5 OIL TANKER DESIGN AND EQUIPMENT

Learning objectives:
that oil tankers can be divided into fore part, tank area and after part
that means must be provided to keep spills away from the accommodation
how SBT and CBT contribute towards the protection of the marine environment
that there are requirements with respect to number and minimum capacity of slop tanks
oil tanker’s cargo system
the stripping system
that not all tankers have separate stripping system
an eductor with the aid of drawing
that steam heating coils are generally used for heating cargo tanks
the operating principle of different level gauges
the operating principle of portable oil/water interface detector

General
Modern civilization is very largely dependent on the products of oil and vast quantities are transported throughout the world. The invention of modern synthetic materials has engendered growing trade in sophisticated chemicals and these are now being carried in quite large quantities in bulk liquid carriers, whereas they used to be carried in very small quantities and were subject to the recommendations in the IMDG code. The carriage of oil product cargoes is dealt with first, then chemical cargoes and liquefied gas cargoes are considered.

Oil is carried in bulk by specially designed ships. A large proportion of this trade consists of the transportation of crude oil, but refined products are also carried in considerable quantities and include fuel oil, diesel oil, gas oil, kerosene, gasoline and lubricating oils.

The design of a tanker must take into account the particular trade for which it is intended. A high rate of loading and discharging is desirable; pumping capacity and size of pipelines being important in this respect. The safety factor must be borne in mind with the provision of a fire smothering installation and the provision of cofferdams at the ends of cargo spaces, ventilating pipes to tanks, etc. Ships intended for the carriage of heavy oils would have steam heating coils fitted in tanks.

The cargo space is generally divided into three sections athwartships by means of two longitudinal bulkheads and into individual tanks by transverse bulkheads.

The maximum length of an oil tank is 20%L (L is length of vessel) and there is at least one wash bulkhead if the length of the tank exceeds 10%L or 15 m. Tanks are generally numbered from forward, each number having port, centre and starboard compartments. Pump rooms are often located aft so that power may easily be supplied to the pumps from the engine room, but ships designed to carry many grades of oil at once may be fitted with two pump rooms placed so as to divide the cargo space into three sections. The system of pipelines used in a tanker is such that great flexibility is possible in the method of loading or discharging, and different parcels of cargo may be completely isolated from one another during loading and subsequently during discharge. In some cases a small, separate line is used for stripping the last few inches of oil from each tank.
5.1 CONSTRUCTION

(This regulation applies to ships constructed on or after 1 February 1992)

5.1.1 Machinery spaces

Machinery spaces shall be positioned aft of cargo tanks and slop tanks; they shall also be situated aft of cargo pump rooms and cofferdams, but not necessarily aft of the oil fuel bunker tanks. Any machinery space shall be isolated from cargo tanks and slop tanks by cofferdams, cargo pump rooms, oil fuel bunker tanks or ballast tanks. Pump-rooms containing pumps and their accessories for ballasting those spaces situated adjacent to cargo tanks and slop tanks and pumps for oil fuel transfer shall be considered as equivalent to a cargo pump-room within the context of this regulation, provided that such pump-rooms have the same safety standard as that required for cargo pump-rooms. However, the lower portion of the pump-room may be recessed into machinery spaces of category A to accommodate pumps provided that the deck head of the recess is in general not more than one third of the moulded depth above the keel, except that in the case of ships of not more than 25,000 tonnes deadweight, where it can be demonstrated that for reasons of access and satisfactory piping arrangements this is impracticable, the Administration may permit a recess in excess of such height, but not exceeding one half of the moulded depth above the keel.

5.1.2 Accommodation spaces

Accommodation spaces, main cargo control stations, control stations and service spaces (excluding isolated cargo handling gear lockers) shall be positioned aft of all cargo tanks, slop tanks, and spaces which isolate cargo or slop tanks from machinery spaces but not necessarily aft of the oil fuel bunker tanks and ballast tanks, but shall be arranged in such a way that a single failure of a deck or bulkhead shall not permit the entry of gas or fumes from the cargo tanks into an accommodation space, main cargo control stations, control station, or service spaces. A recess provided in accordance with paragraph 1 need not be taken into account when the position of these spaces is being determined. However, where deemed necessary, the Administration may permit accommodation spaces, main cargo control stations, control stations, and service spaces forward of the cargo tanks, slop tanks and spaces which isolate cargo and slop tanks from machinery spaces, but not necessarily forward of oil fuel bunker tanks or ballast tanks. Machinery spaces, other than those of category A, may be permitted forward of the cargo tanks and slop tanks provided they are isolated from the cargo tanks and slop tanks by cofferdams, cargo pump-rooms, oil fuel bunker tanks or ballast tanks. All of the above spaces shall be subject to an equivalent standard of safety and appropriate availability of fire-extinguishing arrangements being provided to the satisfaction of the Administration. Accommodation spaces, main cargo control spaces, control stations and service spaces shall be arranged in such a way that a single failure of a deck or bulkhead shall not permit the entry of gas or fumes from the cargo tanks into such spaces. In addition, where deemed necessary for the safety or navigation of the ship, the Administration may permit machinery spaces containing internal combustion machinery not being main propulsion machinery having an output greater than 375 kW to be located forward of the cargo area provided the arrangements are in accordance with the provisions of this paragraph.
5.1.3 Combination carriers only
The slop tanks shall be surrounded by cofferdams except where the boundaries of the slop tanks, where slop may be carried on dry cargo voyages, are the hull, main cargo deck, cargo pump-room bulkhead or oil fuel bunker tank. These cofferdams shall not be open to a double bottom, pipe tunnel, pump room or other enclosed space. Means shall be provided for filling the cofferdams with water and for draining them. Where the boundary of a slop tank is the cargo pump-room bulkhead, the pump-room shall not be open to the double bottom, pipe tunnel or other enclosed space; however, openings provided with gastight bolted covers may be permitted.

5.1.4 Navigation area
Where the fitting of a navigation position above the cargo area is shown to be necessary, it shall be for navigation purposes only and it shall be separated from the cargo tank deck by means of an open space with a height of at least 2 m.

5.1.5 Deck spills
Means shall be provided to keep deck spills away from the accommodation and service areas. This may be accomplished by provision of a permanent continuous coaming of a suitable height extending from side to side. Special consideration shall be given to the arrangements associated with stembow loading.

5.1.6 Superstructure and deckhouses
Exterior boundaries of superstructures and deckhouses enclosing accommodation and including any overhanging decks, which support such accommodation, shall be insulated to "A-60" standard for the whole of the portions which face the cargo area and on the outward sides for a distance of 3 m from the end boundary facing the cargo area. In the case of the sides of those superstructures and deckhouses, such insulation shall be carried as high as is deemed necessary by the Administration.

5.1.7 Access doors, air inlets and openings
Except as permitted in paragraph 5.1.8 below, access doors, air inlets and openings to accommodation spaces, service spaces, control stations and machinery spaces shall not face the cargo area. They shall be located on the transverse bulkhead not facing the cargo area or on the outboard side of the superstructure or deckhouse at a distance of at least 4% of the length of the ship but not less than 3 m from the end of the superstructure or deckhouse facing the cargo area. This distance need not exceed 5 m.

5.1.8 Access doors
The Administration may permit access doors in boundary bulkheads facing the cargo area or within the 5 m limits specified in paragraph 5.1.7, to main cargo control stations and to such service spaces as provision rooms, store-rooms and lockers, provided they do not give access directly or indirectly to any other space containing or provided for accommodation, control stations or service spaces such as galleys, pantries or workshops, or similar spaces containing sources of vapour ignition. The boundary of such a space shall be insulated to "A-60" standard, with the exception of the boundary facing the cargo area. Bolted plates for the
removal of machinery may be fitted within the limits specified in paragraph 5.1.7. Wheelhouse doors and wheelhouse windows may be located within the limits specified in paragraph 5.1.7 so long as they are designed to ensure that the wheelhouse can be made rapidly and efficiently gas and vapour tight.
5.1.9 **Windows and sidescuttles**

Windows and sidescuttles facing the cargo area and on the sides of the superstructures and deckhouses within the limits specified in paragraph 5.1.7 shall be of the fixed (non-opening) type. Such windows and sidescuttles in the first tier on the main deck shall be fitted with inside covers of steel or other equivalent material.

5.2 **PUMPING, PIPING AND DISCHARGE ARRANGEMENTS**

5.2.1 **Line systems in general**

The loading line system is the basic element of the cargo handling equipment on an oil tanker.

Treatment or handling of cargo includes all transport of the cargo, ballast handling, loading, discharging, internal cargo transferring, tank cleaning - either with cargo (cow) or water, cargo heating etc.

On a traditional crude oil tanker; the vessel is equipped with an efficient line system for loading the cargo on board and discharging the cargo ashore. When discharging the cargo ashore, the cargo goes via the vessel’s pump room where the cargo pumps are located. The whole idea is to keep the cargo safely in the tanks, from the time it enters, during the voyage and, finally, during the whole discharging operation.

The main thing with cargo in such a closed system is that the cargo is not visible at any stage of the operation. Fixed checklists provide safe operations and instruments show where and how the cargo flows.

On different vessels the line system in principle is similar, but each vessel has its own peculiarities.

Drawings that show the line systems are very useful when planning an operation, but remember that this is a schematic drawing of the vessel’s line system.

To be sure that the oil is flowing the way it should, one reliable method is a visual inspection of the line system. Every valve will be marked and numbered according to the drawings, and it is extremely important that the line system is visually inspected. Crawl beneath the deck in the pump room or elsewhere; follow the lines wherever you can. To compare the real line with the drawing, bring a drawing with you.

5.2.2 **Discharge manifold**

In every oil tanker, a discharge manifold for connection to reception facilities for the discharge of dirty ballast water or oil-contaminated water shall be located on the open deck on both sides of the ship.

In every oil tanker, pipelines for the discharge to the sea of ballast water or oil contaminated water from cargo tank areas which may be permitted under regulation 9 or regulation 10 of MARPOL 73/78 Annex I shall be led to the open deck or to the ship's side above the waterline in the deepest ballast condition.

In new oil tankers means shall be provided for stopping the discharge into the sea of ballast water or oil contaminated water from cargo tank areas, other than those discharges below the waterline permitted under paragraph (6) of regulation 18 of MARPOL 73/78 Annex I, from a
position on the upper deck or above located so that the manifold in use referred to in paragraph (1) of this regulation and the discharge to the sea from the pipelines referred to in paragraph (2) of this regulation may be visually observed. Means for stopping the discharge need not be provided at the observation position if a positive communication system such as a telephone or radio system is provided between the observation position and the discharge control position.

5.2.3 *Segregated ballast tanks – small diameter line*

Every new oil tanker required to be provided with segregated ballast tanks or fitted with a crude oil washing system shall comply with the following requirements:

(a) it shall be equipped with oil piping so designed and installed that oil retention in the lines is minimized; and

(b) means shall be provided to drain all cargo pumps and all oil lines at the completion of cargo discharge, where necessary by connection to a stripping device. The line and pump drainings shall be capable of being discharged both ashore and to a cargo tank or a slop tank. For discharge ashore a special small diameter line shall be provided and shall be connected outboard of the ship's manifold valves.

Every existing crude oil tanker required to be provided with segregated ballast tanks, or to be fitted with a crude oil washing system, or to operate with dedicated clean ballast tanks, shall comply with the provisions of paragraph (4)(b) of regulation 18 of MARPOL 73/78.

On every oil tanker the discharge of ballast water or oil contaminated water from cargo tank areas shall take place above the waterline, except as follows:

- Segregated ballast and clean ballast may be discharged below the waterline:

- in ports or at offshore terminals, or at sea by gravity, provided that the surface of the ballast water has been examined immediately before the discharge to ensure that no contamination with oil has taken place.

Existing oil tankers, which, without modification, are not capable of discharging segregated ballast above the waterline, may discharge segregated ballast below the waterline at sea, provided that the surface of the ballast water has been examined immediately before the discharge to ensure that no contamination with oil has taken place.

Existing oil tankers operating with dedicated clean ballast tanks, which without modification are not capable of discharging ballast water from dedicated clean ballast tanks above the waterline, may discharge this ballast below the waterline provided that the discharge of the ballast water is supervised in accordance with regulation 13A(3) of MARPOL 73/78 Annex I.

5.2.4 *Discharge of dirty ballast*

On every oil tanker at sea, dirty ballast water or oil contaminated water from tanks in the cargo area, other than slop tanks, may be discharged by gravity below the waterline, provided that sufficient time has elapsed in order to allow oil/water separation to have taken place and the ballast water has been examined immediately before the discharge with an oil/water interface detector referred to in regulation 15(3)(b) of MARPOL 73/78 Annex I, in order to
ensure that the height of the interface is such that the discharge does not involve any increased risk of harm to the marine environment.
5.2.5 **Line system in cargo tanks**

The line system has a diameter and thickness adapted for use and necessary capacity of pressure and flow. The pipes are adapted in handy sized lengths, to position easily in place during construction and to ease prospective disconnecting when repairs and renewals are required. The lines are made of either entirely cast iron or rolled steel plates which are completely welded in the pipe’s length direction.

To connect pipe lengths, flanges are used. These flanges are rings of steel welded to the pipe ends. The flanges have plain surfaces, and with a gasket in between, a liquid proof connection of the pipes is achieved. In the flanges, holes are drilled for the steel bolts.

Usually the number of drilled holes is similar to the pipe's diameter in inches. This makes it easy to control the reducers between the vessels manifold and the load/discharging arms (hoses).

The lines rest on supporters, which are welded to the tank bottom, pump room bottom, main deck and so on. To reduce wear and tear when steel meets steel, a shim of wood or another soft material is placed in between the pipe and supporter. The pipes are fastened to the supporter with hoops.
Now and then, a vessel is exposed to heavy weather forces. When standing on the bridge, viewing pitching on the main deck, it is possible to observe how the hull is bending and distorting due to the weather condition. A stiff line system would easily be shaken badly. To make these lines follow the vessel's movements, caused by the power in these forces, the use of expansion couplings is necessary.

An expansion coupling is a coupling, which makes the pipes capable of moving back and forth inside the coupling. The coupling consists of a ring (piece of pipe), two rubber packings and two outer rings with holes for bolts. The “piece of pipe” is enclosing the two pipe ends, which are placed towards each other. The end of “the piece of pipe” has a fold where the rubber packing fits in like a wedge. On each side, there is an outer ring enclosing the rubber packing and the “piece of pipe”. Bolts through the outer rings keep the coupling together. Remember to cross tighten the bolts to achieve uniform tightening.

The expansion coupling is very efficient. It functions like a muff where the pipes are able to slide back and forth with influence of temperature, stress and torsion. In between two pipe’s holdings, there should be at least one expansion coupling.

In places where the pipes change direction, i.e. from a vertical riser leading from the pump room to a horizontal deck line, a bend is fitted. This is usually a rolled bend, shaped in desired angle. It is important that the bend is internally smooth to allow the liquid flow with as little resistance as possible.
Mud boxes are strategically placed to catch some particles like sand, gravel, rust and so on, which follow the oil during loading. Typical places are just ahead of the cargo pumps in order to protect the impeller. Another typical place is on the main cow line where the branching leads to the cow machines. It is very important to supply the cow machines with pure liquid to reduce wear and tear on the cow machine’s nozzle unit. Keep good routines for inspection and cleaning of filters to avoid blockage in the flow.

A vital part of the line system is where the pipe enters the cargo tank. The branch from a bottom line ends in the aft part of a cargo tank. This is where the cargo comes in when loading and going out when discharging. In the centre tanks, the main suction is placed approximately in the middle, and two stripping suction are placed (one on the port side in the tank and one on the starboard side in the tank). The suction “stub” is shaped like an inverted hopper and is called the bellmouth or “elephant foot”. The area of the bellmouth is required to be one and a half times the size of the loading line. Beneath the bellmouth are welded bars, which subdue the movement of liquid influx and thereby avoid or reduce pump cavitation. The bellmouth is placed with the opening toward the tank bottom, with as little space as possible, without blocking. Usually, the bellmouth on the main suction is placed with a clearance of approximately 10cm from the tank bottom and with the stripping suction, a clearance of approximately 3 - 5cm.

5.2.6 Valves

On board oil tankers there are three main types of valves being used: the gate valve, the globe valve and the butterfly valve.
The gate valve works like a gate, which blocks the pipe cross wise, and stops the liquid flow. In open position, the gate is lifted into the gatehouse. This type of valve is, for example, used on lines leading over board. It provides safe and solid tightening and is very efficient, but bothersome and slow to operate.
The globe valve is also a commonly used valve on board oil tankers. Usually this globe valve is used in the pressure/vacuum system where the valve supervises the pressure condition in the tanks. The valve opens when the pressure is reaching a certain set point and also opens to the atmosphere when reaching a set vacuum point. This valve is common on the inert gas plant, on the main inert gas line and as P/V valve for the cargo tank.

The globe valve is also produced as a non-return valve. The valve is constructed as an open valve, which is open for liquid flow in one direction. However, it is shut down for a liquid flow from the opposite direction.

Both gate and globe valves are mainly operated manually. The most common valve used on oil tankers is the butterfly valve. This valve should be located all over the cargo handling systems, from the bottom lines, through the pump room and all the way up to the manifolds. The butterfly can be operated both manually and hydraulically.

This butterfly valve is also pretty simple in its construction. The closing flap is a round flounder fitted to a spindle, which is turned by the valve’s steering. Around the flounder is a rubber ring, which is fitted in to ensure good tightening. The flounder is made easily available and simply to replace, because wear and tear may cause small leaks. Another cause of leakage on hydraulic operated valves may be that the hydraulic does not shut the valve properly.
Some advantages in using butterfly valves are safe running, relatively fast speed when opening/closing, simple operation due to the flow control, space savings due to the total size of the valve. Beside, the valve is easy to handle and disconnect for overhauling and repairs.

5.2.7 Bottom lines

In this chapter, we are going to describe traditional piping on a crude oil tanker, and start with the cargo tank’s bottom lines. (See the drawing on next page). The vessel is fitted with 4 centre tanks and 5 pairs of wing tanks for cargo. The cargo main lines are located in the vessel’s centre tanks. With the term “bottom lines” we understand that the location of these lines will be on the bottom of the vessel, usually supported about 4 - 6 feet above the vessel’s bottom. Crossover valves, two valves on each crossover, connect the bottom lines to each other. When carrying more than one grade, a two-valve segregation complies with the regulations in force.

From the drawing you find that, from the bottom lines, there are lines, which lead to each cargo tank. These lines end on the cargo tanks suction bellmouth. Each bottom line serves its own set of cargo tanks; for example bottom line no.1 serves CT1 and WT5 p/s. Bottom line no.2 serves WT1 p/s and CT4. Bottom line no. 3 serves WT2 p/s, CT3 and WT6 p/s.
5.2.8 Drop lines

From the manifold area on the main tank deck, the drop line is connected to the deck main lines which leading to the bottom lines. See the drawing below, on the drawing on page 11 you will also find the drop line. These drop lines are used during loading. By closing the deck line’s master valves, the cargo is lead to the vessel’s cargo tanks when using these drop lines. So, the pump room is completely isolated from the cargo during loading. However, during discharging the drop lines are isolated from the cargo by keeping the drop valves closed. You must, however, during loading not forget to keep a routine for checking the pump room both for leaks and being gas free for entry.

![Diagram of drop lines and pump room piping](image)

5.2.9 Pump room piping

On a crude oil carrier the pump room is the main point between the cargo tanks and the main deck, all the way to the manifold, where the ship lines are connected to shore lines. From the cargo tank the bottom lines lead all the way to the main cargo pumps. To simplify the matter we divided the pump room in two parts. One part is called the cargo pumps free flow side; the other part is called the cargo pumps deliver side. These sides are commonly called suction side and pressure side. Note: a centrifugal pump does not have any ability of suction.

On the cargo pumps free flow side, the bottom lines end at the cargo pumps. On this side, some cross over lines connect the systems to each other. The first crossover after the tank area is the stripping cross, marked on the drawing as “Crude oil suction -x-over line”. The stripping cross is located crosswise from the bottom lines, and connected to the bottom lines with pipe bending and valves. By using this crossover, it is, i.e. possible to discharge from cargo tanks on line system no.2 with COP no. 3. And so on.
Further towards the COP, on the bottom lines, you find a valve on each of these lines, usually called the “bulkhead valve”. This is because the location is normally close to the bulkhead, separating cargo tank area and pump room area.

Further on the free flow side of the cargo pump, is the seawater suction crossover line. This line is also crosswise from the bottom lines and is connected to the sea chest on each side (port and starboard). This line supplies the cargo pumps with seawater during water washing of tanks and lines, and used when ballasting for departure, if or when necessary. Crossing between different lines and pumps is also a possibility with this cross over line. We are now leaving the free flow side of the system, and the next step is to pay attention to the delivery side of the pumps.

The first stop is the first valve after the cargo pumps, the delivery valve or throttling valves. Names like discharging-valve, pressure-valve is also common. The most descriptive is “delivery valve”. With this valve, we can adjust the backpressure and the load conditions for what the pump is going to work against. Centrifugal pumps are working their best against a certain load.

When starting a centrifugal pump, start it against a closed delivery valve, which compares with the recommendation.

On the delivery side, the rise lines lead from the cargo pumps to the main deck.

The first is the cow cross over line. With this line, we can bleed off from any riser for supplying crude oil washing during discharging, or supplying water during tank washing. The same line also supplies “drive” when using the ejector for stripping.

The second cross over line leads to a higher inlet in the port slop tank (primary slop) and to the line called “High Overboard”.

The high overboard line is the line where ballast water and washing water is discharged overboard via oil detection monitor equipment. As the drawing shows, it is possible with any cargo pump to cross over to any of the risers.

The pump room is also fitted with other equipment for handling cargo and ballast. The ballast pump is only used for the segregated ballast. The segregated ballast system is totally isolated from the cargo systems.

The ballast pump is connected to the FP-tank and the WT 3 s/p. The ballast system has its own sea chest.

Still there are some vessels, among them M/T Seagull, which have separated lines from the ballast pump to the main deck, which end in drop lines to the cargo tanks that are dedicated for departure/arrival ballast. These tanks can be ballasted without involving any part of the cargo line systems.

The stripping pump is operating its own system, which (via a stripping cross over) strip the last amount of cargo from tanks, cargo pumps and lines, through the small diameter line and ashore.

In addition to a stripping pump and an ejector, the vessel is equipped with a vacuum stripping system, which gives the cargo pumps the ability to maintain suction when only a small quantity is left in a tank.
5.2.10 Deck lines

On a crude oil carrier, the main line system changes name, depending on where it is placed. From cargo tanks to the cargo pumps, the main lines are called “bottom lines”. From the cargo pumps delivery side, the name changes to risers. When they appear on the main deck, the names are deck lines.

Very often the systems are numbered from one side of the ship to the other, for instance from port to starboard or vice versa.

The deck lines are a lengthening of the risers from the pump room. Each deck line can be isolated to the pump room by the deck master valve.

The deck lines end up at the manifold crossover lines. These manifolds are where the vessel is connected to the terminal by hoses, kick arms etc.

The manifold line is numbered with the same number as the main line it belongs to. The conclusion will then be: Manifold no 1 is connected to drop line no 1, which leads down to bottom line no 1, which leads to cargo pump no 1, which leads to riser no 1, which leads to deck line no 1, which leads to manifold no 1. The same occurs with system no 2, 3, and 4.

The vessel is also equipped with manifold cross over, which makes it possible to operate between deck lines, drop lines and manifolds depending on which manifold(s) the vessel is connected to.

By studying the ships line system all over, including valves and crossovers, you will find all the possibilities of leading cargo or water through the systems. The more you are familiar with the line system and its drawings, better you can utilise the system’s possibilities.

On the main deck you also find the small diameter line (MARPOL-line) which leads from the vessel’s stripping pump to one of the vessel’s manifolds. The small diameter line is connected on the outside of the manifold valve. It is connected to the “presentation flange”. The purpose with this line is to strip the last amount of cargo ashore from the tanks, pumps and lines. When using this line, it is important to keep the specific manifold valve closed, to avoid the cargo returning into the vessel’s lines.
5.2.11  Cow Lines

On the main deck you will find the cow main line with branches leading to the ships crude oil washing machines. This line comes from the cow cross over line on the delivery side in the pump room.

The branch lines from the cow main line are gradually reduced in dimension all the way forward to the cow machines. This reduction is to avoid pressure fall on the flow used for crude oil washing.

It is possible to bleed off to the cow main line from any of the main cargo lines. This contributes to several alternative solutions in the cow operation. There are always variations from ship to ship, but the main principle is the same.
5.2.12 Inert Lines

To control the atmosphere in the cargo tanks you will find inert lines on the main deck leading to each tank. These lines are for supplying inert gas during discharging or tank washing. Some inert gas systems are connected to a main riser, which are fitted with a press/vacuum valve for regulation of the pressure and vacuum in the cargo tanks. Other inert gas systems have these press/vacuum valves installed on each cargo tank with the same function as the riser.
5.2.13 Features of a modern product tanker

**Features of a modern product tanker**
(Tanker of 45,000 dwt)

**PRODUCT TANKERS**

Despite the emergence in recent years of bigger tankers for the carriage of large parcels of petroleum products on longer haul routes, the 45,000 dwt product tanker is still the workhorse of the regional balancing and distribution refined product trades. Principal cargoes include gasoline, kerosene, diesel and lpg. The bigger product tankers comprise large range 1 (LR1) ships (55,000-80,000 dwt) and large range 2 (LR2) ships (80,000+ dwt). They carry large volume cargoes such as condensates, naphtene and residual fuel oil, with naphtene, a light product used as a petrochemical feedstock, amongst others. Featuring prominently in LR1 product tankers are able to take 25-30,000 form some parcels of naphtene, while LR2 ships can accommodate three such parcels. Some ships of the 45,000 dwt size product tankers are built to a more sophisticated design to enable the carriage of so-called IMO type 1 class chemicals such as benzene, styrene, toluene and caustic soda solution, in addition to the full array of petroleum products.

**PROPELLION SYSTEM**

Driving a fixed-pitch propeller, the slow-speed diesel engine develops 13,000 shp at 50 rpm to provide a step-on over 11 knots. The auxiliary engines provide electrical power while steam requirements are met by a marine boiler. The tanker is provided with a software package which uses artificial intelligence and data acquisition techniques to monitor and control machinery performance, and offers a diagnostics capability. A remotely driven bow thruster is fitted for increased manoeuvrability.

**OTHER CARGO-HANDLING AND SAFETY FEATURES**

Modern product tankers incorporate many other distinctive cargo-handling and safety features as standard, some of which are itemised below:

- Stainless steel heat exchangers on deck, through which the cargo is circulated using the submerged cargo pumps. The absence of heating coils in the tank facilitates tank cleaning.
- Fully automatic vapour emission control system featuring an independent high level alarm for the cargo and slop tanks, and a fixed oxygen analyser for the vapour manifold.
- Tank levels are monitored by means of radar devices fitted in each tank. Cargo operations are controlled and monitored remotely via a dash computer or bridge control room.
- The ship is fitted with an inert gas generator and emergency towing equipment. Ballast tanks are fitted with crude oil washing can be carried out.

**PIPEING AND CARGO SEGREGATION**

Cargo piping systems are designed with optimal loading, discharge, draining and cleaning characteristics in mind. Dedicated product tankers usually have four to five segregations, with two or more submerged cargo pumps connected to each cargo line and crossover. Combined product/chemical tankers are designed with one pump, line and manifold crossover per tank to ensure that each tank can carry a different cargo in a fully segregated manner.

**SUBMERGED CARGO PUMPS**

Modern product tankers have a stainless steel deepwell cargo pump in each cargo tank. The pumps, which are designed for easy maintenance within the tank, are positioned at the aft of each tank in suction and lift to enable optimal tank emptying. Cargo pumps can be controlled either remotely from the cargo control room or locally by means of their capacity control valves. During cargo discharge, when the tank is empty, the pump can be switched to the "dry running" mode to permit final stripping of the remaining cargoes residue. A typical discharge rate for a cargo pump on a ship of this size is 4,500 m³/hour and the hydraulic power pack enables the use of up to six pumps simultaneously.

**TANK COATINGS AND CLEANING**

The use of corrosion-resistant cladded and the positioning of stiffeners outside the cargo tank, in the double hull spaces and on deck, enables cargo tanks to be designed with flush walls to facilitate cleaning. The arrangement is also conducive to the application of cargo tank linings. Typical product tankers have three-coat epoxy tank lining systems, although if it is a product/chemical tanker which will be engaged in the marine trades, then a zinc silicate lining system will be specified.

**SEGREGATED BALLAST TANKS**

Water ballast is carried in the double bottom and double side spaces. Ballast tanks are fitted with high-coated, anti-free, epoxy coatings to minimize the impact of corrosion and to facilitate inspection and maintenance. Most tankers are provided with two sets of ballasting pumps, located in the shaft room or quarterhouse for ballasting/deballasting. An alternative arrangement has been developed in which ballast pumps are installed submerged in one of the segregated ballast tanks. This approach, in combination with a submerged pump in each cargo tank, enables the traditional pumps to be eliminated.
5.3 Cargo Heating System

5.3.1 Cargo heating

In addition to the provision of cargo compartments, pipelines and pumps for handling the oil, the oil tanker must also provide adequate heating systems for some types of oil and cooling systems for others. Properly constructed ventilation systems are necessary in all oil tankers in order to avoid excessive loss of cargo from evaporation and to control the escape of dangerous gases.

5.3.2 Cargo Heating System.

Heavy fractions, such as fuel oil become very thick and sluggish when cold, and, in order that such oils can be loaded and discharged without delay it is necessary to keep them heated. Today the oil trade is so vast and wide spread that the average oil tankers may be trading in the tropics one voyage and in Arctic conditions the next. It is therefore necessary that cargo heating systems be designed to cope with extreme conditions.

Due to the fact that a loaded tanker has comparatively little freeboard, the temperature of the seawater through which the vessel is passing is of major significance. Cold water washing around the ship's side and bottom, and across the decks, rapidly reduces the temperature of the cargo and makes the task of heating it much harder. Warm seawater, however, has the reverse effect, and can be very useful in helping to maintain the temperature of the cargo with a minimum of steam.

Steam is used to heat the oil in a ship's tank. It is piped from the boilers along the length of the vessel's deck. Generally the catwalk or flying bridge is used for this purpose, the main cargo heating steam and exhaust pipes being secured to either the vertical or horizontal girder work immediately below the foot treads. At intervals, manifolds are arranged from which the steam for the individual cargo tanks is drawn. Each tank has its own steam and exhaust valves, which enables the steam to be shut off or reduced on any of the tanks at will. Generally the main steam lines are well lagged, but obviously it would not be a practical proposition to lag the individual lines leading from the manifold to the cargo tanks.

The heating arrangements in the actual cargo tanks consist of a system of coils, which are spread over the bottom of the tank at a distance of six to eighteen inches from the bottom plating. In wing tanks it is the usual practice to extend the coil system as far as the turn of the bilge but not up the ship's side.

When it becomes necessary to heat cargo, the steam is turned on the individual tanks. The coils in the bottom of the tanks become hot, heating the oil in the immediate vicinity. The warm oil rises slowly and is replaced by colder oil, thus setting up a gradual circulation system in each tank.

The wing tanks insulate the centre tanks on both sides, while they are subject themselves to the cooling action of the sea, not only through the bottom plating, but also through the ship's side. It is therefore advisable to set the steam valves so that the wing tanks obtain a larger share of the steam than the centre tanks. This is particular true in some of the more modern vessels, where the coils are passed through the longitudinal bulkheads between the centre and wing tanks.

Heavy fuel oils are generally required to be kept at a temperature ranging between 120° F. and 135° F. Within this temperature range they are easy to handle. Lubricating oils of which the heavier types require heating, are always the subject of special instructions as they vary widely in quality, gravity and viscosity.
Some types of Heavy Virgin Gas Oil or Cat Feed have very high pour points, and it is necessary to keep the cargo well heated to avoid it going solid. Provided the temperature of this type of oil is twenty to thirty degrees above its pour point, it offers no difficulty when loading or discharging though a wax skin will form on the sides and bottom of the ship. Some crude oils, which contain paraffin wax or have high-pour points are also heated when transported by sea. The main reason for this is to stop excessive deposits of wax forming on cooling surfaces. The heating requirements for such cargoes vary considerably. Waxy crudes with pour points over 100°F may require heating to 120°F – 135°F.

Bitumen cannot normally be carried in ordinary ships, as it requires far more heat than the normal cargo system is capable of. For this reason, bitumen ships are generally designed so that the cargo tanks are insulated by wing tanks, which are reserved for ballast, and by double bottoms under the cargo tanks. This coupled with extra coils, arranged on platforms at different levels, helps to keep the bitumen heated.

In ships carrying heavy lubricating oils which require heating, the coils are generally ordinary steel pipe, but vessels carrying crude oils which have to be heated, are now equipped with cast iron or alloy coils. The reason for this is that the heating surfaces are subjected to excessive corrosion from the lighter fractions in the crude, and ordinary steel pipes do not stand up to the corrosive action so well as the other materials mentioned.

Deck mounted cargo-heating system
Some ships cargoes are heated by circulating the tank contents through a HEAT EXCHANGER where the cargo is passed through a cylindrical tank, mounted on deck, which contains a “nest” of pipes continually fed with steam. The big advantage of this method is the fact that the cargo is continually circulated which prevents stratifying and an even temperature distribution about the tank contents.
Diagram of cargo heating system
Showing a series of heat exchangers.
5.4 Venting arrangements

Extract from SOLAS (Chapter II-2: Construction)

Quote

Regulation 59
Venting, purging, gas freeing and ventilation

(Paragraph 2 of this regulation applies to ships constructed on or after 1 February 1992)

1 Cargo tank venting

1.1 The venting systems of cargo tanks are to be entirely distinct from the air pipes of the other compartments of the ship. The arrangements and position of openings in the cargo tank deck from which emission of flammable vapours can occur shall be such as to minimize the possibility of flammable vapours being admitted to enclosed spaces containing a source of ignition, or collecting in the vicinity of deck machinery and equipment which may constitute an ignition hazard. In accordance with this general principle the criteria in paragraphs 1.2 to 1.10 will apply.
1.2 The venting arrangements shall be so designed and operated as to ensure that neither pressure nor vacuum in cargo tanks shall exceed design parameters and be such as to provide for:

.1 the flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank in all cases through pressure/vacuum valves; and

.2 the passage of large volumes of vapour, air or inert gas mixtures during cargo loading and ballasting, or during discharging.

1.3.1 The venting arrangements in each cargo tank may be independent or combined with other cargo tanks and may be incorporated into the inert gas piping.

1.3.2 Where the arrangements are combined with other cargo tanks, either stop valves or other acceptable means shall be provided to isolate each cargo tank. Where stop valves are fitted, they shall be provided with locking arrangements, which shall be under the control of the responsible ship's officer. Any isolation must continue to permit the flow caused by thermal variations in a cargo tank in accordance with paragraph 1.2.1.

1.4 The venting arrangements shall be connected to the top of each cargo tank and shall be self-draining to the cargo tanks under all normal conditions of trim and list of the ship. Where it may not be possible to provide self-draining lines, permanent arrangements shall be provided to drain the vent lines to a cargo tank.

1.5 The venting system shall be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of these devices shall comply with the requirements established by the Administration, which shall contain at least the standards adopted by the Organization.*

1.6 Provision shall be made to guard against liquid rising in the venting system to a height, which would exceed the design head of cargo tanks. This shall be accomplished by high-level alarms or overflow control systems or other equivalent means, together with gauging devices and cargo tank filling procedures.

1.7 Openings for pressure release required by paragraph 1.2.1 shall:

.1 have as great a height as is practicable above the cargo tank deck to obtain maximum dispersal of flammable vapours but in no case less than 2 m above the cargo tank deck;

.2 be arranged at the furthest distance practicable but not less than 5 m from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment, which may constitute an ignition hazard.

1.8 Pressure/vacuum valves required by paragraph 1.2.1 may be provided with a by pass arrangement when they are located in a vent main or masthead riser. Where such an arrangement is provided there shall be suitable indicators to show whether the by pass is open or closed.
1.9 Vent outlets for cargo loading, discharging and ballasting required by paragraph 1.2.2 shall:

.1.1 permit the free flow of vapour mixtures; or

.1.2 permit the throttling of the discharge of the vapour mixtures to achieve a velocity of not less than 30 m/s;

.2 be so arranged that the vapour mixture is discharged vertically upwards;

.3 where the method is by free flow of vapour mixtures, be such that the outlet shall be not less than 6 m above the cargo tank deck or fore and aft gangway if situated within 4 m of the gangway and located not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment which may constitute an ignition hazard;

.4 where the method is by high-velocity discharge be located at a height not less than 2 m above the cargo tank deck and not less than 10 m measured horizontally from the nearest air intakes and openings to enclosed spaces containing a source of ignition and from deck machinery and equipment, which may constitute an ignition hazard. These outlets shall be provided with high velocity devices of an approved type;

.5 be designed on the basis of the maximum designed loading rate multiplied by a factor of at least 1.25 to take account of gas evolution, in order to prevent the pressure in any cargo tank from exceeding the design pressure. The master shall be provided with information regarding the maximum permissible loading rate for each cargo tank and in the case of combined venting systems, for each group of cargo tanks.

1.10 In combination carriers, the arrangement to isolate slop tanks containing oil or oil residues from other cargo tanks shall consist of blank flanges which will remain in position at all times when cargoes other than liquid cargoes referred to in regulation 55.1 are carried.

2 Cargo tank purging and/or gas-freeing

Arrangements for purging and/or gas freeing shall be such as to minimize the hazards due to the dispersal of flammable vapours in the atmosphere and to flammable mixtures in a cargo tank. Accordingly:

.1 When the ship is provided with an inert gas system, the cargo tanks shall first be purged in accordance with the provisions of regulation 62.13 until the concentration of hydrocarbon vapours in the cargo tanks has been reduced to less than 2% by volume. Thereafter, gas freeing may take place at the cargo tank deck level.

.2 When the ship is not provided with an inert gas system, the operation shall be such that the flammable vapour is discharged initially:
.2.1 through the vent outlets as specified in paragraph 1.9; or

.2.2 through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 30 m/s maintained during the gas-freeing operation; or

.2.3 through outlets at least 2 m above the cargo tank deck level with a vertical efflux velocity of at least 20 m/s and which are protected by suitable devices to prevent the passage of flame.

When the flammable vapour concentration at the outlet has been reduced to 30% of the lower flammable limit, gas freeing may thereafter be continued at cargo tank deck level.
3 Ventilation

3.1 Cargo pump rooms shall be mechanically ventilated and discharges from the exhaust fans shall be led to a safe place on the open deck. The ventilation of these rooms shall have sufficient capacity to minimize the possibility of accumulation of flammable vapours. The number of changes of air shall be at least 20 per hour, based upon the gross volume of the space. The air ducts shall be arranged so that all of the space is effectively, ventilated. The ventilation shall be of the suction type using fans of the non-sparking type.

3.2 The arrangement of ventilation inlets and outlets and other deckhouse and superstructure boundary space openings shall be such as to complement the provisions of paragraph 1. Such vents, especially for machinery spaces, shall be situated as far aft as practicable. Due consideration in this regard should be given when the ship is equipped to load or discharge at the stem. Sources of ignition such as electrical equipment shall be so arranged as to avoid an explosion hazard.

3.3 In combination carriers all cargo spaces and any enclosed spaces adjacent to cargo spaces shall be capable of being mechanically ventilated. The mechanical ventilation may be provided by portable fans. An approved fixed gas warning system capable of monitoring flammable vapours shall be provided in cargo pump rooms and pipe ducts and cofferdams referred to in regulation 56.4 adjacent to slop tanks. Suitable arrangements shall be made to facilitate measurement of flammable vapours in all other spaces within the cargo area. Such measurements shall be made possible from open deck or easily accessible positions.

4 Inerting, ventilation and gas measurement

4.1 This paragraph shall apply to oil tankers constructed on or after 1 October 1994.

4.2 Double hull and double bottom spaces shall be fitted with suitable connections for the supply of air.

4.3 On tankers required to be fitted with inert gas systems:

   .1 double hull spaces shall be fitted with suitable connections for the supply of inert gas;

   .2 where hull spaces are connected to a permanently fitted inert gas distribution system, means shall be provided to prevent hydrocarbon gases from the cargo tanks entering the double hull spaces through the system;

   .3 where such spaces are not permanently connected to an inert gas distribution system, appropriate means shall be provided to allow connection to the inert gas main.

4.4.1 Suitable portable instruments for measuring oxygen and flammable vapour concentrations shall be provided. In selecting these instruments, due attention shall be given to their use in combination with the fixed gas sampling-line systems referred to in paragraph 4.4.2.
4.4.2 Where the atmosphere in double hull spaces cannot be reliably measured using flexible gas sampling hoses, such spaces shall be fitted with permanent gas sampling lines. The configuration of such line systems shall be adapted to the design of such spaces.
4.4.3 The materials of construction and the dimensions of gas sampling lines shall be such as to prevent restriction. Where plastic materials are used, they should be electrically conductive.

5.4.1 Cargo tank ventilation systems

All cargo tanks should be provided with a venting system appropriate to the cargo being carried and these systems should be independent of the air pipes and venting systems of all other compartments of the ship. Tank venting systems should be designed so as to minimize the possibility of cargo vapour accumulating about the decks, entering accommodation, service and machinery spaces and control stations and, in the case of flammable vapours, entering or collecting in spaces or areas containing sources of ignition. Tank venting systems should be arranged to prevent entrance of water into the cargo tanks and, at the same time, vent outlets should direct the vapour discharge upwards in the form of unimpeded jets.

The venting systems should be connected to the top of each cargo tank and as far as practicable the cargo vent lines should be self-draining back to the cargo tanks under all normal operational conditions of list and trim. Where it is necessary to drain venting systems above the level of any pressure/vacuum valve capped or plugged drain cocks should be provided.

5.4.2 Overflow control

Provision should be made to ensure that the liquid head in any tank does not exceed the design head of the tank. Suitable high-level alarms overflow control systems or spill valves, together with gauging and tank filling procedures, may be accepted for this purpose.

5.4.3 Venting operation

Tank venting systems should be designed and operated so as to ensure that neither pressure nor vacuum created in the cargo tanks during loading or unloading exceeds tank design parameters. The main factors to be considered in the sizing of a tank venting system are as follows:

.1 design loading and unloading rate;
.2 gas evolution during loading: this should be taken account of by multiplying the maximum loading rate by a factor of at least 1.25;
.3 density of the cargo vapour mixture;
.4 pressure loss in vent piping and across valves and fittings;
.5 pressure/vacuum settings of relief devices.

5.4.4 Vent piping

Tank vent piping connected to cargo tanks of corrosion-resistant material, or to tanks which are lined or coated to handle special cargoes as required by the Code, should be similarly lined or coated or constructed of corrosion-resistant material.
The master should be provided with the maximum permissible loading and unloading rates for each tank or group of tanks consistent with the design of the venting systems.
5.4.5 Types of tank venting systems

An open tank venting system is a system which offers no restriction except for friction losses to the free flow of cargo vapours to and from the cargo tanks during normal operations. An open venting system may consist of individual vents from each tank, or such individual vents may be combined into a common header or headers, with due regard to cargo segregation. In no case should shutoff valves be fitted either to the individual vents or to the header.

5.4.6 Tank venting control

A controlled tank venting system is a system in which pressure- and vacuum-relief valves or pressure/vacuum valves are fitted to each tank to limit the pressure or vacuum in the tank. A controlled venting system may consist of individual vents from each tank or such individual vents on the pressure side only as may be combined into a common header or headers, with due regard to cargo segregation. In no case should shut-off valves be fitted either above or below pressure- or vacuum-relief valves or pressure/vacuum valves.
Cargo tank vent system (1).

1. Explosion-resistant and long-burning-resistant vent cap
2. Pressure-vacuum valve
3. Drain valve
4. Spill valve
5. Ullage hatch
1 high-velocity relief valve
2 pressure/vacuum relief valve
3 drain cock
4 hatch

Cargo Tank vent system (2).
5.4.7 Tank vent positions

The position of vent outlets of a controlled tank venting system should be arranged:

1. at a height of not less than 6 m above the weather deck or above a raised walkway if fitted within 4 m of the raised walkway;

2. at a distance of at least 10 m measured horizontally from the nearest air intake or opening to accommodation, service and machinery spaces containing an ignition source.

5.4.8 Vent outlets

The vent outlet height may be reduced to 3 m above the deck or a raised walkway, as applicable, provided that high velocity venting valves of a type approved by the Administration, directing the vapour/air mixture upwards in an unimpeded jet with an exit velocity of at least 30 m/s, are fitted.

5.4.9 Tank venting systems

Controlled tank venting systems fitted to tanks to be used for cargoes having a flashpoint not exceeding 60° C (closed-cup test) should be provided with devices to prevent the passage of flame into the cargo tanks. The design, testing and locating of the devices should comply with the requirements of the Administration, which should contain at least the standards adopted by the Organization.

5.4.10 Venting system design

In designing venting systems and in the selection of devices to prevent the passage of flame for incorporation into the tank venting system, due attention should be paid to the possibility of the blockage of these systems and fittings by, for example, the freezing of cargo vapour, polymer build-up, atmospheric dust or icing up in adverse weather conditions. In this context it should be noted that flame arresters and flame screens are more susceptible to blockage. Provisions should be made such that the system and fittings may be inspected, operationally checked, cleaned or renewed as applicable.
An automatic weight-loaded pressure/vacuum valve.

<table>
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<tr>
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<tr>
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<td>Top cover</td>
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<td>8</td>
<td>Spindle</td>
<td>Brass</td>
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</tbody>
</table>

Opening standard
Pressure: 1400 mm W.G.
Vacuum: 350 mm W.G.

Approved by:
Lloyd's Register of Shipping
American Bureau of Shipping
Det Norske Veritas
Bureau Veritas
USCG, Cert.no 192,071/129/1

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Automatic weight-loaded pressure vacuum valve type FLF
5.4.11 Cargo-tank gas-freeing

The arrangements for gas-freeing cargo tanks used for cargoes other than those for which open venting is permitted should be such as to minimize the hazards due to the dispersal of flammable or toxic vapour in the atmosphere and to flammable or toxic vapour mixtures in a cargo tank.

Accordingly, gas-freeing operations should be carried out such that vapour is initially discharged:

1. through the vent outlets specified in 1.9 (SOLAS); or
2. through outlets at least 2 m above the cargo-tank deck level with a vertical efflux velocity of at least 30 m/s maintained during the gas-freeing operation; or
3. through outlets at least 2 m above the cargo-tank deck level with a vertical efflux velocity of at least 20 m/s which are protected by suitable devices to prevent the passage of flame.

When the flammable vapour concentration at the outlets has been reduced to 30% of the lower flammable limit and, in the case of a toxic product, the vapour concentration does not present a significant health hazard, gas freeing may thereafter be continued at cargo-tank deck level.

5.4.12 In-line and end-of-line devices.

Flame-screens should not be used at vent outlets due to the problem with clogging and thereby possibility to build high pressure in the tank during loading.

5.4.13 Precautions regarding high-velocity valves.

A pressure/vacuum (P/V) valve is designed to release and/or let in pressure to protect the cargo tank from exploding or imploding due to too high or too low pressure in the tank. See picture of P/V-valve on previous page.
The P/V-valve must be looked after due to the possibility that they may be clogged from freezing vapours, polymer build-up or icing up in adverse weather conditions, always be sure that the P/V-valve is working before commence loading/discharging.
WHY A HIGH SPEED RELIEF VALVE?

Pres-Vac HIGH SPEED Relief Valves provide positive protection from fire and explosion when installed on your ship's new or existing tank venting system. Designed for closed-system operation, these approved valves will safely, and automatically—
- vent displaced hydrocarbon vapors at high velocity during tank loading operations
- prevent vacuum build-up during tank unloading operations
- equalize pressure differentials caused by temperature or atmospheric pressure changes during transport and storage

Type approved WITHOUT flame screen on pressure unit.

A high-velocity venting valve.
5.4.14 Gas freeing

General
It is generally recognized that tank cleaning and gas freeing is the most hazardous period of tanker operations. This is true whether washing for clean ballast, gas freeing for entry, or gas freeing for hot work. The additional risk from the toxic effect of petroleum gas during this period cannot be over-emphasised and must be impressed on all concerned. It is therefore essential that the greatest possible care is exercised in all operations connected with tank cleaning and gas freeing.

5.4.15 General Procedures

The following recommendations apply to cargo tank gas freeing generally.

(a) The covers of all tank openings should be kept closed until actual ventilation of the individual tank is about to commence.

(b) Portable fans or blowers should only be used if they are hydraulically, pneumatically or steam driven. Their construction materials should be such that no hazard of incendiary sparking arises if, for any reason, the impeller touches the inside of the casing. The capacity and penetration of portable fans should be such that the entire atmosphere of the tank on which the fan is employed can be made non-flammable in the shortest possible time.

(c) The venting of flammable gas during gas freeing should be by the vessel’s approved method, and where gas freeing involves the escape of gas at deck level or through tank hatch openings the degree of ventilation and number of openings should be controlled to produce an exit velocity sufficient to carry the gas clear of the deck.

(d) Intakes of central air conditioning or mechanical ventilating systems should be adjusted to prevent the entry of petroleum gas, if possible by recirculation of air within the spaces.

(e) If at any time it is suspected that gas is being drawn into the accommodation, central air conditioning and mechanical ventilating systems should be stopped and the intakes covered or closed. Window type air conditioning units which are not certified as safe for use in the presence of flammable gas or which draw in air from outside the superstructure must be electrically disconnected and any external vents or intakes closed.

(f) Where cargo tanks are gas freed by means of one or more permanently installed blowers, all connections between the cargo tank system and the blowers should be blanked except when the blowers are in use. Before putting such a system into service, the cargo piping system, including crossovers and discharge lines, should be flushed through with seawater and the tanks stripped. Valves on the systems, other than those required for ventilation, should be closed and secured.

(g) Tank openings within enclosed or partially enclosed spaces should not be opened until the tank has been sufficiently ventilated by means of openings in the tank, which are outside these spaces. When the gas level within the tank has fallen to 25% of the LFL or less, openings in enclosed or partially enclosed spaces may be opened to complete the ventilation. Such enclosed or partially enclosed spaces should also be tested for gas during this subsequent ventilation.

(h) If the tanks are connected by a common venting system, each tank should be isolated to prevent the transfer of gas to or from other tanks.
(i) Portable fans, where used, should be placed in such positions and the ventilation openings so arranged that all parts of the tank being ventilated are equally and effectively gas freed. Ventilation outlets should generally be as remote as possible from the fans.

(j) Portable fans, where used, should be so connected to the deck that an effective electrical bond exists between the fan and the deck.

(k) Fixed gas freeing equipment may be used to gas free more than one tank simultaneously but must not be used for this purpose if the system is being used to ventilate another tank in which washing is in progress.

(l) On the apparent completion of gas freeing any tank, a period of about 10 minutes should elapse before taking final gas measurements. This allows relatively stable conditions to develop within the tank space. Tests should be made at several levels and, where the tank is sub-divided by a wash bulkhead, in each compartment of the tank. In large compartments such tests should be made at widely separate positions. If satisfactory gas readings are not obtained, ventilation must be resumed.

(m) On completion of gas freeing, all openings except the tank hatch should be closed.

(n) On completion of all gas freeing and tank washing the gas venting system should be carefully checked, particular attention being paid to the efficient working of the pressure/vacuum valves and any high velocity vent valves. If the valves or vent risers are fitted with devices designed to prevent the passage of flame, these should also be checked and cleaned. Gas vent riser drains should be cleared of water, rust and sediment, and any steam smothering connections tested and proved satisfactory.

5.4.16  9.3.4 Gas Free for Entry and Cold Work Without Breathing Apparatus

In order to be gas free for entry without breathing apparatus a tank or space must be ventilated until tests confirm that the hydrocarbon gas concentration through the compartment is not more than 1% of the LFL and additional tests have been made to check for oxygen content, the presence of hydrogen sulphide, benzene and other toxic gases as appropriate.
5.5 LEVEL GAUGES

Types of gauges

5.5.1 Mechanically operated float gauges

In this type of gauge, the detecting element is a float. The power to actuate the mechanism comes partly from the movement of the float and partly from the balancing mechanism. The float is connected to the measuring tape, which runs over a pulley system to enter the gauge head. Inside the gauge head the tape passes over a sprocket wheel driving a counter mechanism, and thence on to a storage drum. A spring, which winds off a storage drum on to a power drum connected to the tape storage drum, keeps the tape under tension without lifting the float clear of the product. As the liquid level in the container rises, the tension applied to the tape by the spring takes up the slack on the tape. On the better types of gauge, the spring tension increases as the liquid level fails, in order to compensate for the additional weight of tape used.

![Mechanically operated float gauge diagram]

Mechanically operated float gauge.
5.5.2 **Electrically powered servo-operated gauges**

With this type of gauge the detecting element is a surface-sensing device, which follows the variations of level by means of a servomechanism. Indication of level can be by various electrical or mechanical methods.

A typical arrangement for a servo-operated gauge is shown below. The sensing head is usually designed to sense the liquid surface and to indicate to the control unit the distance from that surface. The control unit endeavours to keep the head at a fixed distance above the product by controlling the driving motor. The tape would actually pass over a sprocket wheel driving a counter mechanism, but this has been omitted in the figure below for the sake of simplicity.
5.5.3 Electrical capacitance gauges - comparative types

These gauges measure the liquid level by comparing the electrical capacitance of a partially immersed element with that of a fully immersed, similar element by means of a bridge circuit. The fig. below shows a gauge of this type. The detector compares the partially immersed element “D” with the fully immersed element “C”. The number of fully immersed elements is also counted. The level of the liquid can then be computed as indicated.
5.5.4 Bubbler gauges

In this type of gauge the head of a liquid of known density is derived by measuring the backpressure generated by the injection of a gas or vapour. This pressure is normally displayed at the required position on a manometer that is calibrated directly in level units. The fig. below is a diagrammatic representation of one type of bubbler gauge. It will be noted that the manometer must be compensated for the tank pressure; otherwise level readings will be completely erroneous.
5.5.5 Pneumatic or hydraulic level gauges using a dosed cell

In these gauges a pressure-sensitive cell is located near the bottom of the container, and changes in pressure are transmitted by electronic, pneumatic or hydraulic means to a remote location. Such an arrangement is shown below. The capillary system is usually compensated for normal changes in ambient temperature.
5.5.6 Other differential-pressure methods

These methods of level measurement use pressure transducers of various types to measure the hydrostatic pressure at the bottom of the container and at the same time correct the reading for the internal tank pressure, as measured at the top of the container. Many different arrangements are possible, but they all have the main features of the system shown below.
5.5.7 Sonic gauges

There are several types of level gauge using this principle. The most commonly available types measure the time difference between a transmitted signal and its reflection from the liquid surface. Gauges can be mounted on the tank top or at the bottom of the tank. The principle is illustrated below.

Sonic gauges

Saab Tank Radar
5.5.8 Radioactive methods

In these methods the level is read by measuring the attenuation of radiation by the product. Several methods are employed. The figures show three possible arrangements. In (a) a single source and a single detector are used, the attenuation of the radiation being measured to ascertain the liquid level. In (b), indication is in comparatively large steps, each radioactive source being associated with its own detection device. The third method has a single source emitting a fan shaped beam in the tank. The direct radiation and that attenuated by the product are both measured to determine the liquid level in the tank.
5.6 ENVIRONMENTAL PROTECTION EQUIPMENT

Regulation 15.3 of Annex II of MARPOL 73/78

(3) (a) An oil discharge monitoring and control system approved by the Administration shall be fitted. In considering the design of the oil content meter to be incorporated in the system, the Administration shall have regard to the specification recommended by the Organization. The system shall be fitted with a recording device to provide a continuous record of the discharge in litres per nautical mile and total quantity discharged, or the oil content and rate of discharge. This record shall be identifiable as to time and date and shall be kept for at least three years. The oil discharge monitoring and control system shall come into operation when there is any discharge of effluent into the sea and shall be such as will ensure that any discharge of oily mixture is automatically stopped when the instantaneous rate of discharge of oil exceeds that permitted by regulation 9(1)(a) of this Annex. Any failure of this monitoring and control system shall stop the discharge and be noted in the Oil Record Book. A manually operated alternative method shall be provided and may be used in the event of such failure, but the defective unit shall be made operable as soon as possible. The port State authority may allow the tanker with a defective unit to undertake one ballast voyage before proceeding to a repair port. The oil discharge monitoring and control system shall be designed and installed in compliance with the guidelines and specifications for oil discharge monitoring and control systems for oil tankers developed by the Organization. Administrations may accept such specific arrangements as detailed in the Guidelines and Specifications.

(b) Effective oil/water interface detectors approved by the Administration shall be provided for a rapid and accurate Determination of the oil/water interface in slop tanks and shall be available for use in other tanks where the separation of oil and water is effected and from which it is intended to discharge effluent direct to the sea.

Regulation 15.3 of Annex II of MARPOL 73/78

(5) Oil filtering equipment referred to in paragraph (2) of this regulation shall be of a design approved by the Administration and shall be such as will ensure that any oily mixture discharged into the sea after passing through the system or systems has an oil content not exceeding 15 parts per million. It shall be provided with alarm arrangements to indicate when this level cannot be maintained. The system shall also be provided with arrangements such as will ensure that any discharge of oily mixtures is automatically stopped when the oil content of the effluent exceeds 15 parts per million. In considering the design of such equipment and arrangements, the Administration shall have regard to the specification recommended by the Organization.

5.6.1 Oil spills in the marine environment

Fate and behaviour of oil in the marine environment

Complex processes of oil transformation in the marine environment start developing from the first seconds of oil's contact with seawater. The progression, duration, and result of these transformations depend on the properties and composition of the oil itself, parameters of the actual oil spill, and environmental conditions. The main characteristics of oil transformations are their dynamism, especially at the first stages, and the close interaction of physical, chemical, and biological mechanisms of dispersion and degradation of oil components up to their complete disappearance as original substances. Similar to an intoxicated living organism, a marine ecosystem destroys, metabolises, and deposits the excessive amounts of hydrocarbons, transforming them into more common and safer substances.

5.6.2 Physical transport.

The distribution of oil spilled on the sea surface occurs under the influence of gravitation forces. It is controlled by oil viscosity and the surface tension of water. Only ten minutes after
a spill of 1 ton of oil, the oil can disperse over a radius of 50 m, forming a slick 10-mm thick. The slick gets thinner (less than 1 mm) as oil continues to spread, covering an area of up to 12 km². During the first several days after the spill, a considerable part of oil transforms into the gaseous phase. Besides volatile components, the slick rapidly loses water-soluble hydrocarbons. The rest - the more viscous fractions - slow down the slick spreading. Further changes take place under the combined impact of meteorological and hydrological factors and depend mainly on the power and direction of wind, waves, and currents. An oil slick usually drifts in the same direction as the wind. While the slick thins, especially after the critical thickness of about 0.1 mm, it disintegrates into separate fragments that spread over larger and more distant areas. Storms and active turbulence speed up the dispersion of the slick and its fragments. A considerable part of oil disperses in the water as fine droplets that can be transported over large distances away from the place of the spill.

5.6.3 Dissolution.
Most oil components are water-soluble to a certain degree, especially low-molecular-weight aliphatic and aromatic hydrocarbons. Polar compounds formed as a result of oxidation of some oil fractions in the marine environment also dissolve in seawater. Compared with evaporation, dissolution takes more time. Hydrodynamic and physicochemical conditions in the surface waters strongly affect the rate of the process.

5.6.4 Emulsification.
Oil emulsification in the marine environment depends, first of all, on oil composition and the turbulent regime of the water mass. The most stable emulsions such as water-in-oil contain from 30% to 80% water. They usually appear after strong storms in the zones of spills of heavy oils with an increased content of non-volatile fractions (especially asphaltenes). They can exist in the marine environment for over 100 days in the form of peculiar "chocolate mousses". Stability of these emulsions usually increases with decreasing temperature. The reverse emulsions, such as oil-in-water (droplets of oil suspended in water), are much less stable because surface tension forces quickly decrease the dispersion of oil. This process can be slowed with the help of emulsifiers - surface-active substances with strong hydrophilic properties used to eliminate oil spills. Emulsifiers help to stabilize oil emulsions and promote dispersing oil to form microscopic (invisible) droplets. This accelerates the decomposition of oil products in the water column.

5.6.5 Oxidation and destruction.
Chemical transformations of oil on the water surface and in the water column start to reveal themselves no earlier than a day after the oil enters the marine environment. They mainly have an oxidative nature and often involve photochemical reactions under the influence of ultraviolet waves of the solar spectrum. These processes are catalysed by some trace elements (e.g., vanadium) and inhibited (slowed) by compounds of sulphur. The final products of oxidation (hydro peroxides, phenols, carboxylic acids, ketones, aldehydes, and others) usually have increased water solubility. An experimental research showed that they have increased toxicity as well. The reactions of photo oxidation, photolysis in particular, initiate the polymerisation and decomposition of the most complex molecules in oil composition. This increases the oil's viscosity and promotes the formation of solid oil aggregates.
5.6.6 Sedimentation.

Some of the oil (up to 10-30%) is adsorbed on the suspended material and deposited to the bottom. This mainly happens in the narrow coastal zone and shallow waters where particulates are abundant and water is subjected to intense mixing. In deeper areas remote from the shore, sedimentation of oil (except for the heavy fractions) is an extremely slow process. Simultaneously, the process of bio sedimentation happens. Plankton filtrators and other organisms absorb the emulsified oil. They sediment it to the bottom with their metabolites and remainders. The suspended forms of oil and its components undergo intense chemical and biological (microbial in particular) decomposition in the water column. However, this situation radically changes when the suspended oil reaches the sea bottom. Numerous experimental and field studies show that the decomposition rate of the oil buried on the bottom abruptly drops. The oxidation processes slow down, especially under anaerobic conditions in the bottom environment. The heavy oil fractions accumulated inside the sediments can be preserved for many months and even years.

5.6.7 Microbial degradation.

The fate of most petroleum substances in the marine environment is ultimately defined by their transformation and degradation due to microbial activity. About a hundred known species of bacteria and fungi are able to use oil components to sustain their growth and metabolism. In pristine areas, their proportions usually do not exceed 0.1-1.0% of the total abundance of heterotrophic bacterial communities. In areas polluted by oil, however, this portion increases to 1-10%.

Biochemical processes of oil degradation with microorganism participation include several types of enzyme reactions based on oxygenises, dehydrogenises, and hydrolase's. These cause aromatic and aliphatic hydro oxidation, oxidative domination, hydrolysis, and other biochemical transformations of the original oil substances and the intermediate products of their degradation.

The degree and rates of hydrocarbon biodegradation depend, first of all, upon the structure of their molecules. The paraffin compounds (alkanes) biodegrade faster than aromatic and naphthenic substances. With increasing complexity of molecular structure (increasing the number of carbon atoms and degree of chain branching) as well as with increasing molecular weight, the rate of microbial decomposition usually decreases. Besides, this rate depends on the physical state of the oil, including the degree of its dispersion. The most important environmental factors that influence hydrocarbon biodegradation include temperature, concentration of nutrients and oxygen, and, of course, species composition and abundance of oil-degrading microorganisms. These complex and interconnected factors influencing biodegradation and the variability of oil composition make interpreting and comparing available data about the rates and scale of oil biodegradation in the marine environment extremely difficult.

5.6.8 Aggregation.

Oil aggregates in the form of petroleum lumps, tar balls, or pelagic tar can be presently found both in the open and coastal waters as well as on the beaches. They derive from crude oil after the evaporation and dissolution of its relatively light fractions, emulsification of oil residuals, and chemical and microbial transformation. The chemical composition of oil aggregates is rather changeable. However, most often, its base includes asphaltenes (up to 50%) and high-molecular-weight compounds of the heavy fractions of the oil.
Oil aggregates look like light grey, brown, dark brown, or black sticky lumps. They have an uneven shape and vary from 1 mm to 10 cm in size (sometimes reaching up to 50 cm). Their surface serves as a substrate for developing bacteria, unicellular algae, and other microorganisms. Besides, many invertebrates (e.g., gastropods, polychaetes, and crustaceans) resistant to oil's impacts often use them as a shelter.

Oil aggregates can exist from a month to a year in the enclosed seas and up to several years in the open ocean. They complete their cycle by slowly degrading in the water column, on the shore (if they are washed there by currents), or on the sea bottom (if they lose their floating ability).

5.6.9 Self-purification.

As a result of the processes previously discussed, oil in the marine environment rapidly loses its original properties and disintegrates into hydrocarbon fractions. These fractions have different chemical composition and structure and exist in different migrational forms. They undergo radical transformations that slow after reaching thermodynamic equilibrium with the environmental parameters. Their content gradually drops as a result of dispersion and degradation. Eventually, the original and intermediate compounds disappear, and carbon dioxide and water form. Such self-purification of the marine environment inevitably happens in water ecosystems if, of course, the toxic load does not exceed acceptable limits.