for the collection of tank drainings, tank washings and other oily mixtures.

Sludge oil – sludge from the fuel or lubricating oil separators waste lubricating oil from main or auxiliary machinery, or waste oil from bilge water separators, oil filtering equipment or drip trays.

Oxides of sulphur (SO_x) emission control area – an area where the adoption of special mandatory measures for SO_x emissions from ships is required to prevent, reduce and control air pollution from SO_x and its attendant adverse impacts on land and sea areas. SO_x emission control areas shall include

Special area – a sea area where, for recognized technical reasons in relation to its oceanographical and ecological condition and to the particular character of its traffic, the adoption of special mandatory methods for the prevention of sea pollution by oil is required. Special areas include Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, Gulf Area, Gulf of Aden, North Sea, English Channel and its approaches, The Wider Caribbean Region and Antarctica.

Substantial corrosion – an extent of corrosion such that the assessment of the corrosion pattern indicates wastage in excess of 75% of the allowable margins, but within acceptable limits.

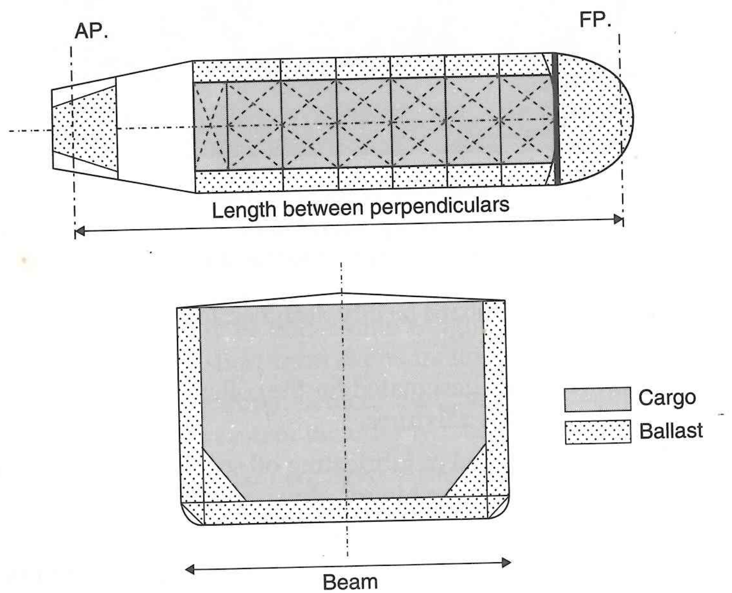
Suspect areas – are locations showing substantial corrosion and/or are considered by the attending surveyor to be prone to rapid wastage.

Tank – an enclosed space which is formed by the permanent structure of the ship and which is designed for the carriage of liquid in bulk.

Tank cover – the protective structure intended to protect the cargo containment system against damage where it protrudes through the weather deck or to ensure the continuity and integrity of the deck structure.

Tank dome – the upward extension of a position of a cargo tank. In the case of below deck cargo containment system the tank dome protrudes through the weather deck or through a tank covering.

Tanker – an oil tanker as defined by the Regulation 1(4) of Annex 1, or a chemical tanker as defined in Regulation 1(1) of Annex II of the present convention (Figure 5.4).



Double hulll design example for deadweight of 150 000 dwt

Threshold limit value (TLV) – airborne concentrations of substances devised by the American Conference of Government Industrial Hygienists (ACGIH). Representative of conditions under which it is believed that nearly all workers may be exposed day after day with no adverse effects. There are three different types of TLV, TWA, STEL and C. *Note*: TLVs are advisory exposure guidelines, not legal standards and are based on evidence from industrial experience and research studies.

Time weighted average (TWA) – that average time over a given work period (e.g. 8 h working day) of a person's exposure to a chemical or an agent. The average is determined by sampling for the containment throughout the time period and represented by TLV – TWA.

Toxic products – are those identified by a 'T' in column 'F' in the table of Chapter 19 of the IGC Code.

Ullage – that measured distance between the surface of the liquid in a tank and the underside decking of the tank.

Vapour pressure – the equilibrium pressure of the saturated vapour above the liquid expressed in bars absolute, at a specified temperature.

Void space – an enclosed space in the cargo area external to a cargo containment system, other than a hold space, ballast space, fuel oil tank, cargo pump or compressor room, or any space in normal use by personnel.

Volatile liquid – a liquid which is so termed is one which has a tendency to evaporate quickly and has a flash point of less than 60°C.

Wing tank – any tank which is adjacent to the side shell plating.

Equipment regulation requirements

Tankers now require:

- *Cargo tank pressure monitoring* systems required under Safety of Life at Sea (SOLAS) II-2 Regulation 59/IBC Code, Chapter 8.3.3 to be fitted after the first dry docking after 1 July between 1998 and 2002. New build vessels would be similarly equipped.
- *Cargo pump bearing temperature monitoring* systems must be fitted under SOLAS II-2, Regulations 4 and 5.10.1 at the next dry docking after 1 July 2002.
- *Cargo pump gas detection/bilge alarm* systems are now required under SOLAS II-2, Regulations 4 and 5.10.3/5.10.4 at the next dry docking after 1 July 2002.
- *High level and overfill alarm* system is now required under United States Coast Guard (USCG) Regulation 39.
- *Emergency escape breathing devices (EEBDs)* are now required under SOLAS II-2, Regulation 13.3.4 by the first survey after 1 July 2002

Double-hull tanker construction

Tankers were generally constructed with either centre tanks and wing tanks dividing the vessel into three athwartships sections, by two longitudinal bulkheads, individual tanks being segregated by transverse bulkheads. Modern construction, which integrates the double hull, has meant that construction designs have changed and twin tanks are now positioned to either side of a centre line bulkhead (Figure 5.5).

Fig. 5.5 Athwartships cross-section of the modern double-hull tanker seen at a late construction stage prior to assembly.

The maximum length of an oil tank is 20% L (L represents the ship's length) and there is at least one wash bulkhead if the length of the tank exceeds 10% L or 15 m. It should be appreciated that in a large tanker of 300 m length and 30 m beam and equivalent depth, each tank would have a capacity for over 20 000 tonnes of oil.

Tanks are usually numbered from forward to aft with pump rooms usually situated aft so that power can be easily linked direct from the engine room. Pipeline systems providing flexibility in loading/discharging interconnecting the tanks to the pumping arrangement.

Tanker pipelines

There are three basic types of pipeline systems:

1. Direct system
2. Ring main system
3. Free flow system.

Each system has their uses and is designed to fulfil a need in a particular

The direct system

This is the simplest type of pipeline system which uses fewer valves than the others. It takes oil directly from the tank to the pump and so reduces friction. This has an affect of increasing the rate of discharge, at the same time improving the tank suction. It is cheaper to install and maintain than the ring main system because there is less pipeline length and with fewer valves less likelihood of malfunction. However, the layout is not as versatile as a ring main system and problems in the event of faulty valves or leaking pipelines could prove more difficult to circumvent. Also, the washing is more difficult since there is no circular system and the washings must be flushed into the tanks Figure 5.6.

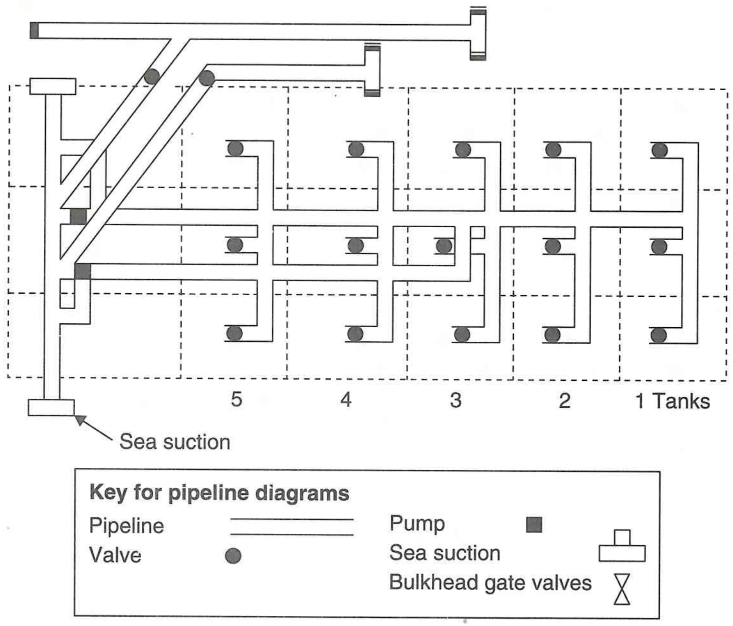


Fig. 5.6 Direct line system. Used mainly on crude and black oil tankers where separation of oil grades is not so important.

The advantages are that:

1. it is easy to operate and less training of personnel is required
2. as there are fewer valves it takes less time to set up the valve system before commencing a cargo operation
3. contamination is unlikely, as it is easy to isolate each section.

The disadvantages are that:

1. it is a very inflexible system which makes it difficult to plan for a multi-port discharge
2. block stowage has to be used which makes it difficult to control 'trim'

The ring main system

This is basically a ring from the pump room around the ship, with crossover lines at each set of tanks. There are various designs usually involving more than one ring. It is extensively employed on 'product tankers' where the system allows many grades of cargo to be carried without contamination. This is a highly versatile system which permits several different combinations of pump and line for any particular tank (Figure 5.7).

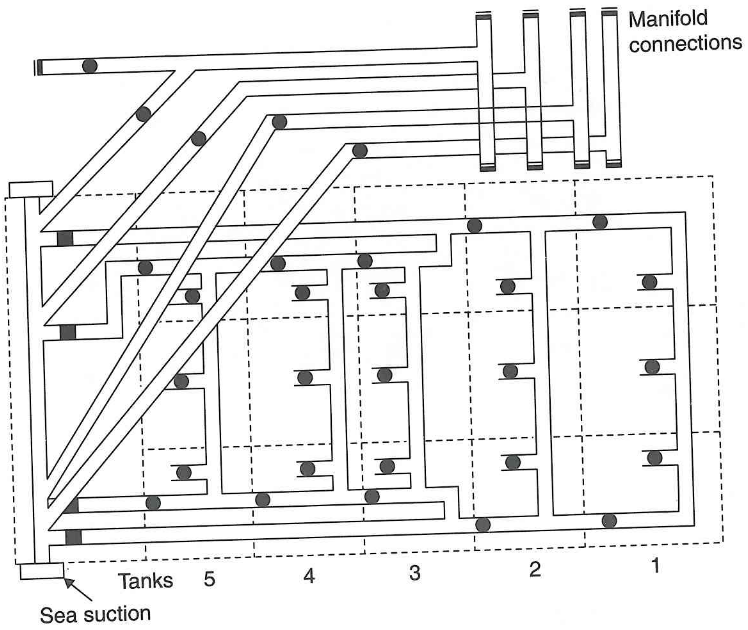


Fig. 5.7 Ring main system. Pump room aft.

The advantages of the system are that:

1. cargoes can be more easily split into smaller units and placed in various parts of the ship
2. line washing is more complete
3. a greater number of different parcels of cargo can be carried
4. trim and stress can be more easily controlled.

The disadvantages are that:

1. because of the more complicated pipeline and valve layout, better training in cargo separation is required
2. contamination is far more likely if valves are incorrectly set
3. fairly low pumping rates are achieved
4. costs of installation and maintenance are higher because of more pipe-

The free flow system

The 'free flow system' employs sluice valves in the tank bulkheads rather than pipelines. With a stern trim this system can discharge all the cargo from the aftermost tank via direct lines to the pump room. The result is that a very high speed of discharge can be achieved and as such is suitable for large crude carriers with a single grade cargo. Tank drainage is also very efficient since the bulkhead valves allow the oil to flow aft easily. There are fewer tanks with this system and it has increased numbers of sluice valves the farther aft you go. The increased number of sluices is a feature to handle the increased volume being allowed to pass from one tank to another (Figure 5.8).

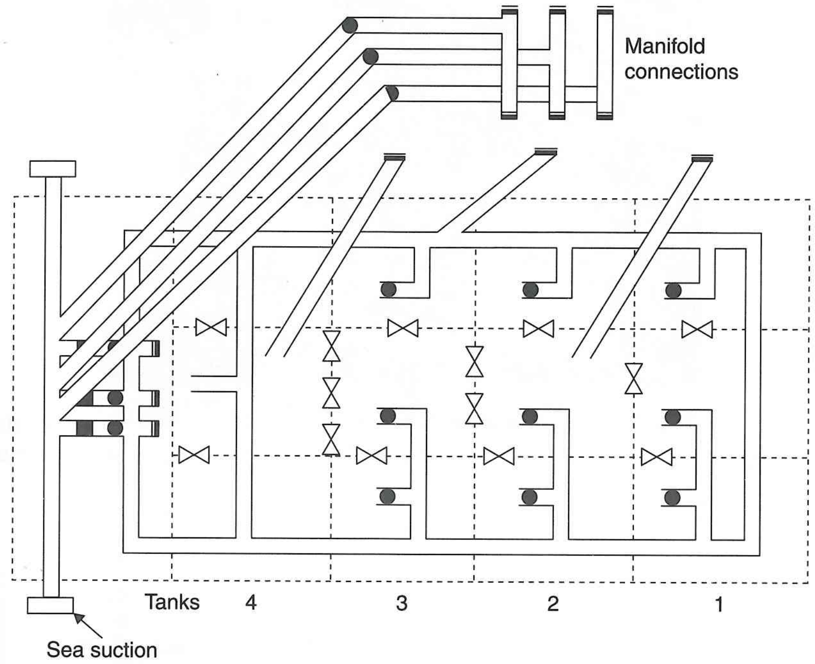


Fig. 5.8 The free flow system.

The main advantage is that a very high rate of discharge is possible with few pipelines and limited losses to friction. The main disadvantage is that overflows are possible if the cargo levels in all tanks are not carefully monitored (Figures 5.9, 5.10 and 5.11).

Measurement of liquid cargoes

The volume of oil in a tank is ascertained by measuring the distance from a fixed point on the deck to the surface of the oil. The distance is known as the 'ullage' and is usually measured by means of a plastic tape. A set of tables is supplied to every ship, which indicate for each cargo compartment, the volume of liquid corresponding to a range of ullage measurements. The

Fig. 5.9 Tanker deck arrangement. Typical example of the pipeline (fore deck) arrangement of a medium size oil tanker seen in the sea-going environment.

Fig. 5.10 Manifold and pipeline connections. Upper deck of an oil tanker showing the manifold, Samson Posts positioned to Port and Starboard, fitted

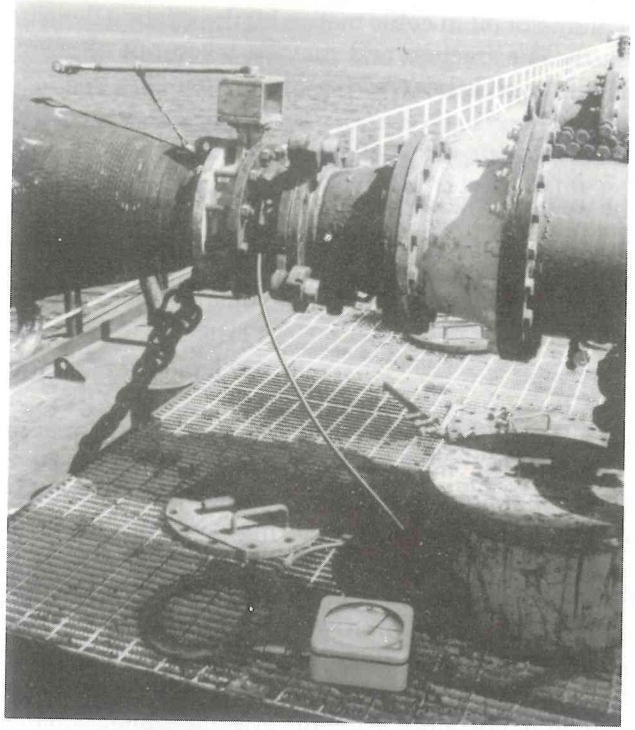


Fig. 5.11 Manifold and pipeline connections. Typical 14-inch oil pipe connection to the manifold.

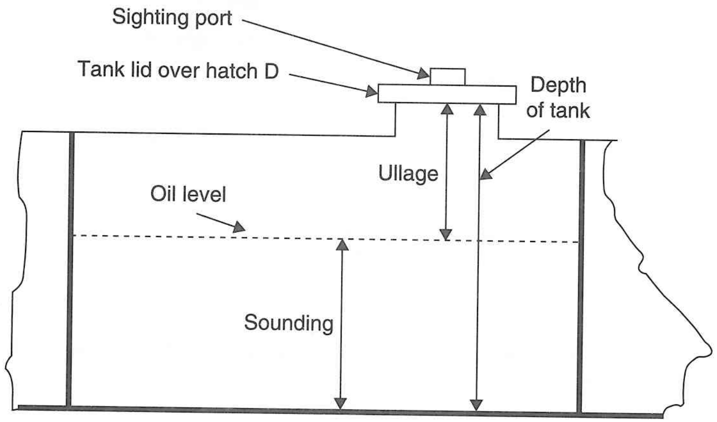


Fig. 5.12 Measurement of liquid cargoes.

ullage opening is usually set as near as possible to the centre of the tank so that for a fixed volume of oil, the ullage is not appreciably affected by conditions of trim and list. If a favourable siting is not possible then the effects

The important measure of oil is weight and this must be calculated from the volume of oil in each tank. Weight in tonnes is quickly found by multiplying the volume of oil in cubic metres by the relative density (RD) of the oil. This density is a fraction and may be taken out of petroleum tables when the RD of the oil is known.

Example

To find the weight of $125\,m^3$ of oil at a RD of 0.98.

$$\text{Density of oil} = 0.98\,t/m^3$$
$$\text{Weight of oil} = \text{volume} \times \text{density}$$
$$= 125\,m^3 \times 0.98\text{ tonnes}$$
$$= 122.5\text{ tonnes}$$

Oil expands when heated and its RD, therefore, decreases with a rise in temperature. In order that the weight may be calculated accurately, it is important that when ullages are taken the RD of the oil should also be known. This may be measured directly, by means of a hydrometer.

The RD of a particular oil may be calculated if the temperature of the oil is taken. The change of RD due to a change of 1°C in temperature is known as the RD coefficient. This lies between 0.0003 and 0.0005 for most grades of oil and may be used to calculate the RD of an oil at any measured temperature if the RD at some standard temperature is known.

Examples

A certain oil has an RD of 0.75 at 16°C. Its expansion coefficient is 0.00027/°C. Calculate its RD at 26°C.

$$\text{Temperature difference} = 26°C - 16°C = 10°C$$
$$\text{Change in RD} = 10 \times 0.00027$$
$$= 0.0027$$
$$\text{RD at } 16°C = 0.75$$
$$\text{RD at } 26°C = 0.7473$$

An oil has an RD 0.75 at 60°F. Its expansion coefficient is 0.00048/°F. Calculate its RD at 80°F.

$$\text{Temperature difference} = 80°F - 60°F = 20°F$$
$$\text{Change in RD} = 20 \times 0.00048$$
$$= 0.0096$$
$$\text{RD at } 60°F = 0.75$$

Tank measurement and ullaging

Use of the Whessoe Tank Gauge

The function of the gauge is to register the ullage of the tank at any given time, in particular when the liquid level in the tank is changing during the loading and discharge periods. The gauge is designed to record the readings not only at the top deck level of the tank but also remotely at a central cargo control room. A transmitter is fitted on the head of the gauge for just this purpose.

The unit is totally enclosed and various models manufactured are suitable for use aboard not only oil tankers, but chemical and gas carriers as well (Figure 5.13).

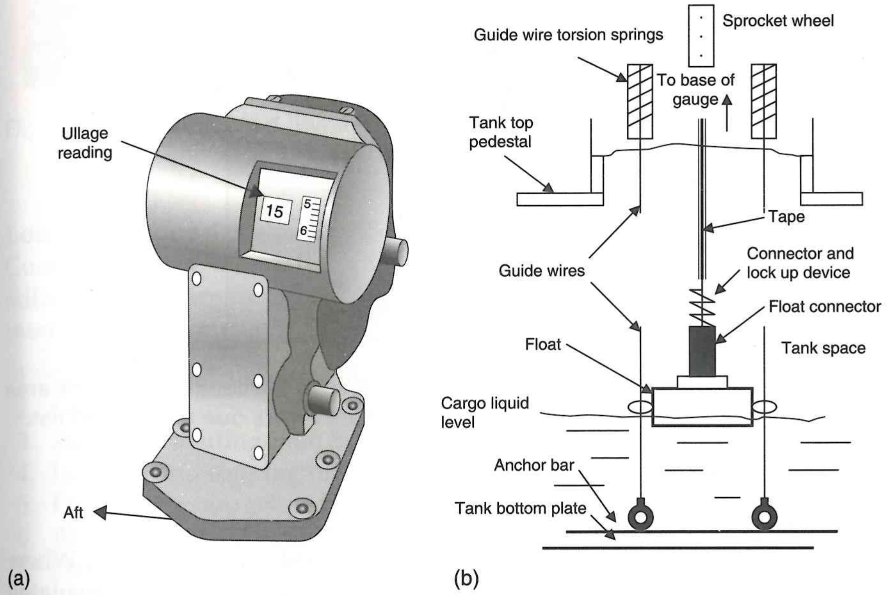


Fig. 5.13 Whessoe Tank Gauge.

Inside the gauge housing is a calibrated ullage tape, perforated to pass over a sprocket wheel and guided to a spring-loaded tape-drum. The tape extends into the tank and is secured to a float of critical weight. As the liquid rises or falls, the tape is drawn into, or extracted out from, the drum at the gauge head. The tape-drum, being spring loaded, provides a constant tension on the tape, regardless of the amount of tape paid out. A counter window for display is fitted into the gauge head, which allows the ullage to be read on site at the top of the tank.

Tank measurement – radar system

This is a totally enclosed measuring system which can only be employed if the tank is fully inerted. Systems are generally fitted with oxygen sensor and temperature sensor switches, so if the atmosphere in the tank is hot or flammable the radar will not function.

The main unit of the system is fitted on the deck with an inserted cable tube into the tank holding a transducer. Cable then carries the signal to a control unit in the cargo control room where the signal is converted to give a digital read-out for each tank monitored (Figure 5.14).

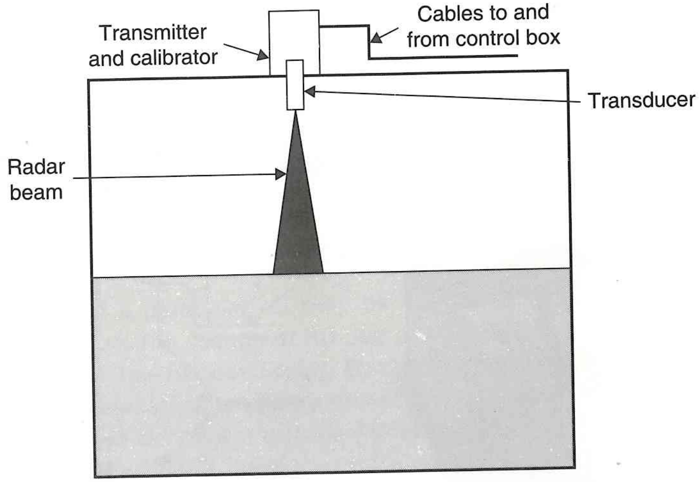


Fig. 5.14 The transducer would be fitted as close to the centre of the tank area as was possible. Such siting tends to eliminate errors due to trim and list.

Loading

Loading of tankers takes place at jetties, from FSUs or from SBM. Where booms carrying oil-bearing pipes are to be connected, these will be insulated to prevent stray currents flowing, as from corrosion prevention systems employed on both ships and jetties. The flow of current in itself should not be a problem, but it may give rise to a spark when making or breaking connections to the manifold. For this reason, these sections are tested regularly for efficient insulation. Lines are often bonded to reduce static electricity effects which could also give rise to an unwanted source of ignition from the fast pumping of liquids (Figure 5.15).

These points are highlighted to illustrate that a high degree of awareness is required in all tanker operations whether loading, discharging or gas freeing. Fire precautions are paramount because the risk of fire aboard the tanker is a real hazard and stringent fire precautions must be adopted

Fig. 5.15 Moorings and floating oil-bearing pipeline seen extending from the FSU 'Zapro Producer'.

Loading procedural checklist

Company policy on loading procedures vary and Cargo Officers should adhere to the company procedures and take additional reference from the International Safety Guide for Oil Tankers and Terminals (ISGOTT):

1. Complete and sign the ship/shore checklist
2. Establish an agreed communication network
3. Agree the loading plan by both parties and confirm in writing
4. Loading and topping off rates agreed
5. Emergency stop procedures and signals agreed
6. All effected tanks, lines, hoses inspected prior to commencing operations
7. Overboard valves sealed
8. All tanks and lines fully inerted
9. Inert gas (IG) system shut down
10. Pump room isolated and shut down
11. Ships lines set for loading
12. Off side manifolds shut and blanked off
13. All fire fighting and Ships Oil Pollution Emergency Plan (SOPEP) equipment in place
14. Notice of readiness accepted
15. First set of tanks and manifold valves open
16. Commence loading at a slow rate
17. Check and monitor the first tanks to ensure cargo is being received
18. Carry out line sample

20. Increase loading rate to full
21. Check ullages at half-hourly intervals and monitor flow rate to confirm with shoreside figures
22. Check valves operate into next set of tanks prior to change over
23. Reduce loading rate when topping off final tank
24. Order stop in ample time to achieve the planned ullage/line draining
25. When the cargo flow has completely stopped close all valves
26. After settling time, take ullages, temperatures and samples
27. Ensure all log book entries are completed
28. Cause an entry to be made into the Oil Record Book.

> ***Note:*** *The loading plan devised by Chief Officers and Shoreside Authorities would take account of the ship's stability and the possibility of stresses being incurred during all stages of the loading procedure.*

Load on top

When a crude oil tanker completes discharge, a large quantity of oil (upto 2000 tonnes) may be left adhering to the bulkheads. The 'load on top' principle is a method designed to gather all this oil and deposit it into a slop tank. Tank cleaning would be carried out in the normal way drawing in sea water from either a ballast tank or directly from the sea suction.

On completion of tank cleaning the slop tank will contain all the tank washings, made up of a mixture of oil and water (probably in the ratio of three parts water to one part oil). This mixture will contain small particles of oil held in suspension in the water and water droplets will be suspended in the oil. For this reason the slop tank must be allowed to 'settle' for up to about 2 or 3 days. After this period of time the oil can be expected to be floating on top of the water content.

Once settling out is completed the interface between the oil and the water levels must be determined (usually carried out by an interface instrument). Once the level of water is known, it is now possible to estimate the amount of water which can be discharged. The pumps and pipelines would be cleaned of oil particles and the water in the tank can be pumped out very carefully as the interface approaches the bottom. The main cargo pump is stopped when the water depth is at about 15–25 cm.

Alternative methods could be to pump the whole of the slop tank contents through an oily water separator or the tank can be de-canted from one tank to another.

On arrival at the loading port the new hot oil can be loaded on top of the remaining slops, which would have been quantified prior to commencing loading of the new cargo. During the loaded passage the old and new oils combine and any further water content sinks to the bottom of the tank.

On arrival at the discharge port, water dips are taken and the water quantity calculated. This is then usually pumped direct to a shoreside slop tank.

The main purpose of 'load on top' is to reduce the possibility of oil pollution while the vessel is at sea while at the same time as carrying out a full tank-cleaning programme.

> ***Note:*** *Tank washings containing any persistent oil must not be disposed of into the sea inside territorial waters or 'special areas'.*

Loading capacity

The amount of cargo a tanker can lift will depend upon the vessel's deadweight when the vessel is floating at her designated loadline. The amount of bunkers, fresh water and stores would be deducted to give the total weight of cargo on board. The order of loading tanks is of high priority in order to avoid excessive stresses occurring. Visible damage might not be an immediate result of a poor loading sequence but subsequent damage may be caused later, when in a seaway, which could be attributable to excessive stresses during loading periods.

Nowadays vessels are equipped with designated 'loadicators' or computer software programs to establish effective loading plans and show shear forces and bending moments throughout the ships length. Such aids are beneficial to Ship's Officers in illustrating immediate problems and permitting ample time to effect corrective action.

Although a high rate of loading is usually desirable, this in itself generates a need for tight ship keeping. Moorings will need to be tended regularly and an efficient gangway watch should be maintained. Communications throughout the loading period should be effective and continuous with shoreside authorities, with adequate notice being given to the pumping station prior to 'topping off'.

Care during transit

It would be normal practice that, through the period of the voyage, regular checks are made on the tank ullage values and the temperatures of all tanks. Empty tanks and cofferdams, together with pump rooms, should be sounded daily to ensure no leakage is apparent. Generally, oil is loaded at a higher temperature than that which will be experienced at sea, as such it would be expected that the oil will cool and the ullage will increase for the first part of the voyage.

Viscous oils like fuel oil or heavy lubricating oil would normally be expected to be heated for several days before arrival at the port of discharge. Heating will decrease the viscosity and a higher rate of discharge can be anticipated. Overheating should be avoided as this could affect the character of the product and may strain the structure of the vessel.

Tanks are vented by exhaust ventilators above deck level via masts and Samson Posts. Volatile cargoes such as 'gasoline' are vented via pressure relief valves which only operate when the tank pressure difference to atmosphere exceeds 0.14 kg/cm^2. This prevents an excessive loss of cargo due to evaporation. Evaporation of cargo can also be reduced in hot weather by spraying the upper decks cool with water.

Discharging

Flexible hoses are connected to the ship's manifold, as at the loading port, and the ship to shore checklist would be completed. Good communications between the ship and the shore authority is essential. All overboard discharges should be checked and if all valves are correct, discharge would be commenced at an initial slow rate. This slow rate is commenced to ensure that if a sudden rise in back pressure is experienced in the line, the discharge can be stopped quickly. Such an experience would probably indicate that the receiving lines ashore are not clear.

Back pressure should be continually monitored during discharge operations and the ship, using ship's pumps, should be ready to stop pumping at short notice from a signal from the terminal. The waterline around the ship should also be kept under regular surveillance in the event of leakage occurring.

As with loading operations, the deck scuppers should all be sealed and SOPEP recommendations followed. All fire-fighting equipment should be kept readily available throughout the operation.

Ballasting

In order that no oil is allowed to escape into the sea when engaging in ballast operations, the pumps should be started before the sea valves are opened. If it is intended to ballast by gravity it is still preferable to pump for the first 10 min or so to ensure that no oil leaks out.

Care should also be taken when topping up ballast tanks since any water overflow could be contaminated with oil. Any gas forced out of tanks during ballast operations constitutes a fire risk as equally dangerous as when loading.

All ballast operations should be recorded in the Ballast Management Record Book and any transfers of oil content should be recorded in the Oil Record Book. Log books should take account of all tank operations regarding loading, discharging, ballasting or cleaning.

Tank-cleaning methods

There are generally three methods of cleaning tanks:

1. Bottom flushing with water, petroleum product or chemical solvents
2. Water washing (hot or cold) employing tank-washing machinery
3. Crude oil washing (COW).

Bottom washing

Bottom flushing is usually carried out to rid the tank bottoms of previous cargo prior to loading a different, but compatible grade of cargo.

It can be effective when carrying refined products in small quantities. Bottom washing with acceptable solvents is sometimes conducted, especially where a tanker is to take say paraffin (kerosene) products after carrying leaded gasolines. It should be realized that bottom washing will not remove heavy wax sediments from the bottom of tanks and is used purely as a means of removing the traces of previous cargo.

Portable or fixed washing machines

Using a high-pressure pump and heater, sea water, via a tank-cleaning deck line, is applied to wash the tank thoroughly. The dirty slop water is then stripped back to the slop tank where it is heated to separate the oil from the water.

This is considered an essential method when changing trades from carrying crude to the white oil cargoes, or when the tank is required for clean ballast, or if it is to be gas freed.

COW

A procedure that is conducted during the discharge and which has positive advantages over water-washing methods. New crude oil carriers over 20 000-dwt tonnes must now be fitted and use a COW facility. The method employs a high-pressure jet of crude oil from fixed tank-cleaning equipment. The jet is directed at the structure of the tank and ensures that no slops remain onboard after discharge, every last drop of cargo-going ashore. The advantages are that tank cleaning at sea is avoided, with less likelihood of accidental pollution; less tank corrosion is experienced than from water washing; increased carrying capacity is available for the next cargo; full tank drainage is achieved; and time saved gas freeing for dry dock periods.

Some disadvantages of the system include crew workload, which is increased at the port of discharge; discharge time is increased; it has a high installation cost and maintenance costs are increased, while crew need special training with operational aspects.

Aspects of COW

The operational principle of the COW system is to use dry crude from a full tank to wash the tanks being discharged. Crude containing water droplets from the bottom of a tank should not be used for washing purposes as this may introduce water droplets that have become electrostatically charged and produce an unnecessary source of ignition in the tank atmosphere.

To this end any tank designated for use as COW should be first de-bottomed into the slop tank or bled ashore with the discharge pump.

One of the main cargo pumps is used to supply the COW line with pressurized crude for washing operations. The line, along the deck, will carry branch lines to all of the fixed machines. Large and very large crude carrier (VLCC) vessels may have up to six (6) machines per tank.

Safety in operation Tanks must be fully inerted prior to commencing washing operations and the heater in the tank-washing system must be isolated by blanks. The line would need to be pressurized and tested for leaks prior to commencing washing.

- *Operation – Stage One*: The limits to cover the top of the cycle would need to be adjusted to be pointing upwards. Where portable drive units are employed these would have to be initially fitted and limits set accordingly (Figure 5.16(a)).
- *Operation – Stage Two*: The second stage starts when one-third of the tank is discharged and the washing jet will only be allowed to travel down to a point where the jet strikes the bulkhead just above the level of the oil in the tank. At this stage the machine completes 1½ cycles and must therefore be adjusted, up again, before the start of the next stage (Figure 5.16(b)).

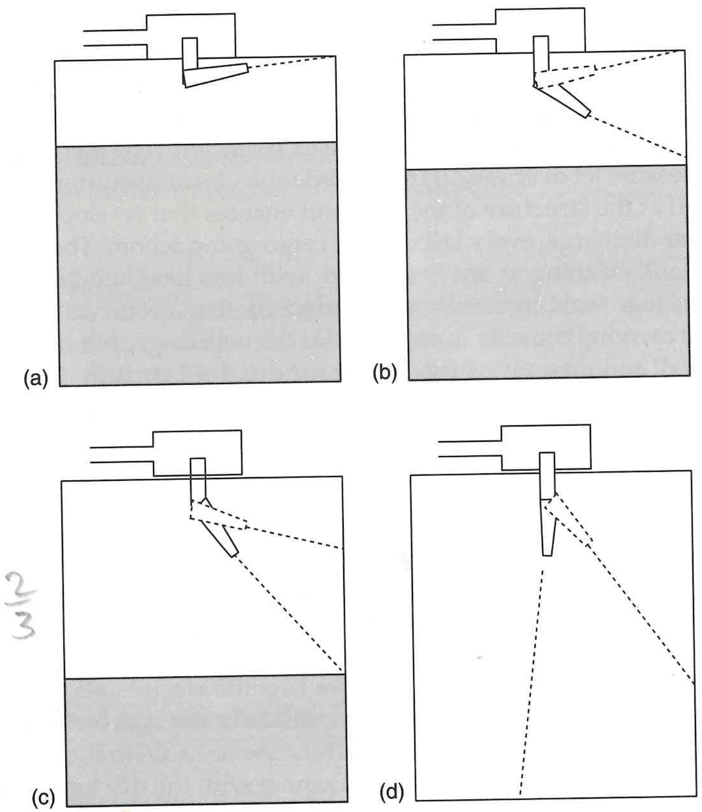


Fig. 5.16 COW cycles. (a) First Cycle Stage One – nozzle elevated for upper level wash. (b) Second Cycle Stage Two – one-third of cargo discharged, nozzle programmed to wash upper third of tank. (c) Third Cycle Stage Three – two-thirds of the cargo is discharged. Nozzle programmed to wash mid levels of the tank. (d) Fourth Cycle, last stage – machine programmed so that the lower levels and the last washing cycle coincide with the end of discharge.

- *Operation – Stage Three*: The third stage is where the machine washes from where two-thirds of the tank has been discharged and between one- and two-thirds of the tanks structure is washed (Figure 5.16(c)).
- *Operation – Last Stage*: The final stage washes the last third and the bottom of the tank with the jet pointing in the downward position (Figure 5.16(d)).

COW – preparation and activities

Prior to arrival at the port of discharge:

1. Has the terminal been notified?
2. Is oxygen-analysing equipment tested and working satisfactorily?
3. Are tanks pressurized with good quality IG (maximum 8% oxygen)?
4. Is the tank-washing pipeline isolated from water heater and engine room?
5. Are all the hydrant valves on the tank-washing line securely shut?
6. Have all tank-cleaning lines been pressurized and leakages made good?

In port:

1. Is the quality of the IG in the tanks satisfactory (8% oxygen or less)?
2. Is the pressure on the IG satisfactory?
3. Have all discharge procedures been followed and ship-to-shore check-list completed?

Before washing:

1. Are valves open to machines on selected tanks for washing?
2. Are responsible persons positioned around the deck to watch for leaks?
3. Are tank ullage gauge floats lifted on respective tanks to be washed?
4. Is the IG system in operation?
5. Are all tanks closed to the outside atmosphere?
6. Have tanks positive IG pressure?

During washing:

1. Are all lines oil tight?
2. Are tank-washing machines functioning correctly?
3. Is the IG in the tanks being retained at a satisfactory quality?
4. Is positive pressure available on the IG system?

After washing:

1. Are all the valves between discharge line and the tank-washing line shut down?
2. Has the tank-washing main pressure been equalized and the line drained?
3. Are all tank-washing machine valves shut?

After departure:

1. Have any tanks due for inspection been purged to below the critical dilution level prior to introducing fresh air?
2. Has oil been drained from the tank-washing lines before opening hydrants to the deck?

The IG system

Tanker vessels have an inherent danger from fire and/or explosion and it is desirable that the atmosphere above an oil cargo or in an empty tank is such that it will not support combustion. The recognized method of achieving this status is to keep these spaces filled with an IG. Such a system serves two main functions:

1. Use of IG inhibits fire or explosion risk
2. It inhibits corrosion inside cargo tanks.

As IG is used to control the atmosphere within the tanks it is useful to know exactly what composition the gases are, not only from a safety point of view but to realize what affect such an atmosphere would have on the construction of the tanks.

Boiler flu gas consists of the following mix (assuming a well-adjusted boiler):

Component	*Percentage of IG*
Nitrogen	83
Carbon dioxide (CO_2)	13
Carbon monoxide	0.3
Oxygen	3.5
Sulphur dioxide	0.005
Nitrogen oxides	Traces
Water vapour	Traces
Ash	Traces
Soot	Traces

Flu gases leave the boiler at about 300°C, contaminated with carbon deposits and sulphurous acid gas. The gas then passes through a scrubber which washes out the impurities and reduces the temperature to within 1°C of the ambient sea temperature.

The clean cooled gas is now moisture laden and passes through a demister where it is dried. It is then fan assisted on passage towards the cargo tanks passing through a deck water seal and then over the top of an oil seal to enter at the top of the tank. It is allowed to circulate and is purged through a pipe which extends from the deck to the bottom of the tank (Figure 5.17).

There is a sampling cock near the deck water seal for monitoring the quality of the IG. Individual tank quality is tested by opening the purge pipe cover and inserting a sample probe.

Excess pressure in the cargo tanks being vented through a pressure vacuum valve (P/V valve) set at 2 psi, which is then led to a mast riser fitted with a gauze screen. The excess is then vented to atmosphere as far from

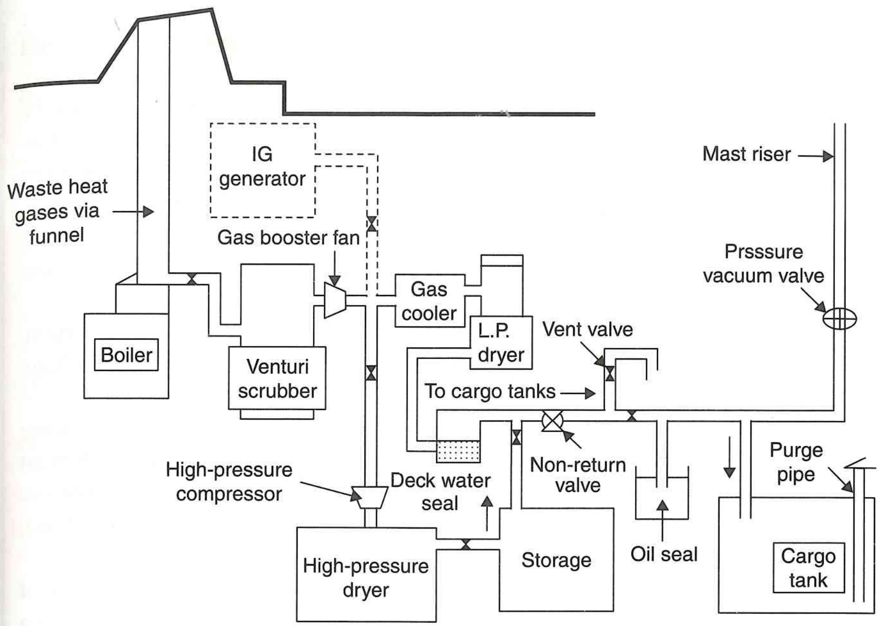


Fig. 5.17 The IG system.

Requirements for IG systems

Additional reference should be made to the Revised Guidelines for Inert Gas Systems adopted by the Maritime Safety Committee, June 1983 (MSC/Circ. 353).

In the case of chemical tankers, reference, Resolution A. 567(14) and A. 473(XIII).

Tankers of 20 000 tonnes deadweight and above, engaged in carrying crude oil, must be fitted with an IG system:

1. Venting systems in cargo tanks must be designed to operate to ensure that neither pressure nor vacuum inside the tanks will exceed design parameters, for volumes of vapour, air or IG mixtures.
2. Venting of small volumes of vapour, air or IG mixtures, caused by thermal variations effecting the cargo tank, must pass through 'P/V valves'.

   Large volumes caused by cargo loading, ballasting or during discharge must not be allowed to exceed design parameters.

   A secondary means of allowing full flow relief of vapour, air or IG mixtures, to avoid excess pressure build-up must be incorporated, with a pressure sensing, monitoring arrangement. This equipment must also provide an alarm facility activated by over-pressure.

3. Tankers with double-hull spaces and double-bottom spaces shall be fitted with connections for air and suitable connections for the supply of IG. Where hull spaces are fitted to the IG permanent distribution system, means must be provided to prevent hydrocarbon gases from cargo tanks, entering double-hull spaces (where spaces are not permanently connected to the IG system appropriate means must be provided to allow connection to the IG main).
4. Suitable portable instruments and/or gas-sampling pipes for measuring flammable vapour concentrations and oxygen must be provided to assess double-hull spaces.
5. All tankers operating with a COW system must be fitted with an IG system.
6. All tankers fitted with an IG system shall be provided with a closed ullage system.
7. The IG system must be capable of inerting empty cargo tanks by reducing the oxygen content to a level which will not support combustion. It must also maintain the atmosphere inside the tank with an oxygen content of less than 8% by volume and at a positive pressure at all times in port or at sea, except when necessary to gas free.
8. The system must be capable of delivering gas to the cargo tanks at a rate of 125% of the maximum rate of discharge capacity of the ship, expressed as a volume.
9. The system should be capable of delivering IG with an oxygen content of not more than 5% by volume in the IG supply main to cargo tanks.
10. Flue gas isolating valves must be fitted to the IG mains, between the boiler uptakes and the flue gas scrubber. Soot blowers will be arranged so as to be denied operation when the corresponding flue gas valve is open.
11. The 'scrubber' and 'blowers' must be arranged and located aft of all cargo tanks, cargo pump rooms and cofferdams separating these spaces from machinery spaces of Category 'A'.
12. Two fuel pumps or one with sufficient spares shall be fitted to the IG generator.
13. Suitable shut offs must be provided to each suction and discharge connection of the blowers. If blowers are to be used for gas freeing they must have blanking arrangements.
14. An additional water seal or other effective means of preventing gas leakage shall be fitted between the flue gas isolating valves and scrubber, or incorporated in the gas entry to the scrubber, for the purpose of permitting safe maintenance procedures.
15. A gas-regulating valve must be fitted in the IG supply main, which is automatically controlled to close at predetermined limits.
(This valve must be located at the forward bulkhead of the foremost gas-safe space.)
16. At least two non-return devices, one of which will be a water seal must be fitted to the IG supply main. These devices should be located in the cargo area, on deck.
17. The water seal must be protected from freezing, and prevent backflow of hydrocarbon vapours.

18. The second device must be fitted forward of the deck water seal and be of a non-return valve type or equivalent, fitted with positive means of closing.
19. Branch piping of the system to supply IG to respective tanks must be fitted with stop valves or equivalent means of control, for isolating a tank.
20. Arrangements must be provided to connect the system to an external supply of IG.
21. Meters must be fitted in the navigation bridge of combination carriers which indicate the pressure in slop tanks when isolated from the IG main supply. Meters must also be situated in machinery control rooms for the pressure and oxygen content of IG supplied (where a cargo control room is a feature these meters would be fitted in such rooms).
22. Automatic shutdown of IG blowers and the gas-regulating valve shall be arranged on predetermined limits.
23. Alarms shall be fitted to the system and indicated in the machinery space and the cargo control room. These alarms monitor the following:
    - Low water pressure or low water flow rate to the flu gas scrubber.
    - High water level in the flu gas scrubber.
    - High gas temperature.
    - Failure of the IG blowers.
    - Oxygen content in excess of 8% by volume.
    - Failure of the power supply to the automatic control system, regulating valve and sensing/monitoring devices.
    - Low water level in the deck water seal.
    - Gas pressure less than 100-mm water gauge level.
    - High gas pressure.
    - Insufficient fuel oil supply to the IG generator.
    - Power failure to the IG generator.
    - Power failure to the automatic control of the IG generator.

Hazards with IG systems

The IG system aboard any vessel has two inherent hazards:

1. If the cooling water in the scrubber should fail, then uncooled gas at 300°C would pass directly to the cargo tank. This is prevented by the fitting of two water sensors in the base of the scrubber which, if allowed to become uncovered, would generate an alarm signal which shuts the system down and vents the gas to atmosphere. In the event that both sensors failed two thermometer probes at the outlet of the scrubber would sense an unacceptable rise in temperature and initiate the same shutdown procedure.
2. If there was a failure in the P/V valve, at the same time as a rise in the pressure within the cargo tank, it would result in pressure working backwards towards the boiler with a possible risk of explosion. This is prevented by the water in the deck seal forming a plug in the IG line until

a sufficient head is generated to blow out the oil seal and the excess pressure vents to the deck. The pressure of water in the water seal is essential; therefore, the two water sensors would sense its absence and shut down the plant as previously stated.

IG pressure should be maintained at a positive pressure at all times, to avoid air being forced into the cargo spaces. Such a positive pressure is also exerted onto the surface of the oil cargo and assists in pushing the oil along the suction line towards the cargo pump, and in so doing assists the draining of the tanks. Any excess pressure in the cargo tanks is vented through the P/V valve.

IG – voyage cycle

- *Phase 1* – Vessel departs dry dock with all tanks vented to atmosphere and partially ballasted. The IG plant is started, empty tanks and ullage spaces purged to atmosphere until oxygen levels are acceptable. IG quality should be monitored and maintained throughout the ballast voyage.
- *Phase 2* – Prior to arrival at the loading port the IG plant would be started and ballast reduced to about 25% of the ships deadweight, ballast being replaced by IG. After berthing, the remainder of the seawater ballast would be discharged and replaced by IG. The IG plant would then be shut down, the deck isolation valve would be closed and the mast riser opened, prior to commencing loading. IG would be displaced through mast risers. On completion of loading, the IG would be topped up to a working pressure which would be maintained though the loaded voyage (this would be expected to reduce evaporation and prevent oxygen access).
- *Phase 3* – On arrival at the port of discharge, the IG plant would be set to maximum output with discharge pumps at maximum output. The IG pressure should be monitored carefully and if it approaches a negative, the rate of discharge of the cargo reduces. The mast riser must never be opened to relieve the vacuum during the discharge period.
- *Phase 4* – On completion of discharge, the IG system should be shut down. If and when ballasting takes place the IG and hydrocarbons would be vented to atmosphere.
- *Phase 5* – On departure from the discharge port all tanks must be drained to the internal slop tank, then purged with IG to reduce the hydrocarbon levels to below 2%.
- *Phase 6* – Tank cleaning can now be permitted with IG in fully inerted tanks. This weakens the hydrocarbon level and the positive pressure prevents pumps draining or drawing atmosphere into the tanks.
- *Phase 7* – When all the vessels tanks have been washed and ballast changed it may be necessary to carry out tank inspections. If this is the case, all tanks would then have to be purged with IG to remove all traces of hydrocarbon gas before venting by fans. All tanks would then be tested with explosi-meter and oxygen analyser (full procedure for enclosed space entry must be observed before internal inspection).

Advantages and disadvantages of the IG system

Advantages

1. A safe tank atmosphere is achieved which is non-explosive
2. It allows high-pressure tank washing and reduces tank-cleaning time
3. It allows COW
4. Reduces corrosion in tanks – with an efficient scrubber in the system
5. Improves stripping efficiency and reduces discharge time
6. Aids the safe gas freeing of tanks
7. It is economical to operate
8. It forms a readily available extinguishing agent for other spaces
9. Reduces the loss of cargo through evaporation
10. Complies with legislation and reduces insurance premiums.

Disadvantages

1. Additional costs for installation
2. Maintenance costs are incurred
3. Low visibility inside tanks
4. With low oxygen content, tank access is denied
5. Could lead to contamination of high-grade products
6. Moisture and sulphur content corrodes equipment
7. An established reverse route for cargo to enter the engine room
8. Oxygen content must be monitored and alarm sensed at all times
9. Instrumentation failure could affect fail-safe devices putting the ship at risk through the IG system
10. An additional gas generator is required in the system in the absence of waste heat products from boiler flue gases.

> ***Note:*** *Instrumentation of the system to cover: IG temperature pressure read outs and recorders. Alarms for: blower failure, high oxygen content alarm, high and low gas pressure alarms, high gas temperature, low seawater pressure and low level alarm in the scrubber and the deck water seal, respectively.*

Deck water seal operation

The water level in the deck water seal is maintained by constant running of the seawater pump and a gooseneck drain system. Under normal IG pressure the IG will bubble through the liquid from the bottom of the IG inlet pipe and exit under normal operating pressure. In the event of a back pressure developing and the water surface experiencing increased pressure, this would force the water level up the IG inlet pipe, sealing this pipe entrance and preventing hydrocarbons entering the scrubber (Figure 5.18).

Tank atmosphere

The Cargo Officer will need to be able to assess the condition of the atmosphere inside the tank on numerous occasions. To this end, various monitoring

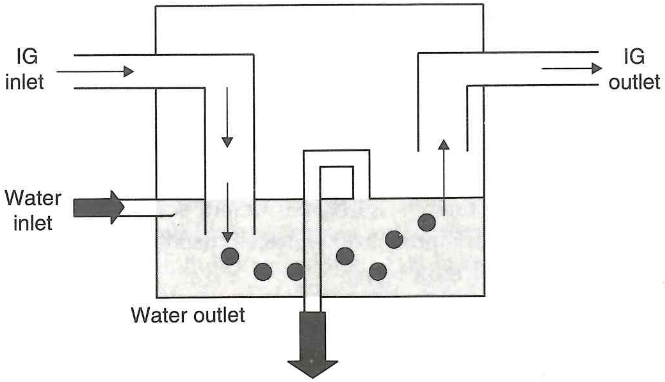


Fig. 5.18 Deck water seal operation.

equipment is available to carry out 'gas detection' and 'oxygen content'. The officer should be familiar with the type of equipment aboard his/her own vessel and have a degree of understanding how such instrumentation operates.

Gas detection

It should be understood from the outset that many accidents and loss of life has occurred through lack of knowledge of gas-detection methods and the correct practice concerning this topic. The explosi-meter, of which there are several trade names available, is used for detecting the presence of flammable gas and/or air mixture.

The explosi-meter The explosi-meter is an instrument which is specifically designed for measuring the lower flammable limit (LFL). It will only function correctly if the filament has an explosive mixture in contact with it. It is contained in a hand-held size box with a battery power supply (Figure 5.19).

When in use, the sample tube is lowered into the tank and a sample of the atmosphere is drawn up into the instrument by several depressions of the rubber aspirator bulb. If the sample contains an explosive mixture the resistance of the catalytic filament will change due to the generated heat. An imbalance of the wheat-stone bridge is detected by the ohmmeter which tells the operator that hydrocarbon gas is present in the tank in sufficient quantity to support combustion.

Note: Combustibles in the sample are burned on the heated filament, which raises its temperature and increases the resistance in proportion to the concentration of combustibles in the sample. This then causes the imbalance in the wheat-stone bridge.

However, it should be realized that a zero reading does not necessarily indicate that there is no hydrocarbon gas present, nor does it mean that no oxygen is present. All it signifies is that the sample taken is either too rich or too lean to support combustion. Care must be taken when testing the

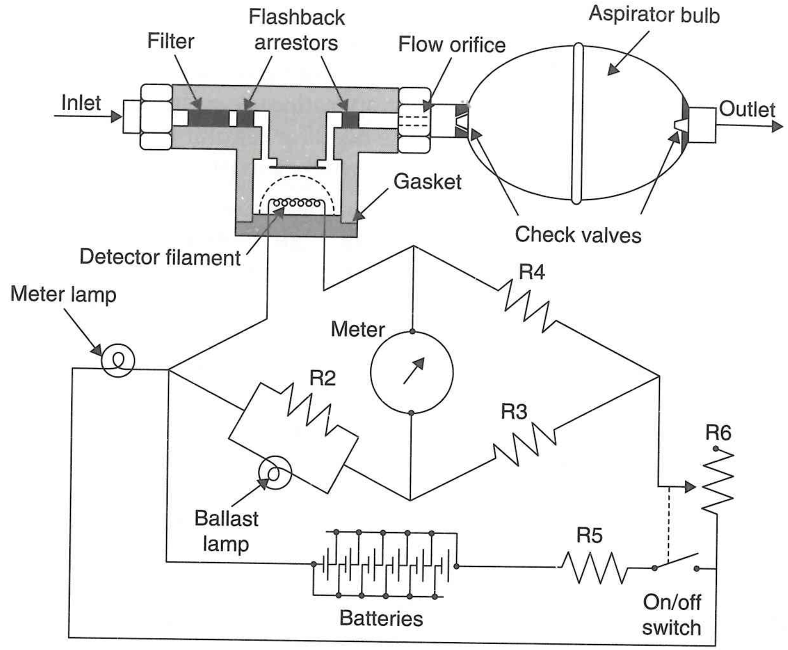


Fig. 5.19 The MSA model 2E explosi-meter (combustible gas detector).

atmosphere in enclosed spaces to give consideration for the relative vapour density where mixtures of gases are encountered. A test at one particular level in a tank should be realized as not necessarily being an equivalent reading for other different levels in the same tank.

The electrical bridge circuit of the instrument is designed so that its balance is established at the proper operating temperature of the detecting filament. The circuit balance and detector current are adjusted simultaneously by adjustment of the rheostat. The proper relationship between these two factors is maintained by a special ballast lamp in the circuit.

The graduations on the meter are a per cent of the lower explosive limit (LEL) reading between 0% and 100%. A deflection of the meter between 0% and 100% shows how close the atmosphere being tested approaches the minimum concentration required for explosion. When a test is made with the explosi-meter, and a deflection to the extreme right-hand side of the scale is noted and remains there, then the atmosphere under test is explosive.

Limitations of explosi-meters – The explosi-meter has been designed to detect the presence of flammable gases and vapours. The instrument will indicate in a general way whether or not the atmosphere is dangerous from a flammability point of view. It is important to realize that such information obtained from the instrument is appraised by a person skilled in the interpretation of the reading, bearing in mind the environment. For example, the atmosphere sample which is indicated as being non-hazardous from the standpoint of fire and explosion, may if inhaled, be toxic to workers who are exposed to that same atmosphere.

Additionally, a tank that is deemed safe before work is commenced may be rendered unsafe by future ongoing operations, e.g. stirring or handling bottom sludge. This would indicate the need for regular testing practices to be in place in questionable spaces while work is in progress.

Explosi-meter special uses – Where the explosi-meter is employed to test an atmosphere which is associated with high boiling point solvents, it should be borne in mind that the accuracy of the reading may be questionable. The space may be at a higher temperature than the instrument, and therefore it must be anticipated that some condensation of combustible vapours would be in the sampling line. As a consequence, the instrument could read less than the true vapour concentration.

A way around this would possibly be to warm the sampling line and the instrument unit to an equivalent temperature as that of the space being tested.

Note: *Under no circumstances should such instruments be heated over 65°C (150°F).*

Furthermore, some types of instruments are designed to measure combustible vapours in air. They are not capable of measuring the percentage vapours in a steam or inert atmosphere, due to the absence of oxygen necessary to cause combustion.

Care in use – When sampling over liquids, care should be taken that the sampling tube does not come into contact with the liquid itself. A probe tube can be used in tests of this character, to prevent liquid being drawn into the sampling tube.

Drager instruments This is an instrument which draws a gas or vapour through an appropriate glass testing tube, each tube being treated with a chemical that will react with a particular gas, causing discolouration progressively down the length of the tube. When measured against a scale, the parts per million (ppm) can be ascertained.

The instrument is used extensively on the chemical carrier trades though it does have tubes for use with hydrocarbons, which make it suitable for use on tankers.

Alarm system detectors An instrument which is taken into a supposedly gas-free compartment and used while work is ongoing. If gas is released or disturbed in the work place a sensitive element on the instrument triggers an audible and visual alarm. Once the alarm has been activated personnel would be expected to evacuate the compartment immediately.

The oxygen analyser

In order for an atmosphere to support human life it must have the oxygen content of 21%. The oxygen analyser is an instrument that measures the oxygen content of an atmosphere to establish whether entry is possible, but ... which must be retained under 5%

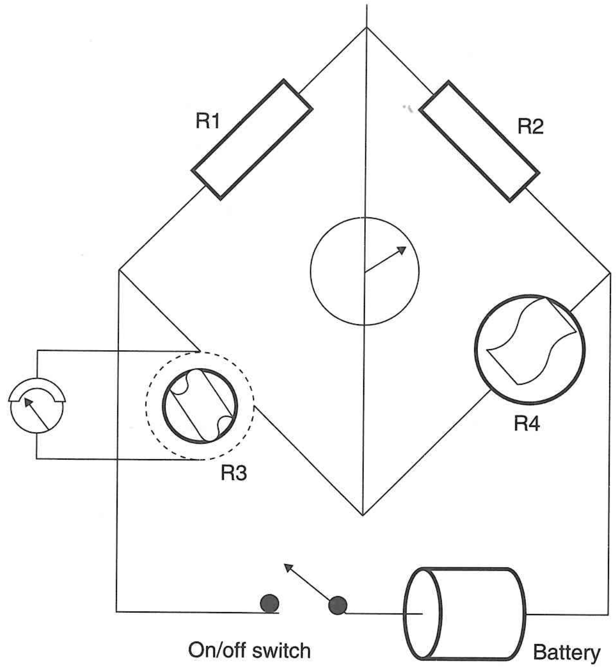


Fig. 5.20 Oxygen analyser – circuitry principle.

The oxygen sensor will be either an electromagnetic heated filament or an electrochemical resistor cell. The instrument was designed to measure the oxygen content only and will not detect the presence of any other gases. As shown in Figure 5.20, the resistor filaments R3 and R4 are of equal rating. The resistor filament R3 is surrounded by a magnetic field. The atmosphere sample drawn past the filament will depend on the permitted current flow through the coil and meter, depending on the amount of oxygen in the sample.

Oxygen analysers are portable instruments which draw a sample of the atmosphere for testing through a sampling hose by means of a rubber aspirator bulb. The principle of operation is a self-generating electrolytic cell in which the electric current is directly proportional to the percentage oxygen in a salt solution connecting to the electrodes. The electrodes are connected to a micro-ammeter, so that the current read by the meter can be calibrated to indicate directly the percentage oxygen of the sample.

There are variations and different types of instruments available. Manufacturer's instructions and manuals for use and maintenance should therefore be followed when these instruments are employed.

Chemical reaction measuring device

Gas detection can also be achieved by using a test sample of the atmosphere to pass over a chemical-impregnated paper or crystal compound

The amount of discolouration occurring in the crystals or on the paper can then be compared against a scale to provide the amount of gas within the sample. The operation uses a bellows to draw through a 100 cm^3 of sample gas and a variety of tubes can be used to indicate specific gases. Example gases indicated are likely to be, but not limited to carbon monoxide, hydrogen sulphide, hydrocarbon, radon, nitrous oxide. A popular instrument is the 'Drager Tube System' for gas detecting.

Although well-used in the industry, the system does have drawbacks in the fact that the tubes required for different gases have a limited shelf life. The bellows can develop leaks and they can be affected by temperature extremes. Tube insertion must also be carried out the correct way.

Coastal and shuttle tanker operations

Numerous small tanker operations are engaged in coastal regions around the world and employ the services of coastal-sized craft to shuttle cargo parcels between main terminal ports, FSUs and the smaller out of the way ports. Restrictions are often put on direct delivery from the ocean-going vessels because of the available depth of water in the smaller enclaves and as such the geography imposes draught restrictions on the larger vessels. This particular drawback is also affecting the container trade, with container vessels currently being increased in overall size, the larger vessels are finding some ports are not available to them because of similar draught restrictions (Figure 5.21).

Fig. 5.21 The coastal oil tanker 'Alacrity' lies port side to a terminal berth in

Examples of tanker cargoes

Bitumen – this cargo solidifies at normal temperatures and must be kept hot during transit. Ships are specifically designed for this trade, with large centre tanks and additional heating coils. The centre tanks being used for cargo and the wing tanks for ballast.

Chemicals (various) – precautions for these cargoes as outlined in previous text. Additional reference to the International Maritime Dangerous Goods (IMDG) Code and respective precautions pertaining to the type of commodity.

Creosote – this is a very heavy cargo and requires constant heating during the voyage.

Crude oil – varies greatly with RD and viscosity. It is not heated unless a very heavy grade, as heating evaporates the lighter fractions. Crude oil has a high fire risk.

Diesel oil – is an intermediate between fuel oil and gas oil. It is generally regarded as a dirty oil but its viscosity is such that it does not require heating prior to discharge.

Fuel oil – is a black oil and is graded according to its weight and viscosity. It has a low fire risk and generally requires heating prior to discharge.

Gas oil – this is a clean oil and is used for light diesel engines as well as for making gas. A reasonable level of cleanliness is required before loading this cargo, which may be used as a transition cargo when a ship is being changed from a black oil carrier to a clean oil trade. Fire risk is low and no heating is required.

Gasoline (petrol) – is light and volatile. It has a high fire risk and may easily be contaminated if loaded into tanks which are not sufficiently clean.

Grain – may be successfully carried in selective tankers since when in a bulk state it has many of the qualities of a liquid. It requires very careful tank preparation and tankers would only normally enter the trade if the oil market was depressed.

Kerosene (paraffin) – this is a clean oil which is easily discoloured. Precautions should be taken to prevent the build-up of static. These may include a slow loading and discharge pattern being employed.

Latex – an occasional cargo carried in tankers and in ships 'deep tanks'. Usually has added ammonia. The tanks should be exceptionally clean and fitted with pressure relief valves. Steelwork is pre-coated in paraffin wax and heating coils in tanks should be removed. Following discharge the tanks should be washed with water to remove all traces of ammonia.

Liquefied gases – generally carried in specifically designed vessels for the transport of LNG and liquid propane gas (a liquefied petroleum gas, LPG).

Lubricating oils – these are valuable cargoes and are usually shipped in the smaller product carriers. Good separation is necessary to avoid contamination between grades. Tanks and pipelines must be free of water before loading. Some grades may require heating before discharging.

Molasses – a heavy viscous cargo which is normally carried in designated tankers specific for the trade. A comprehensive heating system is necessary and special pumps are provided to handle the thick liquid.

Propane – a gas similar to 'butane', see liquefied gases.

Vegetable oils – these are generally carried in small quantities in the deep tanks of cargo ships but some such as 'linseed oil' may be carried in tankers. Exceptional cleanliness of the tanks is required prior to loading such a cargo.

Whale oil – whale factory ships are basically tankers carrying fuel oil on the outward passage and whale oil when homeward bound. Careful cleaning is required before carrying whale oil in tanks which previously carried fuel oil (in recent years the practice of whale hunting has been severely restricted).

Wine – can be carried in tankers but they are usually dedicated ships to the trade. Similar vessels sometimes engage in the carriage of fruit juices, especially orange juice. A high degree of cleanliness in the tanks is expected (Ref. page 162).

Product tankers

Product tankers tend to be smaller and more specialized than the large crude oil carriers and generally lay alongside specialized berths when loading and discharging, employing specialist product lines to avoid contamination of cargoes (Figures 5.22 and 5.23).

Fig. 5.23 The product tanker 'Folesandros' lies port side to the berth, discharging in Gibraltar.

Bulk liquid chemical carriers

Phrases and terminology associated with the chemical industry

Adiabatic expansion – is an increase in volume without a change in temperature or without any heat transfer taking place.

Anaesthetics – chemicals that affect the nervous system and cause anaesthesia.

Aqueous – a compound within a water-based solution.

Auto-ignition – a chemical reaction of a compound causing combustion without a secondary source of ignition.

Boiling point – that temperature at which a liquid's vapour pressure is equal to the atmospheric pressure.

Catalyst – a substance that will cause a reaction with another substance or one that accelerates or decelerates a reaction.

Critical pressure – that minimum pressure which is required to liquefy a gas at its critical temperature.

Critical temperature – that maximum temperature of a gas at which it can be turned into a liquid by pressurization.

Filling ratio – that percentage volume of a tank which can be safely filled allowing for the expansion of the product.

Freezing point – that temperature at which a substance must be at to change from a liquid to a solid state or vice versa.

Hydrolysis – that process of splitting a compound into two parts by the agency of water. One part being combined with hydrogen, the other with hydroxyl.

Hydroscopic – that ability of a substance to absorb water or moisture from the atmosphere.

Inhibitor – a substance which, when introduced to another, will prevent a reaction.

Narcosis – a human state of insensibility resembling sleep or unconsciousness, from which it is difficult to arouse.

Oxidizing agent – an element or compound that is capable of adding oxygen to another.

Padding – a procedure of displacing air or unwanted gasses from tanks and pipelines with another compatible substance, e.g. IG, cargo vapour or liquid.

Polymerization – that process which is due to a chemical reaction within a substance, capable of changing the molecular structure within that substance, i.e. liquid to solid.

Reducing agent – an element or compound that is capable of removing oxygen from a substance.

Reid vapour pressure – is that vapour pressure of a liquid as measured in a Reid apparatus at a temperature of 100°F expressed in psi/°A.

Self-reaction – is that ability of a chemical to react without other influence which results in polymerization or decomposition.

Sublimation – that process of conversion from a solid to a gas, without melting (an indication that the flash point is well below the freezing point).

Threshold limit value – is that value reflecting the amount of gas, vapour, mist or spray mixture that a person may be daily subjected to, without suffering any adverse effects (usually expressed in ppm).

Vapour density – that weight of a specific volume of gas compared to an equal volume of air, in standard conditions of temperature and pressure.

Vapour pressure – that pressure exerted by a vapour above the surface of a ... of mercury mmHg).

Bulk chemical cargoes

The term liquid chemicals within the industry is meant to express those chemicals in liquid form at an ambient temperature or which can be liquefied by heating, when carried at pressures up to 0.7 kg/cm^2. Above this the chemical pressure would fall into the category of 'liquefied gases'.

The chemicals carried at sea have a variety of properties. Nearly half of the 200 chemicals commonly carried have fire or health hazards no greater than petroleum cargoes. Therefore, they can be safely carried by way of ordinary product carriers, though some modification is sometimes required to avoid contamination.

Other chemical substances require quality control much more stringent than petroleum products. Contamination, however slight, cannot be allowed to occur and for this reason tanks are nearly always coated or made of special materials like stainless steel.

Extreme care must be exercised when loading such cargoes that any substance which could cause a reaction are kept well separated. To ensure quality and safe carriage, separate pipelines, valves and separate pumps are the norm for specific cargo parcels. Also reactionary chemicals cannot be placed in adjacent tanks with only a single bulkhead separation. Neither can pipelines carrying one substance pass through a tank carrying another substance with which it may react. Chemical products which react with sea water are carried in centre tanks while the wing tanks are employed to act as cofferdams.

Chemical carriers require experienced and specialized trained personnel in order to conduct their day-to-day operations safely. They also require sophisticated cargo-handling and monitoring equipment. The ships must conform in design and construction practice to the IMO 'Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk'.

The purpose of the 'code' is to recommend suitable design criteria, safety measures and construction standards for ships carrying dangerous chemical substances. Much of the content of the code has been incorporated into the construction regulations produced by the Classification Societies.

Classification – chemical carriers

(Chapter references to the International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk) (IBC)

In general ships carrying chemicals in bulk are classed into three types:

1. *A 'Type 1' ship* is a chemical tanker intended to transport Chapter 17 of the IBC Code products with very severe environmental and safety hazards which require maximum preventive measures to preclude an escape of such cargo.
2. *A 'Type 2' ship* is a chemical tanker intended to transport Chapter 17 of the IBC Code products with appreciably severe environmental and safety hazards which require significant preventive measures to preclude an escape of such cargo.

3. *A 'Type 3' ship* is a chemical tanker intended to transport Chapter 17 of the IBC Code products with sufficiently severe environmental and safety hazards which require a moderate degree of containment to increase survival capability in a damaged condition.

Many of the cargoes carried in these ships must be considered as extremely dangerous and, as such, the structure of the ship's hull is considered in the light of the potential danger, which might result from damage to the transport vessel. Type 3 ships are similar to product tankers in that they have double hulls but have a greater subdivision requirement. Whereas Types 1 and 2 ships must have their cargo tanks located at specific distances inboard to reduce the possibility of impact load directly onto the cargo tank (Figure 5.24).

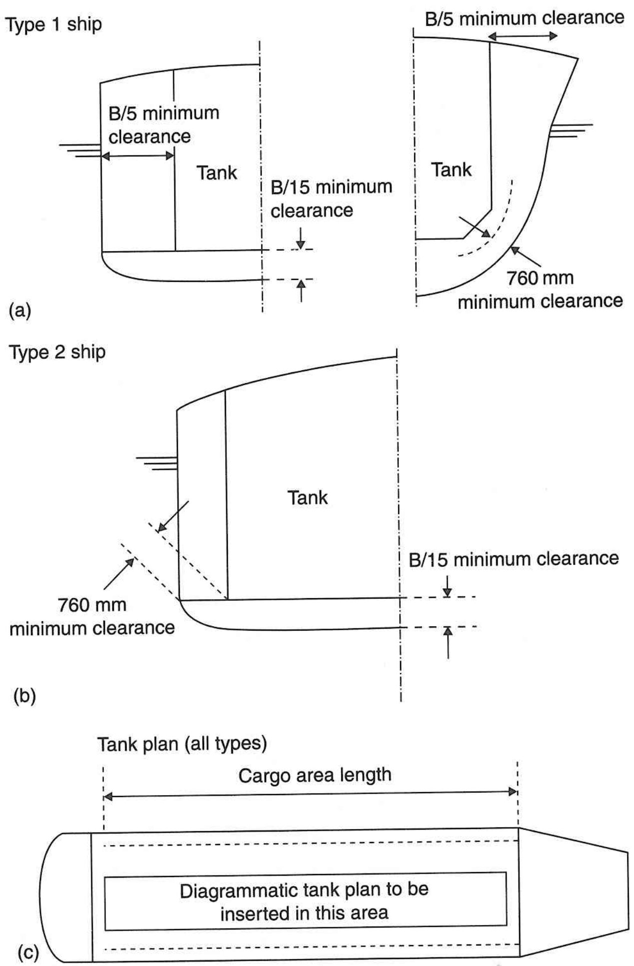


Fig. 5.24 The tank arrangement must be attached to the International Certificate of Fitness for the carriage of Dangerous Chemicals in Bulk.

Parcel tankers – construction features

Ships built specifically as parcel tankers with the intention of carrying a wide variety of cargoes will generally have some tanks of 'stainless steel' or tanks clad in stainless steel. For reasons of construction and cost this means having a double skin. Mild steel tanks may similarly be built with side cofferdams and a double bottom and are usually coated in either epoxy or silicate. Chemicals of high density like 'ethylene dibromide' may have specially constructed tanks or in some cases only carry partly filled cargo tanks (Figure 5.25).

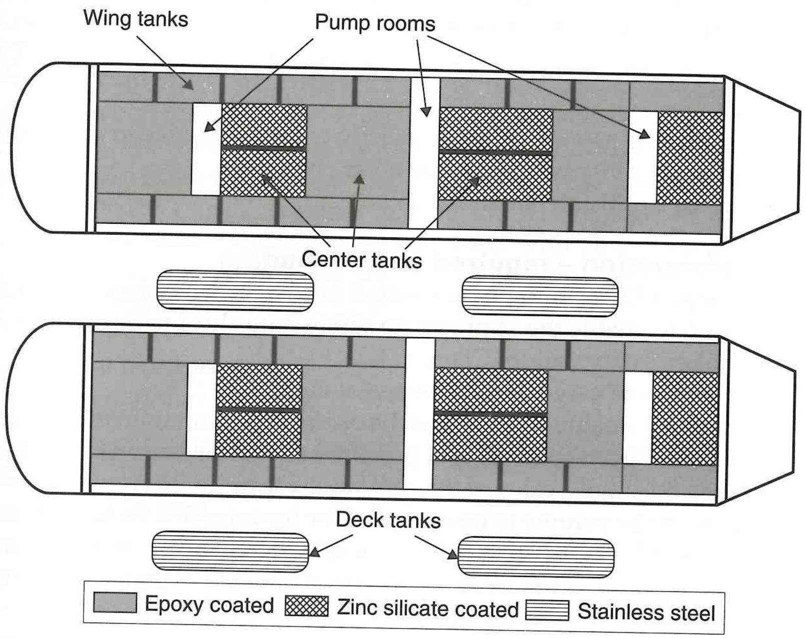


Fig. 5.25 Diagram of a parcel tanker.

Similarly, cargoes with higher vapour pressures may generate a need for tanks to be constructed to withstand higher pressures than say the conventional tanker – particularly relevant where the boiling point of the more volatile cargoes is raised and the risk of loss is increased.

The IBC Code specifies requirements for safety equipment to monitor vapour detection, fire protection, ventilation in cargo-handling spaces, gauging and tank filling. Once all criteria is met the Marine Authority (Maritime and Coastguard Agency (MCA) in the UK) will issue, on application an MCA/IMO Certificate of Fitness for the Carriage of Dangerous Cargoes in Bulk.

Vapour lines

In general, each tank will have its own vapour line fitted with P/V valves but grouped tanks may have a common cargoes are highly toxic or flammable, the lines are led well over accommodation and are expected to release vapour as near as possible in a vertical direction. Some vessels carry provision to return vapour expelled during the loading process to the shoreside tank. Examples are when the cargo is highly toxic or the chemicals react dangerously with air.

Main hazards associated with chemicals to humans

The substances carried in chemical tankers present certain hazards to operations of transport and to the crews of the ships. The main hazards fall into one of a combination of the following:

1. danger to health – toxicity and irritant characteristics of the substance or vapour
2. water pollution aspect – human toxicity of the substance in the solution
3. reactionary activity with water or other chemicals
4. fire and/or explosion hazard.

Cargo information – required before loading

1. The Cargo Officer must be informed of the correct chemical name of the cargo to enable the appropriate safety data sheet to be consulted in the Tanker Safety Guide (Chemicals).
2. The quantity of cargo and respective weight.
3. Clearance on quality control must be confirmed. Contamination, usually measured in ppm so tanks and pipelines must be assured to be clean.
4. The specific gravity value of the commodity must be advised to allow an estimate of the volume to be occupied for the intended weight of cargo.
5. Incompatibility with other cargoes or specifically other chemicals must be notified. Correct stowage must be achieved so that incompatible cargoes are not stowed in adjacent compartments.
6. Temperature of the cargo: (a) at the loading stage and (b) during the carriage stage. This criterion is required because temperature of the commodity will affect the volume of the total cargo loaded, while the expected carriage temperature will indicate whether heating of the cargo will be required.
7. The tank-coating compatibility must be suitable for the respective cargo.
8. Any corrosive properties of the chemical. This information would also be relevant to the tank-coating aspect and provide possible concerns for incurring damage to shipboard fittings.
9. Electrostatic properties can be acquired by some chemicals. With this in mind the principles applicable to hydrocarbons should be applied.
10. Data on the possibility of fire or explosion – 50% of chemicals carried are derived from hydrocarbons and the risk of fire or explosion is similar to the carriage for hydrocarbons.
11. The level of toxicity of the chemical. If high-toxic vapours are a characteristic of the cargo then enclosed ventilation may be a requirement.
12. Health hazards of any particular parcel of cargo.

13. Reactivity with water, air or other commodities.
14. What emergency procedures must be applicable in the event of contact or spillage.

The chemical data sheets of respective cargoes usually provide all of the above along with additional essential information for the safe handling and carriage of the commodity.

The protection of personnel

The hazards of the chemical trade have long been recognized and the need for personal protection of individuals engaged on such ships must be considered as the highest of priorities. A chemical cargo can be corrosive and destroy human tissue on contact. It can also be poisonous and can enter the body by several methods. It may be toxic and if inhaled damage the brain, the nervous system or the body's vital organs. Additionally, the chemical may give off a flammable gas giving a high risk of fire and explosion.

The IMO (IBC) Code requires that personnel involved in cargo operations aboard chemical carriers be provided with suitable protection by way of clothing and equipment, which will give total coverage of the skin in a manner that no part of the body is left exposed (i.e. chemical suits).

Protective equipment

Protective equipment to include:

1. full protective suit manufactured in a resistant material with tight-fitting cuff and ankle design
2. protective helmet
3. suitable boots
4. suitable gloves
5. a face shield or goggle protection
6. a large apron.

Where the product has inhalation problems for individuals then the above equipment would be supplemented by breathing apparatus (B/A).

Where toxic cargoes are carried, SOLAS requires that the ship should carry a minimum of three (3) *additional* complete sets of safety equipment, over and above the SOLAS '74 requirements.

Safety equipment set

Safety equipment set shall comprise:

1. a self-contained B/A (SCBA)
2. protective clothing (as described above)
3. steel core rescue line and harness
4. explosive-proof safety lamp.

An air compressor, together with spare cylinders, must also be carried and all compressed air equipment must be inspected on a monthly basis and tested annually.

Where toxic chemical products are carried, all personnel on board the vessel must have respiratory equipment available. This equipment must have adequate endurance to permit personnel to escape from the ship in the event of a major accident.

Associated operations

Heating of cargoes

Certain cargoes are required to be carried and/or discharged at high temperatures and to this end, heating while inside the ship's tanks must take place. Heating is usually provided by either heating coils inside the tanks themselves or, in the case of double-hull vessels, by heating channels on the outside of the tanks. The medium used is either steam, hot water or oil, but care must be taken that the medium is compatible with the cargo.

Tanks that contain chemicals, which could react with each other, must not be on the same heating circuit. Another safety factor is that a heat exchanger must be used between the boiler and the cargo system. This would prevent the possibility of the cargo product finding its way into the ship's boilers, in the event of a leak occurring in the system.

IG systems with chemical cargoes

IG, usually nitrogen, is used to blanket some cargoes. These are usually ones that react with air or water vapour in the atmosphere. They are loaded into tanks after they have been purged with IG and the tank must remain inerted until cleaning has been completed. Other cargoes have the ullage space inerted either as a fire precaution or to prevent reactions, which, while not necessarily dangerous, may put the cargo off specification. The nitrogen is supplied by a shipboard generator or from ashore, or from storage cylinders.

Precautions during loading, discharging and tank cleaning

In addition to the usual safety precautions for tanker practice, if handling toxic cargoes full protective clothing, including B/A, should be worn by all persons on deck. Goggles should be worn when handling cargoes which may cause irritation to the eyes. Such vessels are generally equipped with decontamination deck showers together with escape sets for each crew member.

Tank cleaning After discharge of the majority of cargoes, the tanks can be washed out with salt water as a first wash, then finished with a fresh water wash. Stainless steel tanks are usually washed only with fresh water because of damage, which may be incurred to the steelwork by use of sea water. Washing is often assisted by one of a range of cleansing compounds, which can be sprayed onto the tank sides and then washed off. One of the advantages of double-hull construction is that all the stiffening members of the tanks are on the outside of the tank and cleaning and drainage is there-

Some special chemicals may require special cleaning procedures and solvent use, and extreme care should be taken that mixtures created are not of a dangerous nature. Similarly, if washing into a slop tank a dangerous mixture of unknown chemical properties should not be generated.

Fire fighting

Fire-fighting arrangements are similar to that aboard petroleum tankers, with the exception that nitrogen is commonly employed as a smothering agent because some cargoes would be incompatible with CO_2. Ships are therefore generally supplied with an adequate supply of nitrogen. Ordinary foam breaks down when used on water-soluble chemicals so a special alcohol-foam is required – so named as being suitable for fires involving alcohol. In addition, large fixed dry powder plants may be provided for use on the tank deck. Some specialized cargoes require specific fire-fighting techniques and relevant details can be obtained from the shore authorities, prior to loading.

Note: *Many cargoes give off harmful vapours when burning and fire parties are advised to ensure that they wear protective clothing and B/A when fighting chemical fires.*

Compatibility

Great care must be taken during the cargo planning stage to ensure that chemicals that react with one another do not come into contact. Such planning is often a shore-based operation which is checked by the Ship's Master or the Chief Officer prior to the commencement of loading.

Chemicals must be located in an appropriate tank according to the IMO Code, and at the same time be compatible with the tank coating as specified in the tables provided by the tank-coating manufacturers. Incompatible cargoes must have positive segregation, and failure to observe such requirements could give rise to a most hazardous situation involving toxics or flammable gas being given off as a by-product.

Additionally, some mixtures of chemicals may react together, but equally some are potentially dangerous on their own. Those that react with air can be contained by IG, or provided with vapour return lines as previously described. However, some react with water (e.g. 'sulphuric acid') and must be loaded in double-skin tanks.

A number of chemicals are self-reactive, in the sense that they may polymerize with explosive violence or cause a generation of considerable heat. Examples of these are 'vinyl acetate' or 'styrene monomers'. If shipped, these have an inhibitor added, but care must be taken with all monomers to ensure that no impurities are introduced, which may act as a catalyst and cause polymerization. Accidental heating with such cargoes should also be avoided.

Volatile cargoes
Such cargoes of a volatile nature must not be stowed adjacent to heated cargoes. The possibility of flammable or toxic vapour release could lead to an after affect which could lead to disastrous consequences should the vapour reach the deck area.

Cargo-handling reference
Most shipping companies have prepared their own operational and safety manuals but most are based on the International Chamber of Shipping (ICS) Tanker Safety Guide for Oil Tankers and Terminals (ISGOTT). This contains an index of chemical names, including synonyms. Cargo information from data sheets for the most common chemicals is also included. Checklists are now also commonly employed to ensure correct procedures are observed throughout all cargo operations.

Merchant Shipping Notices
Merchant Shipping Notices stress the danger from asphyxiation and/or affects of toxic or other harmful vapours. They also strongly advise on the entry procedures into tanks and enclosed spaces alongside the Code of Safe Working Practice (CSWP). Notices emphasize the need for continuous monitoring of the vapour with gas detectors and the necessity of providing adequate ventilation when personnel enter enclosed spaces. Full procedures must include the use of a stand by man at the entrance of an enclosed space while personnel are inside that space.

Compatibility tables
There are various compatibility tables available, but perhaps the most widely applied are the USCG – Bulk Liquid Cargoes Guide to the Compatibility of Chemicals. A hazardous reaction is defined as a binary mixture which produces a temperature rise greater than 25°C or causes a gas to evolve.

The cargo groups for the two chemicals under consideration are first established from an alphabetical listing, then cross-referenced in the compatibility table; unsafe combinations being indicated by an 'X', and reactivity deviations within the chemical groups by the letters 'A' to 'I'.

IMO/IBC code
The International Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk and Index of Dangerous Chemicals Carried in Bulk are clearly the main recognized authority regarding the bulk chemical trade. It is recognized as the definitive source of names for products subject to Appendices II and III of Annex II of MARPOL 73/78.

IMO/IGC code
The International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk. Applicable to all ships regardless of size, inclusive of those vessels under 500-tonne gross, which are engaged in the carriage of liquefied gases having a vapour pressure exceeding 2.8 bar

absolute temperature of 37.8°C, and other products as appropriate under Chapter 19 (of the code), when carried in bulk.

(Exception: vessels constructed before October 1994 to comply with Resolution MSC. 5(48) adopted on 17 June 1983).

Bulk liquefied gas cargoes
The liquefied gases which are normally carried in bulk are hydrocarbon gases used as fuels or as feed stocks for chemical processing and chemical gases used as intermediates in the production of fertilizers, explosives, plastics or synthetics. The more common gases are LPGs, such as propane, butane, propylene, butylene, anhydrous ammonia, ethylene, vinyl chloride monomer (VCM) and butadiene. LNG is also transported extensively in dedicated ships (Figure 5.26), LNG being a mixture of methane, ethane, propane and butane with methane as the main component.

Gas properties
Liquefied gases are vapours at normal ambient temperatures and pressures. The atmospheric boiling points of the common gases are given as follows:

LPG
- Propane −42.3°C
- Butane −0.5°C
- LPG propylene −47.7°C
- Butylene −6.1°C

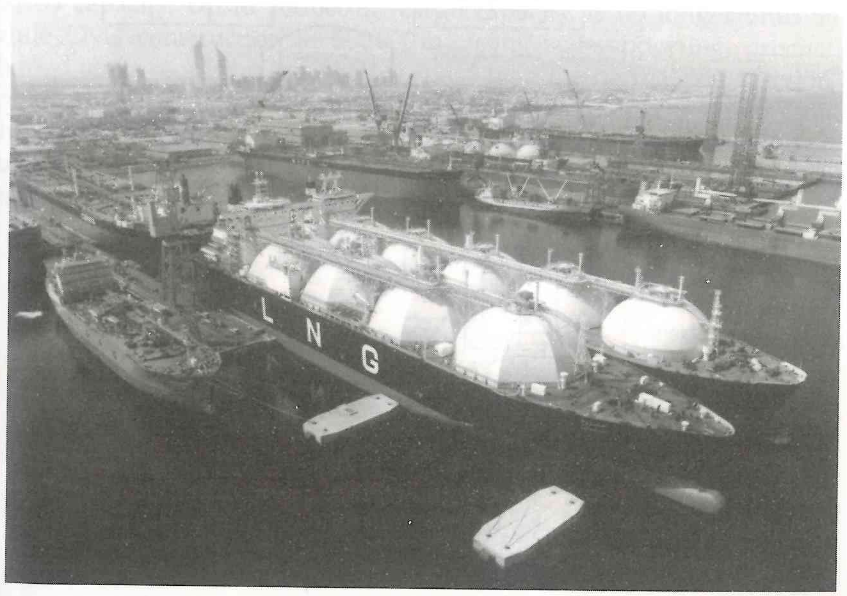


Fig. 5.26 Two LNG carriers lie alongside each other outside the Dubai Dry Dock Complex. These dedicated ships are prominent by the conspicuous cargo

Ammonia −33.4°C
Ethylene −103.9°C
VCM −13.8°C
LNG −161.5°C
Butadiene −5.0°C

The carriage of gases in the liquid phase can only be achieved by lowering the temperature or increasing the pressure or a combination of both low temperatures and increased pressures.

The carriage condition is classified as either: 'fully refrigerated' (at approximately atmospheric pressure) or 'semi-refrigerated' (at approximately 0 to −10°C and medium pressure) and fully pressurized (at ambient temperature and high pressures).

LNG and ethylene are normally always carried in the fully refrigerated condition – they cannot be liquefied by increasing the pressure alone – while the LPGs, ammonia, VCM and butadiene can be liquefied by lowering the temperature or increasing the pressure. This permits them to be carried in the fully refrigerated, or the semi-refrigerated or the fully pressurized condition. The IMO/IGC Code provides standards for 'gas tankers' and identifies the types of tanks which must be employed for the carriage of liquefied gases (Figure 5.27).

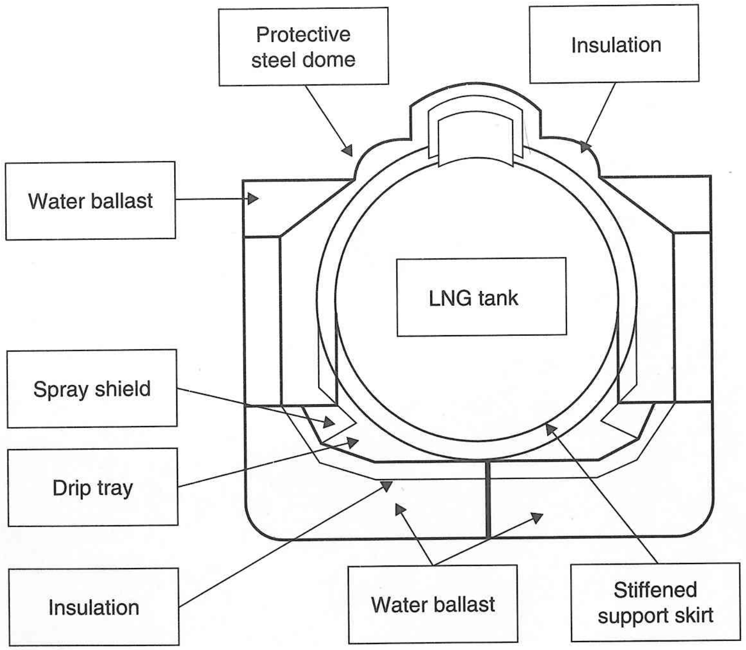


Fig. 5.27 Gas tank construction (spherical tanks). Fully refrigerated spherical LNG tank, the protective steel dome protects the primary barrier above the

- Integral tanks – tanks which form part of the ships hull
- Membrane – non-self-supporting, completely supported by insulation
- Semi-membrane – non-self-supporting and partly supported by insulation
- Independent tanks – self-supporting tanks not forming part of the ships hull, independent tanks being subdivided into Types A, B and C.

Integral membrane and semi-membrane tanks are designed primarily with plane surfaces. Of the independent tanks, both A and B can either be constructed of plane surfaces or of bodies of revolution, Type C is always constructed of bodies of revolution.

Note: *Prismatic tanks (fully refrigerated), carrying cargo at atmospheric pressure, require a primary and secondary barrier to resist undetermined design stresses. The space between the primary and secondary barriers is known as 'hold space' and is filled with IG to prevent a flammable atmosphere in the event of cargo leakage.*

Hazards of gas cargoes

Hazards associated with gas cargoes are from fire, toxicity, corrosivity, reactivity low temperatures and pressure.

Gas carrier types

Gas carrier profile

The more recent builds of LPG carriers include double-hull structure with varied capacity. Up to 100 000 m^3 cargo capacity, is no longer unusual – while LNG construction of 250 000 m^3 using self-supporting, prismatic-shaped tanks requiring less surface space than the normal construction of spherical 'Moss' tanks are under construction with IHI Marine United Shipbuilders (LNG carriage at −162°C and essentially at atmospheric pressure). Cargo boil-off with LNG is used as fuel for the ships propulsion system in some cases or vented to atmosphere (Figure 5.28).

Fully pressurized carriers

These tankers are normally constructed to the maximum gauge pressure at the top of the tank. In all cases, the design vapour pressure should not be less than the maximum, allowable relief valve settings (MARVs) of the tank. This corresponds to the vapour pressure of propane at +45°C, the maximum ambient temperature the vessel is likely to operate in. Relief valves blow cargo vapour to atmosphere above this pressure. Cargo tanks are usually cylindrical pressure vessels. Tanks below deck are constructed with a dome penetrating the deck on which all connections for the loading, discharging, sampling and gauging for monitoring pressure and temperature are placed. Pumps are not normally installed on this type of ship, the cargo being discharged by vapour pressure above the liquid. No vapour reliquefaction facilities are provided.

Semi-refrigerated carriers

This type of vessel is normally designed to carry the full range of LPG and chemical gases in tanks designed for a minimum service temperature of −48°C and working under design pressure. Simultaneous carriage of different cargoes is usually possible. The ships are generally installed with deepwell cargo pumps to facility discharge. If delivery is required into pressurized shore storage units, these deep-well pumps operate in series with booster pumps mounted on deck. Cargo heating using sea water is the usual practice. Vapours produced by heat are drawn off into a reliquefaction unit and the resultant liquid is returned to the tank. This action maintains the tank pressures within limits.

Fully refrigerated carriers

Cargo tanks are usually designed for a minimum service temperature of −50°C and a maximum design pressure.

Discharge of the cargo is achieved by using deepwell pumps or submerged pumps. Unlike the deepwell pumps, the submerged pump assembly, including the motor, is installed in the base of the tank. As a result, it is completely immersed in cargo liquid. Booster pumps and cargo heating may also be installed for discharge into pressurized storage. Reliquefaction plant is also installed on board for handling boil-off vapours. Fully refrigerated carriers now have capacities up to 250 000 m^3.

Fully refrigerated ethylene tankers

The majority of liquid ethylene tankers can carry the basic LPG cargoes as well. Ethylene cargoes are normally carried at essentially atmospheric pressure. Product purity is very important in carriage and care must be taken during cargo operations to avoid impurities, such as oil, oxygen, etc. Reliquefaction plant is also provided on these ships.

Gas operational knowledge

One of the main operational features of working on 'gas carriers' is the awareness of personnel to what is and what is not a gas-dangerous space. This is given by the following definition:

- A *gas-dangerous space, or zone* is a space in the cargo area which is not arranged or equipped in an approved manner to ensure that its atmosphere is at all times maintained in a gas – safe condition.
  - Further: an enclosed space outside the cargo area through which any piping containing liquid or gaseous products passes, or within which such piping terminates, unless approved arrangements are installed to prevent any escape of product vapour into the atmosphere of that space.
  - Also: a cargo containment system and cargo piping.
  - And: a hold space where cargo is carried in a cargo containment system requiring a secondary barrier; a space separated from a hold space described above by a single gas-tight steel boundary; or a cargo pump room and cargo compressor room; or a zone on the open deck, or semi-enclosed space on the open deck, within 3 m of any cargo tank outlet, gas or vapour outlet, cargo pipe flange or cargo valve or of entrances and ventilation openings to cargo pump rooms and cargo compressor rooms.
  - The open deck over the cargo area and 3 m forward and aft of the cargo area on the open deck up to a height of 2.4 m above the weather deck.
  - A zone within 2.4 m of the outer surface of a cargo containment system where such surface is exposed to the weather; an enclosed or semi-enclosed space in which pipes containing products are located. A space which contains gas-detection equipment complying with Regulation 13.6.5 of the IGC Code and space-utilizing boil-off gas as fuel and complying with Chapter 16 are not considered gas-dangerous spaces in this context.
  - A compartment for cargo hoses; or an enclosed or semi-enclosed space having a direct opening into any gas-dangerous space or zone.
- A *Gas-Safe space* is defined by a space other than a gas-dangerous space.

The deepwell cargo pump

Advantages of the deepwell cargo pumps are (Figure 5.29):

1. high speed, high efficiency and high capacity pumps
2. compact in construction when installed in either the vertical or horizontal position
3. choice of power/drive – electric, steam, hydraulic or pneumatic
4. self-flooding
5. automatic self-priming and eliminates stripping problems
6. easy vertical withdrawal for maintenance purposes
7. easy drainage, essential on hazardous cargoes

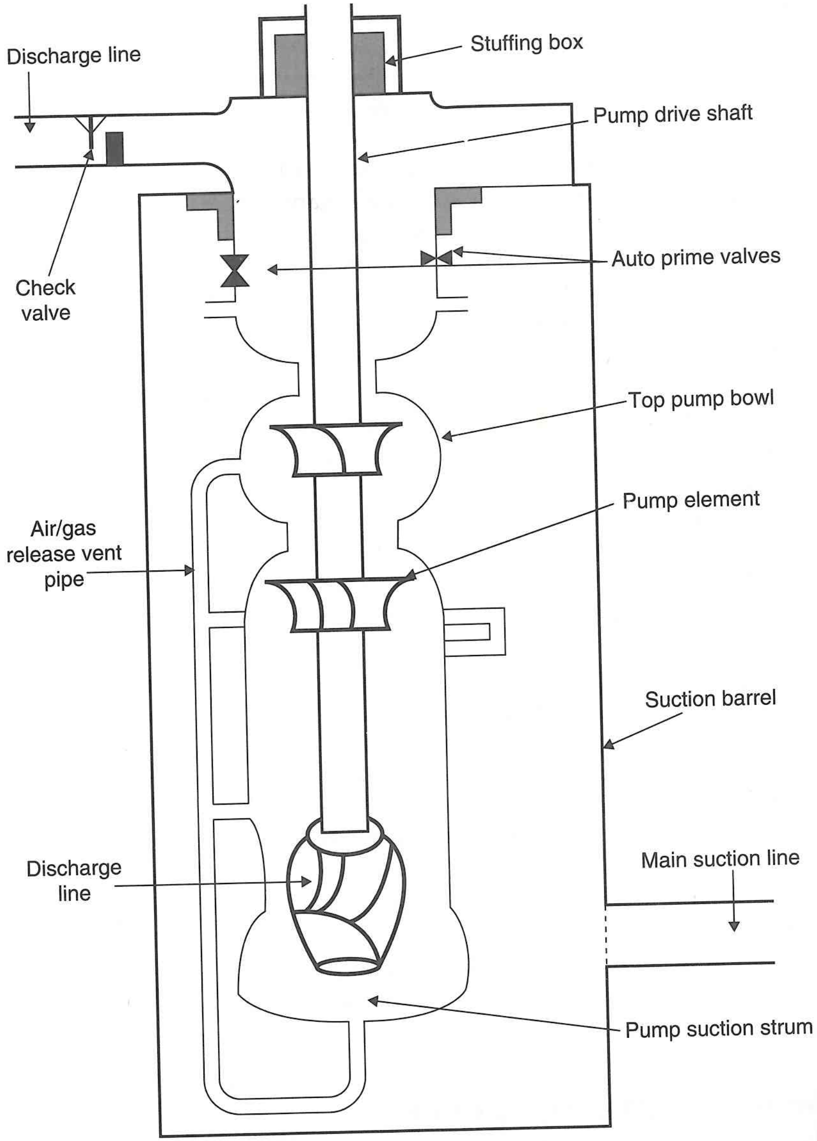


Fig. 5.29 The deepwell cargo pump.

8. tolerance of contaminates in fluid (no filters)
9. improved duty regulation and performance
10. air and vapour locks.

Disadvantages include being suspended, the pump can create construction problems during installation and requires essential rigid bracing supports within the tank, in order to prevent swaying. It also has a long drive shaft which is subject to vibration and torsional stresses.

Deepwell pumps must always be operated and handled in accordance with the recommended operating procedures. The net positive suction head (NPSH) requirements of the pump must always be maintained to prevent cavitation and subsequent pump damage.

LNG carriers

The LNG vessels are normally custom-built for the trade and carriage of the cargo at −162°C and essentially at atmospheric pressure. It is usual for LNG boil-off to be used as fuel for the ship's adopted main propulsion system and they subsequently are not always equipped with reliquefaction plant (Figure 5.30).

Fig. 5.30 LNG carrier. Profile of an LNG vessel seen lying at anchor off Gibraltar harbour. Prismatic tank design as opposed to the spherical tanks.

Cargo operations – safety

Three main safety aspects should be borne in mind when handling liquefied gas:

1. Flammability of the cargo and the need to avoid the formation of explosive mixtures at all times
2. Toxicity of the cargo
3. Low temperature of the cargo which could cause serious damage to the ships hull