1 INTRODUCTION

*(STCW Code, section A-V/1 paragraph 9)*

Learning Objectives:

On completion of this section the trainee should have a good knowledge of:

- the way in which oil tankers have developed over the past 100 years
- the way tankers have evolved into crude and product tankers, combination carriers and more specialized vessels
- the difference between oil tankers and combination carriers
- the oil tanker terminology
- the load on top (LOT) procedures
- the international and national regulations concerning oil tankers

1.1 Oil Tankers

1.1.1 History of oil transportation at sea

Transportation of oil by water was the indirect result of the first oil well. Mineral oil had been known to exist below the surface of the earth for quite some time. There are indications that the Chinese obtained small quantities from shallow mines several thousand years ago, but the small quantities obtained by them and people inhabiting the Middle East could never have justified the time and energy needed in developing it as a fuel for heating, lighting, and the multitude of other purposes which man has found for oil in the present highly Industrial Age.

The first oil well was sunk in Pennsylvania in June 1859, and it was brought in at a depth of some seventy feet, on August 27th of the same year.

*The Elizabeth Watts* is generally credited with being the first ship to carry a full cargo of oil across the Atlantic. She commenced her career in 1861. Several factors tended to retard the development of the early tanker, not the least of these was the attitude of owners and crews of the numerous wooden sailing ships of that period. Not without cause they regarded oil as a dangerous cargo. Leakage from barrels in the holds resulted in the spaces below deck becoming permeated with dangerous gas, which slowly made its way into the living accommodation, this in turn meant disaster or extreme discomfort as all lamps and cooking fires had to be extinguished.

The use of the iron hull to some extent offset these difficulties, and several sailing ships were built and converted for this trade. Several were fitted with specially built tanks for the carriage of oil. The future of the oil trade was then thought to lie in the large iron hulled sailing ship, fitted with iron tanks and equipped with hand pumps for the rapid and safe discharge of cargo. The idea of using a steamer for such cargo was as yet unthinkable, due to the danger of vapour reaching the coal fires in the machinery spaces.

As the industry developed, so did the early tanker. In 1878, the first ship to use the hull or skin as a container for oil was built. This vessel was called the *Zoroaster*, and her building marked a major step in the development of the modern tanker. To the bolder minded, the advantages of a steam-powered tanker became apparent, apart from the question of propulsion, steam powered pumps were an added advantage. To control the flow of liquid
when the vessel was rolling in a seaway, and to avoid large areas of free surface, the tanks were provided with trunk-ways, which considerably reduced the area at the top of the tank. Vessels, however, were often far short of their marks when loading light products, later types began to incorporate the "summer tank" which was housed on the trunk deck and was generally filled by means of a drop valve from the main tank below.

Towards the middle of the 1920's, the twin bulkhead ship made its appearance, and slowly but surely the advantages of the new design made itself felt, and the centre line bulkhead type began to be replaced in all but a few special types and coasters, where size made the twin bulkheads impracticable.

Welding was used in ship construction for a considerable period before World War II. However, where hull construction was concerned, welding was always viewed with grave suspicion, but like all new methods, material and techniques improved, and during World War II whole ships were constructed on this basis. The advantage of the welded hull is fairly obvious. All the plates are welded in a straight line, and there are no plate landings to restrict the flow of water along the hull as the vessel is propelled through the water. In addition to this, rivets have a tendency to work, leaks from this source are quite frequent both in the hull and in the bulkheads separating the cargo tanks. Welding has more or less eliminated leakage of this nature.

In the last ten to fifteen years, a great deal has been learnt about the use of metal in all types of construction. Research into metal fatigue and wastage as well as the use of coatings to prevent this, has helped considerably to simplify some of the problems encountered when carrying highly corrosive hydrocarbon liquids. Large-scale models in ship model basins have
assisted the ship designer to examine stress problems and to simplify the design and layout of large tankers, thus reducing the cost of construction.

Apart from the layout of the cargo compartments and pumping systems, there have been significant changes in other directions, e.g. power operated valves and remote control are becoming increasingly common. Properly used and maintained, such improvements show an economic return by reducing manpower requirements and eliminating human error from a complex operation where expensive equipment can be seriously damaged. It would not be wise to neglect other areas where changes are taking place. Nearly all the new ships have no amidship house. The bridge and living accommodation are located aft. Safety and economics have been the main reason for this change and the arguments of Masters and Pilots who have opposed it on navigational and ship handling grounds can find little support today.

In 1974 tankers were classified by size for freight purposes:

2. Medium range: 25,000/49,999 dwt.
3. L.RI (Large Range 1): 45,000/79,999 dwt.
4. L.R2 (Large Range 2): 80,000/159,999 dwt.
5. VLCC or Very Large Crude Carriers: 160,000/320,000 dwt.
6. ULCC or Ultra Large Crude Carriers: 320,000 dwt. and above.

While VLCC and ULCC were, and always are, likely to be exclusively engaged in the carrying of crude oil handy size and medium size vessels tend to cover a very large range of duties.

The larger vessels in the L.R2 range - i.e. over 100,000 dwt. tend to be crude carriers. They trade between ports that are restricted by draft or other limitations so that VLCC or ULCC cannot be used.

L.R1 and L.R2 range vessels of less than 100,000 dwt. are mainly divided into two classes - (a) Dirty product carriers. (b) Clean product carriers. The larger dirty product carriers are frequently switched between the crude trades and carrying refined dirty products. After carrying crude, the cargo tanks have to undergo cleaning to remove wax and crude residue, which might affect the flashpoint of dirty products like fuel oil. Some large dirty product carriers have their tanks coated to reduce corrosion from crude and water washing and facilitate changing from one to the other.
Clean product carriers in the medium size range tend to be less than 50,000 dwt. Many are purpose built with coated tanks and have sophisticated pumping systems capable of handling 12 or more grades.

A typical crude oil tanker, 2000

The largest dirty and clean product tankers have evolved from changing trade practices and requirements and though some of these vessels may be involved in short haul coastal distribution of refined products many are now involved in longer haul work. General purpose tankers probably cover the largest range and variety of different cargoes carried. This size range includes some chemical carriers as well as a host of purpose built clean and dirty product carriers engaged in short haul and coastal distribution. Tankers smaller than 16,500 are generally clean or dirty product short haul coastal vessels, but some are built to handle special products like bitumen, chemicals, acids as well as lubricating oil.

The big building programmes of the 1960's and early '70s were the result of high freight rates. The large numbers of ULCC and VLCC, which came into service, received a lot of publicity and to some extent hid the fact that the number of smaller ships produced was also significant.

The biggest tanker produced in the building boom was the Seawise Giant (now “Jahre Viking”). She was originally built as the Oppama before being enlarged in Japan. She had the highest recorded deadweight of 564,739 tons.
1.1.2 Types of oil carriers

*Oil tanker* means 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 Annex II of MARPOL 73/78 when it is carrying a cargo or part cargo in bulk.

*Crude oil tanker* means an oil tanker engaged in the trade of carrying crude oil.

*Product carrier* means an oil tanker engaged in the trade of carrying oil other than crude oil.
Combination carrier means a ship designed to carry either oil or solid cargoes in bulk.

1.1.3 Combination carriers

Oil/Ore (O/O)
This is an oil tanker, which is equipped to carry ore in its centre cargo compartments. Compared with a similar-sized conventional tanker, the main differences revolve around the centre compartments, which are located over double bottom tanks, and have large, heavy
steel hatch covers. The centre compartments are normally arranged so that the longitudinal plating slopes inwards, providing a self-stowing factor when loading ore. The centre compartments are generally free from all structural members, which would hinder loading or discharging ore.

If coils are required for heating the oil these are installed in the wings or the holds and welded on racks to the plating near the bottom or the tank top. The centre compartments contain no piping, and are loaded and pumped out by utilising wells let into the double bottoms and connected to the cargo piping system through the wing tanks.

The wing tanks are arranged in the same manner as a conventional tanker and carry oil and ballast as required. Coils and cargo piping are similar to those found in conventional tankers. These ships are designed to carry their full deadweight when trading as tankers and also when carrying heavy ore concentrates. They are not usually designed to carry light bulk cargoes. Heavy ore concentrates are carried only in the centre holds. Oil cargo may be carried in both centre holds and cargo wing tanks.

Holds are constructed so as to extend approximately one half of the total breadth of the ship. Conventional wing tanks incorporate the main strengthening sections, allowing smooth sides in the centre holds. Holds are always constructed with double bottom spaces beneath them. Hatches are generally single piece side rolling with a sealing arrangement similar to that on OBO ships.

Cargo pipelines are usually installed in the wing tanks, whilst ballast pipelines are typically installed in the double bottom tanks. Where cargo pipelines pass through permanent ballast tanks, the possibility of pollution caused by pipeline failure should be borne in mind.
Oil/Bulk/Ore (OBO)
The OBO ship is capable of carrying its full deadweight when trading as an ore carrier with cargoes of heavy ore concentrates. This type of ship is also designed to carry other types of dry bulk cargo such as grain and coal.

Holds are usually arranged to extend the full breadth of the ship, with upper and lower hopper tanks and double bottom tanks. In some cases holds may have wing tanks. Oil or dry bulk cargo is carried in the holds. Oil may in addition be carried in one or more sets of upper hopper tanks, and where there are wing tanks they may also be used. Normally wing tanks for the carriage of oily slops are fitted aft of the cargo holds. Segregated (clean) ballast may be carried in top and bottom hopper tanks and in double bottom tanks. Conventional bulk carrier hatches, normally of the side rolling type, are fitted with a special sealing arrangement.

Cargo and ballast pipelines are typically installed in a duct keel or in two pipe tunnels located either side of the centre line and separated by a double bottom tank. The ballast system is entirely independent from the cargo system. Ballast can be loaded in the holds if this is necessary, but has to be done by utilising the cargo system. In some vessels each hold or centre compartment has a separate loading line which enters the ducts via the void spaces, thus allowing the pump room to be kept gas-free.

This type of vessel at first appears to be much the same, as an Oil-Ore Carrier, as the centre compartments are constructed along similar lines. The main difference is that the bulk oil carrier does not carry either oil or ore in its wing tanks, which are purely for ballast. Looked at from a structural standpoint, the holds of the Bulk-Oil carrier are bigger and wider, and the wing tanks are much narrower. Both ships have double bottoms, which can be used for ballast, and the cargo piping system is generally arranged so that cargo is loaded through pipes or ducts which run fore and aft through the double bottoms.
1.1.4 General instructions

Petroleum and dry bulk cargoes must not be carried simultaneously. Attention should be paid to the gas contents of wing tanks when the vessel is discharging bulk ore. Similarly, it should be realised that damaged bulkheads may lead to flammable gas mixtures in ore holds.

1.1.5 Comparison of both Types of Combined Carrier

Size for size, the “O/O” and “OBO” carriers are reported to cost about 15 per cent. to 20 per cent. more than a conventional tanker. Ore is a much heavier cargo than oil. It requires less stowage space and concentrates the weight directly below each hold. It follows therefore, that much of the extra cost goes in making the vessel stronger, and in providing the flexibility to handle ore as well as oil.

Some Bulk-Oil carriers have difficulty loading to their marks when handling light crude, this is particularly true on short voyages when bunkers, water and stores are kept to a minimum. Tank cleaning is reduced and there should be no delays in port for ballasting and deballasting, as with a segregated ballast system this can be done simultaneously. Both types vary considerably with regard to the type and arrangement of cargo-pumping systems.

In some instances the cargo manifolds are cramped for space by the cargo hatches, and it becomes difficult to connect an adequate number of loading arms or hoses.

Loading rates are more likely, to be restricted in Bulk-Oil carriers than Oil-Ore carriers, as the centre compartments are very large. Most are restricted to loading 50 per cent. or less of their cargo compartments at any one time because of stress and stability problems. If such a vessel takes a list, it is very difficult to correct without stopping the loading operation.

When discharging, the Bulk-Oil carrier should have little or no stripping to do, and apart from getting the oil out of the ducts there should be no delays in discharging crude. In some of the vessels fitted with ducts, great care has to be taken when oil first enters a duct, or when switching tanks during a loading operation. Air trapped in the duct can be compressed by, the incoming liquid, and finally vent itself taking some crude with it up the vent pipe with messy, if not disastrous consequences.

1.1.6 The Economics of the Combined Carrier

Ideally the combined carrier, whether it is Oil-Ore or Bulk-Oil should carry coal or ore way, and oil the other, thus eliminating the ballast passage. A minority of such vessels are fortunate to be fixed in such trades. More frequently a vessel engaged in carrying solid as well as liquid cargo, will make a triangular or box voyage with a short ballast voyage between longer loaded passages. For the main part, many of the larger ships may carry oil all their useful lives, in much the same way as a conventional tanker, but the ability to switch is a useful hedge against low freight rates.

1.1.7 Double hull tankers

The double-hull design has many advantages over the more traditional single-hull designs, performing better in low-speed collision or grounding situations. Looking at 30 tanker groundings between 1969 and 1973, a study by the U.S. Coast Guard concluded that 96 percent of the spills could have been prevented with double hulls. How these monstrous tankers can so successfully avoid oil spillage is a direct outcome of their engineering and design.

There are two types of double-hull ballast arrangements. The first is the "L" type arrangement, where the ballast is the space between the outer and inner hulls. This design has the potential for large off-centre weights if any portion of the cargo in either the port or
starboard tanks is lost. This can lead to instability and in rough seas potentially to capsize. The second type of double-hull tanker is the "U" type, in which the ballast is one continuous divider between the outer and inner hulls. This design is much more stable under spill conditions, and because it separates the cargo into smaller containers (assuming standard tanker size), less oil will spill if one tank is ruptured.

Both configurations of double-hulled tankers achieve the same, major objective. During a low-speed collision, because the outer and inner hulls are separated by at least 6 feet, typically only the outer hull will rupture. This leaves the inner hull intact and consequently, the oil that it contains. So theoretically, it is possible for a double-hull tanker to run aground, and not spill any oil. However, a severe accident such as the grounding of the VALDEZ would probably puncture both hulls and spill oil. But as far as protecting more efficiently against oil spills in all accident scenarios, double-hulls are far superior to their predecessors.

In a study recently performed by scientists the strength of double-hull tankers under grounding conditions was examined. The researchers chose four double-hull and two single-hull tankers of conventional type and modelled their design characteristics using various calculation models. Then, varying the parameters of stresses and other factors involved in tanker groundings they determined which design was more effective in preventing spills. They found that all four double-hull designs were safe, and would not leak oil upon grounding. When compared to the results with single-hull designs, they also found that the older design was far more likely to spill oil when grounded. Not only are single-hulled tankers weaker when subjected to grounding conditions, but also they are harder to clean. The internal sides of single-hull tankers are a matrix of support beams and girders.
These help support the ship, but make it difficult to clean out the tanks. In a double-hull tanker the insides of the tanks are smooth (supports are between outer and inner hulls) and subsequently side clingage is minimized, making tank cleaning much easier. Periodic cleaning prevents excess corrosion, and makes the tanks more accessible to mandatory and company-sponsored inspections. Together, this reduces the risk of an oil spill.

In addition, the void between the two hulls is subject to minimal corrosion. This is accomplished by the continuous evacuation of water from this space using a bilge pump or a similar device. Making the newer design more corrosion resistant accomplished a number of things. First, it preserves the integrity of the design for a greater amount of time increasing the longevity of the ship. Second, it reduces the need for maintenance and inspection of the hulls.

Paired with the overwhelming spill prevention aspects of double-hulls are also some drawbacks. The void between the two hulls discussed above produces some immediately obvious problems. Since it is a large vacant space adjacent to a large concentration of hydrocarbons (in the cargo tanks) it is possible that combustible vapours accumulate in this void. The outcome of a collision or grounding would then be disastrous, a spark producing not only an explosion of the vapours in the void but also a breach of the inner and outer hulls. This could further lead to the ignition of the cargo. Pollution from the burning oil slick would be disastrous, not to mention the sheer amount of oil spilled by such an explosion. Regulatory controls such as the Oil Protection Act of 1990 have accommodated for such a possibility, prohibiting any sort of cargo transport piping in the area between the two hulls. Regardless, a small risk remains.

Another problem with double-hulls has to do with the stability of ships after collisions. In this scenario a collision breaches the outer hull of the tanker, and seawater flows into the void between the cargo tanks and the outer hull. The asymmetric flooding of this void could cause the tanker to become unstable, and possibly list to one side (port/starboard tilt). In rough waters such a tilt could cause the ship to become swamped and potentially lead to it’s capsize. The results of such a scenario would be disastrous, resulting in the sinking of the ship and potentially the loss of all its cargo into the surrounding water.
1.1.8 Building double hulls

The new requirements imposed by IMO will significantly change shipping around the world. Data made available suggests that the implementation of double-hull tankers has the potential to prevent nearly half of all accident-related oil spills, comprising one-fifth of all maritime oil pollution. Building contracts for tankers made on and after July 6, 1993, are required to have double hull structure, or an equivalent method offering same protection, in accordance with amendment adopted at the MARPOL Conference in 1992.

One design that is promising has a double bottom and an oil tight deck across its middle. This divides the cargo into upper and lower containers, and would theoretically minimize the amount of oil spilled in an accident. Other designs include variations and combinations of ballast configurations and each has its advantages and drawbacks.
The design standards for new ships are included in regulation 13F of Annex I of MARPOL 73/78. All new tankers of 5,000 dwt and above must be fitted with double hulls, separated by a space up to 2 metres (on tankers below 5,000 dwt the space must be at least 0.76 metre.

Converting older, single-hull tankers into double-hulls will be perhaps the hardest task. Retrofitting a single-hull vessel with a new double bottom would cost an estimated 25 percent of the full replacement cost of the tanker. Fulfilling other requirements such as changing the hull plating could raise the cost up to 50 to 60 percent of the full replacement cost. Even though the double-hull is the best of all the possible barrier designs it would be nearly impossible to retrofit old tankers within a reasonable cost with a double hull.

1.1.9 New global timetable to phase-out single-hull tankers agreed (30.4.2001)


In a landmark decision for the cause of safer shipping and cleaner oceans, the International Maritime Organization (IMO) has approved a new global timetable for accelerating the phase-out of single-hull oil tankers.

At the end of a weeklong meeting of the Organization’s Marine Environment Protection Committee (MEPC 46, April 23rd – 27th, Chairman, Mr Mike Julian of Australia) at IMO headquarters in London, delegates from IMO’s 158 member States agreed to a timetable that will see most single-hull oil tankers eliminated by 2015 or earlier. Double-hull tankers offer greater protection of the environment from pollution in certain types of accident. All new oil tankers built since 1996 are required to have double hulls.

The new phase-out timetable, which will be enshrined in a revised regulation 13G of the MARPOL Convention on the prevention of marine pollution, is one of a range of post-Erika measures tabled by IMO. The new regulation will enter into force in September 2002, the earliest possible time permitted under the MARPOL Convention.

According to IMO Secretary-General William O’Neil, IMO has demonstrated quite clearly that it can respond to the needs of member governments and the world shipping community. He said, “To deal with the fallout from the Erika we worked out a schedule, in consultation with the chairmen of our two main committees, which advanced the date of this session of the MEPC so that any amendments adopted now could be put into force as soon as the IMO Convention allows.” The 46th session of the MEPC was brought forward from its original proposed date of July 2001.

Mr O’Neil added, “The adoption of the proposed amendments to MARPOL regulation 13G reaffirms IMO’s position as the proper forum for dealing with complex technical, economic and political issues concerning international shipping, where significant differences in viewpoints can be resolved and a solution found that is acceptable to all.”

The revised regulation identifies three categories of tankers, as follows:

“Category 1 oil tanker” means oil tankers of 20,000 tons deadweight and above carrying crude oil, fuel oil, heavy diesel oil or lubricating oil as cargo, and of 30,000 tons deadweight and above carrying other oils, which do not comply with the requirements for protectively located segregated ballast tanks (commonly known as Pre-MARPOL tankers).

“Category 2 oil tanker” means oil tankers of 20,000 tons deadweight and above carrying crude oil, fuel oil, heavy diesel oil or lubricating oil as cargo, and of 30,000 tons deadweight and above carrying other oils, which do comply with the protectively located segregated ballast tank requirements (MARPOL tankers),

while “Category 3 oil tanker” means an oil tanker of 5,000 tons deadweight and above but less than the tonnage specified for Category 1 and 2 tankers.
Although the new phase-out timetable sets 2015 as the principal cut-off date for all single-hull tankers, the flag state administration may allow for some newer single-hull ships registered in its country that conform to certain technical specifications to continue trading until the 25th anniversary of their delivery.

However, under the provisions of paragraph 8(b), any Port State can deny entry of those single-hull tankers, which are allowed to operate until their 25th anniversary to ports or offshore terminals. They must communicate their intention to do this to IMO. The European Community Member States, together with Cyprus and Malta, indicated that they would make use of paragraph 8(b) and would deny port entry to single-hull tankers beyond 2015.

As an additional precautionary measure, a Condition Assessment Scheme (CAS) will have to be applied to all Category 1 vessels continuing to trade after 2005 and all Category 2 vessels after 2010. A resolution adopting the CAS was passed at the meeting.

Although the CAS does not specify structural standards in excess of the provisions of other IMO conventions, codes and recommendations, its requirements stipulate more stringent and transparent verification of the reported structural condition of the ship and that documentary and survey procedures have been properly carried out and completed.

The requirements of the CAS include enhanced and transparent verification of the reported structural condition and of the ship and verification that the documentary and survey procedures have been properly carried out and completed. The Scheme requires that compliance with the CAS is assessed during the Enhanced Survey Programme of Inspections concurrent with intermediate or renewal surveys currently required by resolution A.744(18), as amended.

The existing MARPOL regulation 13G, adopted in 1992, already legislated for the phasing-out of single-hull tankers but over a more protracted period which would have allowed some ships to continue trading until their 30th anniversary.

1.1.10 Load on top (LOT)

Not all oil pollution is caused by tankers. However, the huge volume of crude oil transported by sea has created a major problem in disposing of dirty ballast and tank washings without harming the marine environment or damaging coastal amenities.

Most crude oils contain wax and other materials in solution, together with sediments, which may settle out during the voyage and form a residue with any cargo remaining after discharge (of the order of 0.2 to 0.5 per cent of the cargo carried). If discharged into the sea in heavy concentrations in the course of tank washing the residue will stay on the surface for a long time and cause pollution.

Hence it must be kept on board and may be discharged at loading terminals where the necessary facilities are available. If not, the residue must be retained and the new cargo loaded on top (LOT). In no circumstances may the residue be discharged into the sea unless the safety of the ship or its personnel is at hazard.

Objects of Load on Top

The essential purpose of the Load on Top system is the collection and settling on board of the water and oil mixtures resulting from ballasting and tank operations-usually in a special slop tank or tanks-and their subsequent disposal ashore at the discharge port.

When oil and water are agitated together droplets of oil can enter the water and water can enter the oil. When oil droplets enter water they are generally well dispersed and will settle out, the rate depending upon the specific gravity of the oil and the size of the oil droplets.

Tank washing and pumping of wash water and oil residues produce water droplets, which will enter the oil. Most crude oils contain emulsifying elements, which hinder the separation
of water dispersed in the oil. The oil residues in the slop tank generally contain this type of water-in-oil emulsion, which is stable and long-lasting.

**The 1954 Convention as Amended**

All tankers can perform Load on Top operations, which will enable them to meet the requirements of the 1954 Convention as amended in 1969. The 1969 amendments impose a total prohibition on the discharge of any oil or oily mixture from a tanker within 50 miles of any coast, and limit the flow, concentration and quantity discharged anywhere else at sea.

Limited discharges may be made when the following conditions are satisfied:

(i) "The tanker is proceeding en route".
   (This eliminates the possible concentration of the permitted discharge from a stationary vessel or from a vessel steaming in tight circles, and ensures that the discharge is well distributed).

(ii) "The instantaneous rate of discharge of oil content of any effluent shall not exceed 30 litres per mile".
   (The "instantaneous rate" means the rate of discharge of oil content in litres per hour at any instant divided by the speed of the tanker in knots at the same instant. Experiment has shown that 30 litres per mile discharged in this way disperses rapidly and leaves no trace of oil on the surface of the water within 2 or 3 hours of discharge.)

(iii) "The total quantity of oil discharged into the sea does not exceed for existing tankers $1/15,000$ of the total quantity of the particular cargo which the residue formed a part, and for new tankers $1/30,000$ of the total quantity of the particular cargo which the residue formed a part; and the tanker has in operation an oil discharge monitoring and control system ".
   (This puts a limit on the total amount of oil that can be discharged even at the reduced rate set out in (ii)).

(iv) "The tanker is more than 50 miles from the nearest land".
   (This is to make quite certain that the very small amounts of oil permitted to be discharged in compliance with requirements (ii) and

These restrictions, all of which must be complied with, apply to crude oil, fuel oil, heavy diesel oil and lubricating oil. Discharges from pump-room bilges should be treated in a similar manner.

When a tanker is within 50 miles of land the only permitted discharge is clean ballast from a cargo tank, which has been so cleaned that, the effluent from which would produce no visible traces of oil on the surface of the water (max 15 parts per million).
1.1.11 Definitions

Administration
Means the Government of the State whose flag the ship is entitled to fly.

Approved equipment
Equipment of a design that has been tested and approved by an appropriate authority such as a government department or classification society. The authority should have certified the equipment as safe for use in a specified hazardous atmosphere.

Auto-ignition
The ignition of a combustible material without initiation by a spark or flame, when the material has been raised to a temperature at which self-sustaining combustion occurs.

Bonding
The connecting together of metal parts to ensure electrical continuity.

Cathodic protection
The prevention of corrosion by electrochemical techniques. On tankers it may be applied either externally to the hull or internally to the surfaces of tanks. At terminals, it is frequently applied to steel piles and fender panels.

Clingage
Oil remaining on the walls of a pipe or on the internal surfaces of tanks after the bulk of the oil has been removed.

Cold work
Work, which cannot create a source of ignition.

Combination carrier
A ship, which is designed to carry either petroleum cargoes or dry bulk cargoes.

Combustible (also referred to as ‘Flammable’)
Capable of being ignited and of burning. For the purposes of this guide the terms ‘combustible’ and ‘flammable’ are synonymous.

Combustible gas indicator
An instrument for measuring the composition of hydrocarbon gas/air mixtures, usually giving the result as a percentage of the lower flammable limit (LFL).

Dangerous area
An area on a tanker, which for the purposes of the installation and use of electrical equipment is regarded as dangerous.

Dry chemical powder
A flame inhibiting powder used in fire fighting.

Earthing (also referred to as ‘Grounding’)
The electrical connection of equipment to the main body of the earth to ensure that it is at earth potential. On board ship, the connection is made to the main metallic structure of the ship, which is at earth potential because of the conductivity of the sea.
Entry permit
A document issued by a responsible person permitting entry to a space or compartment during a specific time interval.

Explosimeter
See ‘Combustible gas indicator’.

Explosion-proof (‘Flame-proof’)
Electrical equipment is defined and certified as explosion- (flame-) proof when it is enclosed in a case, which is capable of withstanding the explosion within it of a hydrocarbon gas/air mixture or other specified flammable gas mixture. It must also prevent the ignition of such a mixture outside the case either by spark or flame from the internal explosion or as a result of the temperature rise of the case following the internal explosion. The equipment must operate at such an external temperature that a surrounding flammable atmosphere will not be ignited.

Explosive range
See ‘Flammable range’.

Flame arrester
A permeable matrix of metal, ceramic or other heat resisting materials which can cool a deflagration flame, and any following combustion products, below the temperature required for the ignition of the flammable gas on the other side of the arrester.

Flame screen
A portable or fitted device incorporating one or more corrosion resistant wire woven fabrics of very small mesh which is used for preventing sparks from entering a tank or vent opening or, for a short time, preventing the passage of flame. (Not to be confused with flame arrester.)

Flammable (also referred to as ‘Combustible’)
Capable of being ignited and of burning. For the purposes of this guide the terms ‘flammable’ and ‘combustible’ are synonymous.

Flammable range (also referred to as ‘Explosive range’)
The range of hydrocarbon gas concentrations in air between the lower and upper flammable (explosive) limits. Mixtures within this range are capable of being ignited and of burning.

Flashlight (also referred to as ‘Torch’)
A battery operated hand lamp. An approved flashlight is one, which is approved by a competent authority for use in a flammable atmosphere.

Flashpoint
The lowest temperature at which a liquid gives off sufficient gas to form a flammable gas mixture near the surface of the liquid. It is measured in a laboratory in standard apparatus using a prescribed procedure.

Foam (also referred to as ‘Froth’)
An aerated solution, which is used for fire prevention and fire fighting.

Foam concentrate (also referred to as ‘Foam compound’)

The full strength liquid received from the supplier, which is diluted and processed to produce foam.
**Foam solution**
The mixture produced by diluting foam concentrate with water before processing to make foam.

**Free fall**
The unrestricted fall of liquid into a tank.

**Gas free**
A tank, compartment or container is gas free when sufficient fresh air has been introduced into it to lower the level of any flammable, toxic, or inert gas to that required for a specific purpose, e.g. hot work, entry, etc.

**Gas free certificate**
A certificate issued by an authorized responsible person confirming that, at the time of testing, a tank, compartment or container was gas free for a specific purpose.

**Hazardous area**
An area on shore which for the purposes of the installation and use of electrical equipment is regarded as dangerous. Such hazardous areas are graded into hazardous zones depending upon the probability of the presence of a flammable gas mixture.

**Hot work**
Work involving sources of ignition or temperatures sufficiently high to cause the ignition of a flammable gas mixture. This includes any work requiring the use of welding, burning or soldering equipment, blow torches, some power driven tools, portable electrical equipment which is not intrinsically safe or contained within an approved explosion-proof housing, and internal combustion engines.

**Hot work permit**
A document issued by a responsible person permitting specific hot work to be done during a specific time interval in a defined area.

**Hydrocarbon gas**
A gas composed entirely of hydrocarbons.

**Inert condition**
A condition in which the oxygen content throughout the atmosphere of a tank has been reduced to 8 per cent or less by volume by the addition of inert gas.

**Inert gas**
A gas or a mixture of gases, such as flue gas, containing insufficient oxygen to support the combustion of hydrocarbons.

**Inert gas distribution system**
All piping, valves, and associated fittings to distribute inert gas from the inert gas plant to the cargo tanks, to vent gases to atmosphere and to protect tanks against excessive pressure or vacuum.

**Inert gas plant**
All equipment fitted to supply, cool, clean, pressurize, monitor and control the delivery of inert gas to the cargo tank systems.
**Inert gas system (IGS)**
An inert gas plant and inert gas distribution system together with means for preventing backflow of cargo gases to the machinery spaces, fixed and portable measuring instruments and control devices.

**Inerting**
The introduction of inert gas into a tank with the object of attaining the inert condition.

**Insulating flange**
A flanged joint incorporating an insulating gasket, sleeves and washers to prevent electrical continuity between pipelines, hose strings or loading arms.

**Interface detector**
An electrical instrument for detecting the boundary between oil and water.

**Intrinsically safe**
An electrical circuit or part of a circuit is intrinsically safe if any spark or thermal effect produced normally (i.e., by breaking or closing the circuit) or accidentally (e.g. by short circuit or earth fault) is incapable, under prescribed test conditions, of igniting a prescribed gas mixture.

**Loading overall**
The loading of cargo or ballast ‘over the top’ through an open ended pipe or by means of an open ended hose entering a tank through a hatch or other deck opening, resulting in the free fall of liquid.

**Lower flammable limit (LFL)**
The concentration of a hydrocarbon gas in air below which there is insufficient hydrocarbon to support and propagate combustion. Sometimes referred to as lower explosive limit (LEL).

**Mooring winch brake design capacity**
The percentage of the minimum breaking load (MBL) of a new mooring rope or wire it carries, at which the winch brake is designed to render. Winch brakes will normally be designed to hold 80% of the line’s MBL and will be set in service to hold 60% of the mooring line’s MBL. Brake holding capacity may be expressed either in tonnes or as a percentage of a line’s MBL.

**Mooring winch design heaving capacity**
The power of a mooring winch to heave in or put a load on its mooring rope or wire. Usually expressed in tonnes.

**Naked lights**
Open flames or fires, lighted cigarettes, cigars, pipes or similar smoking materials, any other unconfined sources of ignition, electrical and other equipment liable to cause sparking while in use, and unprotected light bulbs.

**Non-volatile petroleum**
Petroleum having a flash point of 60°C or above as determined by the closed cup method of test.
**Oxygen analyzer/meter**
An instrument for determining the percentage of oxygen in a sample of the atmosphere drawn from a tank, pipe or compartment.

**Packaged cargo**
Petroleum or other cargo in drums, packages or other containers.

**Permissible Exposure Limits (PEL)**
The maximum exposure to a toxic substance that is allowed by appropriate regulatory standards, including those of flag States. PEL’s are usually expressed as:
- **Time Weighted Average (TWA)** — the airborne concentrations of a toxic substance averaged over an 8 hour period, usually expressed in parts per million (ppm).
- **Short Term Exposure Limit (STEL)** — the airborne concentration of a toxic substance averaged over any 15 minute period, usually expressed in parts per million (ppm).

**Petroleum**
Crude oil and liquid hydrocarbon products derived from it.

**Petroleum gas**
A gas evolved from petroleum. The main constituents of petroleum gases are hydrocarbons, but they may also contain other substances, such as hydrogen sulphide or lead alkyls, as minor constituents.

**Pour point**
The lowest temperature at which petroleum oil will remain fluid.

**Pressure surge**
A sudden increase in the pressure of the liquid in a pipeline brought about by an abrupt change in flow velocity.

**Pressure/vacuum relief valve (P/V valve)**
A device, which provides for the flow of the small volumes of vapour, air or inert gas mixtures caused by thermal variations in a cargo tank.

**Purging**
The introduction of inert gas into a tank already in the inert condition with the object of: (1) further reducing the existing oxygen content; and/or (2) reducing the existing hydrocarbon gas content to a level below which combustion cannot be supported if air is subsequently introduced into the tank.

**Pyrophoric iron sulphide**
Iron sulphide capable of a rapid exothermic oxidation causing incandescence when exposed to air and potential ignition of flammable hydrocarbon gas/air mixtures and created by the reaction of hydrogen sulphide crude oils with rusty metal surfaces. (See sour crude oil)

**Reid vapour pressure (RVP)**
The vapour pressure of a liquid determined in a standard manner in the Reid apparatus at a temperature of 37.8°C and with a ratio of gas to liquid volume of 4:1. Used for comparison purposes only. See ‘True Vapour Pressure’.
**Responsible officer (or person)**
A person appointed by the employer or the master of the ship and empowered to take all decisions relating to a specific task, having the necessary knowledge and experience for that purpose.

**Resuscitator**
Equipment to assist or restore the breathing of personnel overcome by gas or lack of oxygen.

**Self-stowing mooring winch**
A mooring winch fitted with a drum on which a wire or rope is made fast and automatically stowed.

**SOLAS**
The International Convention for the Safety of Life at Sea.

**Sour crude oil**
A crude oil containing appreciable amounts of hydrogen sulphide and/or mercaptans.

**Spontaneous combustion**
The ignition of material brought about by a heat producing (exothermic) chemical reaction within the material itself without exposure to an external source of ignition.

**Static electricity**
The electricity produced by dissimilar materials through physical contact and separation.

**Stripping**
The final operation in pumping bulk liquid from a tank or pipeline.

**Tanker**
A ship designed to carry liquid petroleum cargo in bulk, including a combination carrier when being used for this purpose.

**Tank Cleaning**
The process of removing hydrocarbon vapours, liquid or residue. Usually carried out so that tanks can be entered for inspection or hot work.

**Terminal**
A place where tankers are berthed or moored for the purpose of loading or discharging petroleum cargo.

**Terminal representative**
A person designated by the terminal to take responsibility for an operation or duty.

**Threshold limit value (TLV)**
The time-weighted average concentration of a substance to which workers may be repeatedly exposed, for a normal 8-hour workday or 40-hour workweek, day after day, without adverse effect. (See also Permissible Exposure Limits.)

**Topping off**
The operation of completing the loading of a tank to a required ullage.
**Topping up**
The introduction of inert gas into a tank, which is already in the inert condition with the object of raising the tank pressure to prevent any ingress of air.

**Torch**
See ‘Flashlight’.

**Toxic**
Poisonous to human life.

**True vapour pressure (TVP)**
The true vapour pressure of a liquid is the absolute pressure exerted by the gas produced by evaporation from a liquid when gas and liquid are in equilibrium at the prevailing temperature and the gas/liquid ratio is effectively zero.

**Ullage**
The depth of the space above the liquid in a tank.

**Upper flammable limit (UFL)**
The concentration of a hydrocarbon gas in air above which there is insufficient oxygen to support and propagate combustion. Sometimes referred to as upper explosive limit (UEL).

**Vapour**
A gas below its critical temperature.

**Vapour emission control system**
An arrangement of piping and equipment used to control vapour emissions during tanker operations, including ship and shore vapour collection systems, monitoring and control devices and vapour processing arrangements.

**Vapour lock system**
Equipment fitted to a tank to enable the measuring and sampling of cargoes without release of inert/inert gas pressure.

**Volatile petroleum**
Petroleum, having a flash point below 60ºC as determined by the closed cup method of testing.

**Water fog**
A suspension in the atmosphere of very fine droplets of water usually delivered at a high pressure through a fog nozzle for use in fire fighting.

**Water spray**
A suspension in the atmosphere of water divided into coarse drops by delivery through a special nozzle for use in fire fighting.

**Work permit**
A document issued by a responsible person permitting specific work to be done during a specific period in a defined area.
This part introduces the international and national rules and regulations affecting chemical shipping. Shipping is perhaps the most international of all the world's great industries - and one of the most dangerous. It has always been recognised that the best way of improving safety at sea is by developing international regulations that are followed by all shipping nations and from the mid-19th century; onwards a number of such treaties were adopted. Several countries proposed that a permanent international body should be established to promote maritime safety more effectively, but it was not until the establishment of the United Nations itself that these hopes were realised. In 1948, an international conference in Geneva adopted a convention formally establishing IMO. It entered into force in 1958 and the new Organisation met for the first time the following year.

**1.2.1 IMO: what it is, what it does and how it works**

When the establishment of a specialised agency of the United Nations dealing with maritime affairs was first proposed, the main concern was to evolve international machinery to improve safety at sea. Because of the international nature of the shipping industry, it had long been recognised that action to improve safety in maritime operations would be more effective if carried out at an international level rather than by individual countries acting unilaterally and without co-ordination with others. Although a number of important international agreements had already been adopted, many States believed that there was a need for a permanent body, which would be able to co-ordinate and promote further measures on a more regular basis. It was against this background that a conference held by the United Nations in 1948 adopted a convention establishing the International Maritime Organisation (IMO) as the first ever international body devoted exclusively to maritime matters.

In the 10-year period between the adoption of the Convention and its entry into force in 1958, other problems related to safety but requiring slightly different emphasis had attracted international attention. One of the most important of these was the threat of marine pollution from ships, particularly pollution by oil carried in tankers. An international convention on this subject was actually adopted in 1954, four years before IMO came into existence, and responsibility for administering and promoting it was assumed by IMO in January 1959. From the very beginning, the improvement of maritime safety and the prevention of marine pollution have been IMO's most important objectives. IMO is a technical organisation and most of its work is carried out in a number of committees and sub-committees. The Maritime Safety Committee (MSC) is the most senior of these. It has a number of sub-committees whose titles indicate the subjects they deal with:
- Safety of Navigation (NAV);
- Radio communications and Search and Rescue (COMSAR);
- Training and Watchkeeping (STW);
- Carriage of Dangerous Goods, Solid Cargoes and Containers (DSC);
- Ship Design and Equipment (DE);
- Fire Protection (FP);
- Stability and Load Lines and Fishing Vessel Safety (SLF);
- Flag State Implementation (FSI);
- Bulk Liquids and Gases (BLG).
The Marine Environment Protection Committee (MEPC) was established by the Assembly in November 1973. It is responsible for co-ordinating the Organisation’s activities in the prevention and control of pollution of the marine environment from ships. The FSI and BLG Sub-Committees are also sub-committees of the MEPC.

The Legal Committee was originally established to deal with the legal problems arising from the Torrey Canyon accident of 1967, but it was subsequently made a permanent committee. It is responsible for considering any legal matters within the scope of the Organisation.

1.2.2 What it does

In order to achieve its objectives, IMO has, in the last 35 years, promoted the adoption of some 40 conventions and protocols and adopted well over 700 codes and recommendations concerning maritime safety, the prevention of pollution and related matters.

The initial work on a convention is normally done by a committee or sub-committee; a draft instrument is then produced which is submitted to a conference to which delegations from all States within the United Nations system - including States which may not be IMO Members - are invited. The conference adopts a final text, which is submitted to Governments for ratification.

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

1.2.3 Safety

The first conference organised by IMO in 1960 was, appropriately enough, concerned with maritime safety. That conference adopted the International Convention on Safety of Life at Sea (SOLAS), which came into force in 1965, replacing a version adopted in 1948. The 1960 SOLAS Convention covered a wide range of measures designed to improve the safety of shipping. They included subdivision and stability; machinery and electrical installations; fire protection, detection and extinction; life-saving appliances; radiotelegraphy and radiotelephony; safety of navigation; carriage of grain; carriage of dangerous goods; and nuclear ships.

The safety of ships and their crews is IMO’s greatest concern. The 1960 SOLAS Convention was the basic international instrument dealing with matters of maritime safety and, in response to new developments, it was amended several times. However, because of the rather difficult requirements for bringing amendments into force, none of these amendments actually became binding internationally.

To remedy this situation and maybe introduce the needed improvements more speedily, in 1974 IMO convened a conference to adopt a new international convention for the safety of life at sea, which would incorporate the amendments adopted to the 1960 Convention as well as introduce other changes, including an improved amendment procedure. Under the new procedure, amendments adopted by the MSC would enter into force on a predetermined date unless they were objected to by a specific number of States. The 1974 SOLAS Convention entered into force on 25 May 1980.
In 1966 a conference convened by IMO adopted the International Convention on Load Lines. Limitations on the draught, to which a ship may be loaded, in the form of freeboards, are an important contribution to its safety. An international convention on the subject had been adopted in 1930; the new instrument brought this up to date and incorporated new and improved measures. It came into force in 1968.

The tonnage measurement of ships has been one of the most difficult problems in international shipping. IMO began work on this subject soon after coming into being, and in 1969 the first ever international convention dealing with it was adopted. It is an indication of the complexity of the matter that the Convention did not enter into force until 1982.

Among the most common causes of accidents at sea are collisions. Regulations for preventing collisions were adopted by the 1960 SOLAS Conference and annexed to the Final Act of the Conference. However, these rules were not part of the SOLAS Convention and were therefore not legally binding internationally. In 1972 IMO adopted the Convention on International Regulations for Preventing Collisions at Sea (COLREG).

This included a number of new features, including a provision, which made traffic separation schemes adopted by IMO mandatory. Traffic separation schemes had been introduced, as recommendations, in several parts of the world where maritime traffic was particularly congested. The adoption of such schemes has considerably reduced the number of collisions in many areas, and the coming into force of the Convention in 1977 led to further improvements in the implementation of these schemes.

Ultimately, safety rests very largely with the crews of ships rather than with the ships themselves. For this reason IMO has attached the utmost importance to the training of ships' personnel. In 1978 the Organisation convened a conference, which adopted the first ever, Convention on Standards of Training, Certification and Watchkeeping for Seafarers. The Convention entered into force in April 1984.

The Convention established, for the first time, internationally acceptable minimum standards for crews. It is not intended as a model on which all States must necessarily base their crew requirements, for in many countries the requirements are actually higher than those laid down in the Convention. The Convention was revised in 1995. Apart from bringing the Convention up to date from a technical point of view, the amendments also gave IMO the power to audit the administrative, training and certification procedures of Parties to the Convention. The amendments will enter into force in 1997.

1.2.4 Preventing pollution - providing compensation

The 1954 Oil Pollution Convention was the first major convention designed to curb the impact of oil pollution. But in the years that followed the pollution threat increased dramatically and, since coming into existence, IMO has devoted increasing attention to the problem of marine pollution. The 1954 Convention was amended in 1962, but the wreck of the Torrey Canyon in 1967 dramatically alerted the world to the great dangers, which the transport of oil poses to the marine environment.

Following this disaster, IMO produced a series of conventions and other instruments, including further amendments to the 1954 Convention, which were adopted in 1969.

In 1969, two conventions were adopted. One was the International Convention relating to Intervention on the High Seas in Cases of Oil Pollution Casualties, which established the
right of coastal States to intervene in incidents on the high seas, which are likely to result in oil pollution. It entered into force in 1975.

The second was the **International Convention on Civil Liability for Oil Pollution Damage**, which deals with the civil liability of the owner of a ship or cargo for damage suffered as a result of an oil pollution incident. The Convention is intended to ensure that adequate compensation will be readily available to victims of pollution, and places the obligation for paying such compensation on the ship owner. That Convention also entered into force in 1975.

It was felt by some Governments that the liability limits established by this Convention were too low, and that the compensation made available could, in some cases, prove to be inadequate. As a result, another conference was convened by IMO in 1971, which adopted the **Convention on the Establishment of an International Fund for Compensation for Oil Pollution Damage**. This Convention came into force in 1978.

In 1971, the 1954 Oil Pollution Convention was further amended to limit the hypothetical outflow of oil resulting from an accident and also to provide special protection for the Great Barrier Reef of Australia.

It was generally felt, however, that a completely new instrument was required to control pollution of the seas from ships, and in 1973, IMO convened a major conference to discuss the whole problem of marine pollution from ships. It resulted in the adoption of the first ever-comprehensive anti-pollution convention, the **International Convention for the Prevention of Pollution from Ships (MARPOL)**. The Convention deals not only with pollution by oil, but also pollution from chemicals, other harmful substances, garbage and sewage.

### 1.2.5 MARPOL

The present consolidated edition, 1997 edition presents the texts and unified interpretations of the Convention, articles, protocols, and Annexes I to V:

- **Annex I** - Regulation for the Prevention of Pollution by Oil
- **Annex II** - Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk
- **Annex III** - Regulation for the Prevention of Pollution by Harmful Substances in Packaged Form
- **Annex IV** - Regulation for the Prevention of Pollution by Sewage from Ships
- **Annex V** - Regulation for the Prevention of Pollution by Garbage from Ships

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

Certain technical problems made it difficult for many States to ratify the Convention. In the meantime, a series of tanker accidents in the winter of 1976/77 led to demands for further action. IMO responded to these demands and took rapid steps to convene the Conference on
Tanker Safety and Pollution Prevention in 1978. This Conference adopted a Protocol to the 1973 MARPOL Convention which introduced further measures, including requirements for such operational techniques as crude oil washing (a development of the earlier "load on top" system) and a number of modified constructional requirements such as protectively located segregated ballast tanks. The Protocol of 1978 relating to the 1973 MARPOL Convention in effect absorbs the parent Convention with modifications. This combined instrument is commonly referred to as MARPOL 73/78 and entered into force in October 1983. The Convention has been amended on several occasions since then.
In 1990, IMO adopted the **International Convention on Oil Pollution Preparedness, Response and Co-operation (OPRC)**. It is designed to improve the ability of nations to cope with a sudden emergency, such as a tanker accident. It entered into force in May 1995, but some of its provisions were used as the basis for IMO's response to the massive pollution of the Persian Gulf resulting from hostilities in the area in the spring of 1991. These measures, assisted by a special IMO fund, helped to save many ecologically important sites from major damage.

In 1996 IMO adopted an international convention on liability and compensation for damage in connection with the carriage of hazardous and noxious substances (HNS) by sea. The Convention establishes a two-tier system for providing compensation up to a total of around £250 million. It covers not only pollution aspects but also other risks such as fire and explosion. The Convention is not yet in force.

### 1.2.6 SOLAS

**SOLAS Part 1**

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**Part 2**

**Annex 1**

New chapter IX of the annex to the International Convention for the Safety of Life at Sea

**Annex 2**

Resolution A.718(17), as modified by resolution A.754(18): Early implementation of the harmonized system of survey and certification

**Annex 3**

Certificates and documents required to be carried on board ships

**Annex 4**

Resolutions of the conference of Contracting Parties to the International Convention for the Safety of Life at Sea, 1974, adopted on 24 May 1994

**Annex 5**

1.2.7 IMO's codes & recommendations

In addition to conventions and other formal treaty instruments, IMO has adopted several hundred recommendations dealing with a wide range of subjects. Some of these constitute codes, guidelines or recommended practices on important matters not considered suitable for regulation by formal treaty instruments. Although recommendations -whether in the form of codes or otherwise - are not usually binding on Governments, they provide guidance in framing national regulations and requirements. Many Governments do in fact apply the provisions of the recommendations by incorporating them, in whole or in part, into national legislation or regulations. In some cases, important codes have been made mandatory by including appropriate references in a convention. These recommendations are generally intended to supplement or assist the implementation of the relevant provisions of the conventions and, in some cases, the principal codes, guidelines, etc.

In appropriate cases, the recommendations may incorporate further requirements, which have been found to be useful or necessary in the light of experience gained in the application of the previous provisions. In other cases, the recommendations clarify various questions, which arise in connection with specific measures and thereby ensure their uniform interpretation and application in all countries.

Examples of the principal recommendations, codes, etc., adopted over the years are:

- International Maritime Dangerous Goods Code (IMDG Code) (first adopted in 1965);
- Code of Safe Practice for Solid Bulk Cargoes (1965);
- International Code of Signals (IMO took over responsibility for the Code in 1965);
- Code for the Construction and Equipment of Ships Carrying Dangerous Chemicals in Bulk (1971);
- Code of Safe Practice for Ships Carrying Timber Deck Cargoes (1973);
- Code of Safety for Fishermen and Fishing Vessels (1974);
- Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (1975);
- Code of Safety for Dynamically Supported Craft (1977);
- Code for the Construction and Equipment of Mobile Offshore Drilling Units (1979);
- Code on Noise Levels on Board Ships (1981);
- Code of Safety for Nuclear Merchant Ships (1981);
- Code of Safety for Special Purpose Ships (1983);
- International Gas Carrier Code (1983);
- International Bulk Chemicals Code (1983);
- Code of Safety for Diving Systems (1983);
- International Code for the Safe Carriage of Grain in Bulk (1991);
- International Safety Management Code (1993);
- International Code of Safety for High-Speed Craft (1994);
- Other important recommendations have dealt with such matters as traffic separation schemes (which separate ships moving in opposite directions by creating a central prohibited area); the adoption of technical manuals such as the Standard Marine Navigational Vocabulary, the IMO Search and Rescue Manual and the IMO Manual on Oil Pollution; crew training; performance standards for ship borne equipment; and many other matters. There are also guidelines to help the implementation of particular conventions and instruments.

The provisions of recommendations are sometimes incorporated into amendments to the relevant conventions. Recommendations enable provisions or requirements to be suggested relatively quickly to Governments for consideration and action. It is also easier for Governments to act on such matters than in respect of provisions in formal treaty instruments, which involve international legal obligations.
1.2.8 Dumping at sea
In addition to other aspects of marine pollution prevention, IMO also carries out Secretariat functions in connection with the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter. This Convention, now called the London Convention, was adopted in 1972 at a conference held under the auspices of the United Kingdom. It entered into force in 1975. The Convention controls and regulates on a global level the disposal at sea of wastes and other material of any kind (including ships and platforms). The disposal of certain substances which from the environmental point of view are known to be particularly harmful (such as organ halogen compounds, mercury, cadmium, plastics, mineral oils and radioactive wastes) is prohibited. The Convention also contains specific regulations concerning the dumping of several other materials, which may present a risk to the marine environment and human health. In addition, it bans the incineration of wastes on board ships.

1.2.9 How it works
The International Maritime Organisation works through a number of specialist committees and sub-committees. All these bodies are composed of representatives of Member States who discharge their functions with the assistance and advice of appropriate bodies of the United Nations or the specialised agencies, as well as international governmental and non-governmental organisations with which formal relationships have been established. Formal arrangements for co-operation have been established with more than 30 intergovernmental organisations, while nearly 50 non-governmental, international organisations have been granted consultative status to participate in the work of various bodies in an observer capacity. These organisations represent a wide spectrum of maritime, legal and environmental interests and they contribute to the work of the various organs and committees through the provision of information, documentation and expert advice. However, none of these organisations has a vote.

1.2.10 The future
Over the years, IMO has continually evolved to meet changing conditions and requirements. In its early days, it concentrated on formulating international conventions and codes. Today, however, IMO is just as concerned to ensure that the conventions, codes and other instruments already adopted are effectively enforced and implemented. There is significant evidence that IMO measures have already proved beneficial in many areas. Oil pollution of the sea, for example, is less of a threat now than it was 20 years ago and the number of collisions between ships has been greatly reduced in areas where IMO-approved traffic separation schemes have been introduced. But because of economic factors, the average age of the world's ships has risen steadily over the same period and statistics show that old ships have more accidents than young ones. The fleets of the traditional maritime countries - which tend to have good safety records - have declined, while many of the flags that are growing most rapidly have relatively poor records. As a result, nobody can afford to be complacent and IMO is concentrating not only on better implementation but also on improving such factors as management and training. All the
evidence shows that most accidents happen because people do not obey the regulations, not because the regulations are themselves defective.
10 CRUDE OIL WASHING (COW)
(STCW Code Sec. A-V/1 pa. 10, 12)

Learning objectives
- Crude oil washing
- Pollutions from oil cleaning operations
- Crude oil washing regulations
- Design of COW systems
- Design criteria
- Cowable cargoes.
- Advantages and disadvantages.
- Demands to cow personnel.
- Washing strategy.
- Washing machines.
- Tank atmosphere control.
- Cow simulation.

10.1 INTRODUCTION

Crude oil washing (COW) is a system whereby oil tanks on a tanker are cleaned out between voyages not with water, but with crude oil - the cargo itself. The solvent action of the crude oil makes the cleaning process far more effective than when water is used. (There is usually a final water rinse but the amount of water involved is very low.) The system helps prevent pollution of the seas from operational measures.

COW is mandatory on new tankers under the International Convention for the Prevention of Pollution by Ships (MARPOL 73/78).

10.1.1 The problem – pollution from oil cleaning operations

Tankers carry their cargo in a number of tanks or compartments within the hull of the ship. Before the introduction of segregated ballast tanks, tanks were cleaned after the oil was discharged and about one third of them filled with seawater so that the ship's propeller is properly immersed and it has correct handling and sea-keeping characteristics. This process is known as ballasting.

In the early days of oil tanker operations it was a common practice to clean tanks by means of jets spraying seawater. The jets washed the oil residues from the tank surfaces, resulting in a mixture of oil and water, which collected at the bottom of the tank and was then pumped overboard. This naturally led to a considerable amount of oil getting into the sea. The ballast water, which was pumped overboard to make way for a fresh cargo of oil, was also contaminated.

In the 1950s, there were no alternative ways of cleaning tanks. The OILPOL Convention, adopted in 1954, tried to alleviate the pollution from this process by prohibiting the discharge of oil or oily mixtures within 50 miles of land. This limit was extended to 100 miles in certain areas, which were regarded as being particularly endangered.

In the late 1960s, concern about the waste of oil and pollution caused by this process led the industry to look for an alternative. The result was to become known as "load on top".

Development of Load on Top
Under load on top, tanks were cleaned as previously using high-pressure hot-water cleaning machines. However, instead of pumping the resulting oily mixtures overboard, they were pumped into a special slop tank. During the course of the return voyage to the loading terminal this mixture separates. Oil, being lighter than water, gradually floats to the surface leaving the denser water at the bottom. This water is then pumped into the sea, leaving only crude oil in the tank. At the loading terminal fresh crude oil is then loaded on top of it. The process had advantages for the owner of the oil, since the oil normally lost during tank cleaning can be saved (as much as 800 tons of oil on a large tanker), but the main beneficiary was the environment. Some experts believe that without load on top the amount of oil being dumped into the sea as a result of tank cleaning could have reached more than 8 million tons a year.

10.1.2 Development of Crude Oil Washing

The introduction of load on top was a great contribution to the fight against marine pollution but it did not completely eliminate pollution resulting from tank cleaning operations. Although the amount and rate of discharge is carefully regulated the process still resulted in some pollution occurring.

In the late 1970s an improvement was introduced. Instead of using water, the tank cleaning machines used crude oil - in other words, the cargo itself.

When sprayed onto the sediments clinging to the tank walls, the oil simply dissolved them, turning them back into usable oil that could be pumped off with the rest of the cargo. There was no need for slop tanks to be used since the process left virtually no slops. The process became known as Crude Oil Washing (COW).

Crude oil washing meant that the mixture of oil and water, which led to so much operational pollution in the past, was virtually ended. At the same time, the owner is able to discharge far more of this cargo than before, since less of it is left clinging to the tank walls and bottoms.

10.1.3 Crude oil washing regulations

Crude oil washing was made mandatory for new tankers by the 1978 Protocol to the MARPOL Convention.

MARPOL Annex I Regulation 13 (6) requires every new crude oil tanker of 20,000 tons deadweight and above to be fitted with a cargo tank cleaning system using crude oil washing. Regulation 13B states that COW installation and arrangements should comply with at least all of the provisions of the Specifications for the Design, Operation and Control of Crude Oil Washing Systems adopted by IMO in 1978, as may be revised.

In 1999, IMO adopted revised specifications for COW by resolution A. 897(21) Amendments to the revised Specifications for the Design, Operation and Control of Crude Oil Washing Systems (Resolution A.446(XI), as amended by resolution A.497(XII).

10.1.4 General

MARPOL 73/78 recognises that Crude Oil Washing (COW) provides a means of reducing the contact between oil and water. Washing cargo tanks with crude oil reduce the amount of water washing needed for those tanks required for clean ballast and eliminate it for sludge control purposes.

Preparing tanks to acceptable clean ballast standards by water washing has always been intensive in time and labour, and when using hot water, costly in terms of bunkers consumed.
In steam turbine ships there was inevitably some loss of engine revolutions and the whole operation could take a week. Translated into financial terms the loss was significant.

Water is not the best medium for tank cleaning because:

- It contributes to corrosion of the tank structure;
- sludge remains on board after washing when operating load on top;
- it introduces unwanted salt-water into refineries;
- it leads to large quantities of oily-water slops which require decanting with consequent operationally allowed or accidental pollution;
- it increases dead freight; and
- it is incompatible with oil.

In some tank areas sludge deposits were difficult to remove, even when washing with hot water and chemicals. This led to expensive hand digging when preparing for repair periods and it was not unusual for VLCC’s to take between two and three weeks for cleaning tanks to hot work standard.

On occasions heavy wax deposits had been removed by using other oils (such as heated gas oil) which were pumped round tanks and were found particularly effective in cleaning and removing heavy sludge from tank sides and horizontal surfaces. This became standard operational procedure at some oil terminals 30 years ago. Cleaning with crude oil could not be considered (although its solvent properties had been known from biblical times) as it could only be carried out during cargo discharge and the recirculation of crude oil through portable tank washing machines would have presented a considerable pollution danger on the decks of ships.

The introduction of the fixed-in-place tank washing machines, operated by cargo pumps via permanent piping, solved the pollution problem. However in December 1969 three VLCC’s exploded off the African coast whilst water washing of tanks was in progress. One ship sank and the other two suffered severe structural damage. Development of crude oil washing in non-inerted tankers was held in abeyance while the causes were established.

10.1.5 Why COW is more efficient than water washing

Cleaning with water gives reasonable good result only when water jets with sufficient impact force are directly hitting the surfaces within a tank. Accordingly the cleaning effect is almost non-existent as far as reflected jets and drainage's are concerned. When using crude oil a surprisingly good cleaning result is obtained even from drainage's and reflected jets of crude oil - the so-called “splash-back effect”. Maintaining a pressure of at least 10 bar assists this process.

Crude oil has a latent ability to “clean up its own mess”. i.e. to dissolve and suspend the deposits. This process is facilitated by the thixotropic property of crude oils; i.e., the viscosity of the oil considerable reduced when being pressurized in pump(s), lines and nozzles of tank washing machines. As a result of the thixotropic property, crude oil used for tank washing drains effectively leaving only a surprisingly thin film upon the tank surface.

The superiority of crude oil to water as a tank cleaning fluid is exclusively dependent upon the dissolving property of crude oil. It is not possible to dissolve sediments from crude oil cargoes with water. But the latent dissolving property alone, oil is not enough. To explain
this, reference can be made to an everyday example: sugar on the bottom of a cup filled with water. Although the sugar is completely soluble in water, it does not dissolve to any greater extent unless the water is stirred. Sediments in a cargo tank are soluble in crude oil in a corresponding way. However no dissolving occurs until the deposits are agitated by direct or reflected jets of crude oil and by downward/aft running crude. Deposits are also dissolved by the heavy turbulence caused by powerful jets during washing in the surrounding oil. When pointing out the superiority of crude oil to water as cleaning medium, a very important part of the explanation is frequently overlooked: COW is carried out on surfaces which are still wet, while washing with water was done for most part several days after the unloading, when the surfaces to be cleaned had dried up.
10.1.6 Advantages and disadvantages of COW over water washing of cargo tanks.

Advantages with COW
Providing that equipment and procedures are well adapted for COW, the following advantages are gained in comparison with water washing:

- Considerable reduction in pollution potential since less oil remains on board after discharge and less oil-contaminated water is handed during the ballast passage.
- Reductions in time and cost of tank cleaning.
- De-sludging by hand obviated.
- Reduced tank cleaning time at sea.
- Increased out-turn of cargo.
- Reduced deadfreight as less oil-water slops are retained on board.
- Less salt water discharged to refineries.
- Tank corrosion due to water washing is reduced.
- More time for maintenance work at sea, since no additional tank cleaning is required, except water rinsing of tanks to contain arrival ballast.

Disadvantages with COW

- Increased workload during discharging.
- Prolonged time for discharging.
- Costs for extra personnel.
- Costs for COW equipment
- Potential safety and pollution risks.
- More equipment - higher demand for maintenance.

Therefore it is important to plan the discharge operation properly so that COW is not interfere with in any way, increase of discharge time will be least when cargo discharge is restricted by shore limitations.

Disadvantages with Water Washing
As tanker sizes increased and more stringent regulations against oil pollution were enforced, it was realised that water washing alone is an inferior tank cleaning method. LOT (Load On Top), no matter how complete and sophisticated it may be, can never remove the great disadvantages with water washing compared with COW:

- Longer time for washing each tank, resulting in increased bunker costs.
- Handling larger amounts of water is costly and causes increased pollution of the sea since the water is contaminated with oil, even when LOT procedures are used.
- Increased corrosion due to extensive water washing.
Reduced cargo capacity due to larger slop quantity.
Discharge of more salt water with the slops to refineries.
Longer period of time needed to prepare the tanks for dry dock or intermediate cold or hot work, tank inspections included.

10.1.7 Diagram for improved cargo out-turn due to COW

This diagram is based on the commonly recognised estimation that approximately one per cent of Bill of Lading quantity will remain in ship's cargo tanks after discharging without COW and thorough draining.

Line 3
The “economy stripping” philosophy - quick turnaround in the discharge port more appreciated than spending few hours on stripping to get well drained tanks - was practised and encouraged until the price of crude oil started to rise drastically.

Line 2
Several investigations have shown that a thorough after-draining with educators have increased the cargo out-turn with 0.2 - 0.5 per cent of the Bill of Lading quantity, and even more in some cases, approximately 500 - 1,250 tonnes for 250,000 tonnes of cargo.

Line 1
Draining (discharging) and COW according to IMO specifications, utilizing the small diameter line, will further improve the cargo out-turn compared to result obtained according to line 2.

Note that COW improves the cargo outturn in all three cases.

EXAMPLE:
A tanker with 250 000 tonnes of crude oil has crude oil washed 65 per cent of the total cargo tank volume in order to comply with IMO Specification 6.1

Questions:
a) How has this COW influenced the cargo out-turn and
b) was the extent of the washing sufficient to ensure a cargo out-turn of 99.7 per cent of the Bill of Lading quantity, (not more than 0.3 per cent of the Bill of Lading quantity remaining in ship's tanks)?

Solution:
A perpendicular through 65 per cent on the horizontal scale intersects line 1 in a point corresponding to 0.69 on the left and 0.31 on the right vertical scale, fun lines.

Answer to question a):
250,000 x 0.0069 = 1725 is the improvement in cargo out-turn in tonnes, and
250,000 x 0.0031 = 785 is remaining cargo on board in tonnes.
**Answer to question b):**
It is clear from the previous answer (0.31) that the extent of this washing was not quite sufficient. As the dotted lines indicate on the diagram at least two per cent more of the total cargo tank volume should have been washed in order to obtain a cargo out-turn of 99.7 per cent of the Bill of Lading quantity.

**Remark:**
There is a trend now that the cargo out-turn should be improved so that the remaining cargo on board after final discharge does not exceed 0.25 per cent of the Bill of Lading.
10.1.8 Applicability of the Requirements

By 1977 crude oil washing had been widely adopted by a large number of major oil companies and independent tanker owners as a means of sediment control. It was offered as an alternative to the fitting of segregated ballast tanks, SBT.

Briefly, existing crude oil carriers must be fitted with SBT systems if they are 40,000 dwt or above but, as an alternative, crude oil washing or a clean ballast tank system (CBT) may be allowed. In the case of CBT, the ship owner declares certain cargo tanks as "dedicated ballast tanks" and these are not allowed to carry cargo. A CBT system is similar to an SBT system except that pumps and lines serving the CBT tanks may also be used for cargo operations.

New crude oil ships over 20,000 dwt must be fitted with SBT/PL and COW: they are not allowed to operate CBT. Lastly, any ship must have an inert gas system (IGS) before it may operate Cow.

### 10.1.9 Pollution Prevention Certificate

Implementation of the MARPOL will require all ships that carry oil to be issued with an International Oil Pollution Prevention Certificate (IOPP). Trading patterns require ships to carry crude or product, or both simultaneously, and under the new regulations ships in each category must fulfill certain requirements. As some of these are the same for both product ships and crude oil ships, IMO have agreed to three categories for the IOPP which are:

- **Crude oil and products carrier**
  (Allowed to carry either crude oil or product oil or both simultaneously)

- **Product carrier.**
  (Allowed to carry product oil but not crude oil)

- **Crude oil carrier**
  (Allowed to carry crude oil but not product oil).

One anomaly among new ships are those larger than 70,000 dwt, fitted with SBT but without PL or COW that are built between the differing "new ship" dates laid down by MARPOL 73/78.

The IOPP certificate is issued for a period of five years, during which there will be at least one intermediate survey to ensure that ships' equipment does not materially differ from that shown on the certificate. In addition the inspections will check that ships are being operated in a correct and approved manner.
10.2 DESIGN OF COW SYSTEMS

The crude oil washing installation, associated equipment and arrangements, must meet the requirements established by the Administration based on the Specifications for the Design, Operation and Control of Crude Oil Washing Systems adopted by the Conference in resolution 15 and as may be revised by the Organization (Regulation 13B of Annex I of MARPOL 73/78).

Every tanker, which operates with crude oil washing, in accordance with Regulation 13, must be provided with an Operations and Equipment Manual approved by the Administration. The Manual must detail the system and equipment and specify operational procedures (Regulation 13B of Annex I of MARPOL 73/78).

10.3 COW PIPING

The crude oil washing pipes and all valves incorporated in the supply piping system shall be of steel or other equivalent material and shall be of adequate strength having regard to the pressure to which they may be subjected, and shall be properly jointed and supported. The crude oil washing system shall consist of permanent pipework and shall be independent of the fire mains and of any system other than for tank washing except that sections of the ship's cargo system may be incorporated in the crude oil washing system provided that they meet the requirements applicable to crude oil pipework.

Notwithstanding the above requirements, in combination carriers the arrangement may allow: The use of flexible hose pipes to connect the crude oil washing system to tank washing machines if it is necessary to locate these machines in a cargo tank hatch cover. Such flexible hose pipes must be provided with flanged connections and be manufactured and tested in accordance with standards acceptable to the Administration and be consistent with the duties the hoses are required to perform. The length of these hoses shall be no greater than necessary to connect the tank washing machines to an adjacent point just outside the hatch coming. These hoses shall be removed to suitably prepared and protected stowage when not in use and be pressure tested by an authority acceptable to the Administration at intervals of not more than two and a half years.

Provision shall be made to prevent overpressure in the tank washing supply piping. Any relief device fitted to prevent overpressure shall discharge into the suction side of the supply pump. Alternative methods to the satisfaction of the Administration may be accepted provided an equivalent degree of safety and environmental protection is provided.

Where hydrant valves are fitted for water washing purposes on tank washing lines, all such valves shall be of adequate strength and provision shall be made for such connections to be blanked off by flanges when washing lines may contain crude oil. Alternatively, hydrant valves shall be isolated from the crude oil washing system by spade blanks.

All connections for pressure gauges or other instrumentation shall be provided with isolating valves adjacent to the lines unless the fitting is of the sealed type.

No part of the crude oil washing system shall enter the machinery spaces. Where the tank washing system is fitted with a steam heater for use when water washing, the heater must be
Effectively isolated during crude oil washing by double shut-off valves or by clearly identifiable blanks.

Where a combined crude oil-water washing supply piping is provided the piping shall be so designed that it can be drained so far as is practicable of crude of before water washing is commenced, into spaces designated in the Operations and Equipment Manual. These spaces may be the slop tank or other cargo spaces.

10.3.1 Diameter of COW lines

The piping system shall be of such diameter that the greatest number of tank cleaning machines required, as specified in the Operations and Equipment Manual, can be operated simultaneously at the designed pressure and throughput. It is up to the owner to specify in the Manual the number of machines to be operated simultaneously based on the capability of the piping system. However, piping dimensions restricting the number too much will increase significantly the cargo-discharging period.

The arrangement of the piping shall be such that the required number of tank cleaning machines to each cargo compartment, as specified in the Operations and Equipment Manual referred to in these Specifications, can be operated simultaneously. It is recommended that it should be possible to perform COW simultaneously of at least in two wing tanks (i.e. the two wing tanks with the maximum number of washing machines will be decisive).

The following guidance may be applied to limit the dynamic pressure drop in the COW lines:

- the fluid velocity in the COW main line should not exceed 4-5 m/s
- the fluid velocity in the branch lines should not exceed 5-6 m/s.

This can be read directly from diagram “FLOW RATE VS INNER DIAMETER OF PIPE”

Example:

- Two wing tanks, each with 5 machines of 160 m³/h capacity.
- Flow in COW main line: 2 x 5 x 160 m³/h = 1,600 m³/h.
- Inner diameter of COW main line of 350 mm should be satisfactory without excessive pressure drop.
- Flow velocity is then 4.6 m/s.

The piping system shall be tested to one and one half times the working pressure after it has been installed on the ship. The crude oil washing supply piping shall be anchored (firmly attached) to the ship's structure at appropriate locations, and means shall be provided to permit freedom of movement elsewhere to accommodate thermal expansion and flexing of the ship. The anchoring shall be such that any hydraulic shock can be absorbed without undue movement of the supply piping. The “anchor points” should normally be situated at the ends furthest from the entry of the crude oil supply to the supply piping. If tank washing machines are used to anchor the ends of branch pipes then special arrangements are necessary to anchor these sections when the machines are removed for any reason.
Q: FLOW RATE [M³/H]
ν: FLUID VELOCITY [M /S]
D: INNER DIAMETER OF PIPE [MM]

\[ Q = 0.0028274 \cdot \nu \cdot D^2 \]

\[ \nu = \frac{Q}{D^2} \]

\[ D = 18.8 \sqrt{\frac{Q}{\nu}} \]

REF: IMCO’S «REVISED SPECIFICATIONS FOR THE DESIGN, OPERATION AND CONTROL OF CRUDE OIL WASHING SYSTEMS» ITEM 4.1.8.
10.4 TANK WASHING MACHINES

10.4.1 Fixed washing machines

The tank washing machines for crude oil washing shall be permanently mounted and shall be of a design acceptable to the Administration. Fixed tank washing machines, originally constructed for water are used for COW. As a general rule any system designed for effective water washing is even more effective with COW. The main types of washing machines most commonly used for COW are:

1. Single nozzle machines (fig. 10) These are usually programmable to cover pre-set sectors (capacities up to about 200 m$^3$/h) and are intended for deck mounting, but submerged unprogrammable single nozzle machines are also available.

2. Dual nozzle unprogrammable washing machines (fig. 11). This type may be deck mounted or submerged (capacities up to about 250 m$^3$/h).

The performance characteristic of a tank washing machine is governed by nozzle diameter, working pressure and the movement pattern and timing. Each tank cleaning machine fitted shall have a characteristic such that the sections of the cargo tank covered by that machine will be effectively cleaned within the time specified in the Operations and Equipment Manual.

Washing with the programmable single nozzle machines is performed in one, two or three stages (singlestage/multistage); the machines are normally reprogrammed before each stage is started (see fig. 12).

The dual nozzle machines are usually fully orbital and need no programming (singlestage).

10.4.2 Single Nozzle - programmable washing machines - characteristics:

- the nozzle may be concentrated on the area where the jet is most needed - less consumption of crude oil to obtain required cleanliness of a tank.
- higher jet impact force - longer jet - with the same total nozzle area.
- big/ heavy and strong to allow for “reactive” force caused by jet of fluid from nozzle.
- more complicated - probably more maintenance.
- more time-consuming/labour-demanding operation, especially when the drive units are of portable type.
- expensive.
TYPICAL SINGLE NOZZLE PROGRAMMABLE COW MACHINES

A: WITH INTEGRATED DRIVE UNIT
C: WITH PORTABLE DRIVE UNIT

FIG. 10
TYPICAL TWO NOZZLE UNPROGRAMMABLE COW MACHINE

FIG. 11
SINGLE-/MULTISTAGE WASHING

FIG. 12
FIG. 13

THROUGHPUT

WATER THROUGHPUT, TON/H

WATER PRESSURE, BAR

FIG. 14

WATER PRESSURE, BAR

EFFECTIVE HORIZONTAL JET LENGTH, METRES

JET LENGTH

TYPICAL CHARACTERISTICS FOR SINGLE NOZZLE WASHING MACHINES
10.4.3 Dual Nozzle - unprogrammable washing machines - characteristics:

- low price.
- simple operation - no programming.
- mechanically simpler - probably less maintenance.
- less weight - easier to handle and transport.
- higher consumption of crude oil to obtain required cleanliness of the tank.

10.4.4 Choice of type

For an optimum COW system, the fitting of different types of machines on board the same ship should be practised to a greater extent than is witnessed today. E.g. in a centre tank with a minimum of internal structure, washing is normally necessary in the lower regions and on the bottom in particular. From an overall economic point of view, fitting of a programmable washing machine may be preferred in such tanks.

However, in tanks with complicated internal structure, where the effect of splash-back and running oil is more essential to achieve acceptable cleanliness, a dual nozzle unprogrammable machine may be equally or more efficient.

There are of course a number of factors influencing the choice of type of washing machines. The characteristics mentioned above may vary in importance from ship to ship and company to company; e.g., where the number of crewmembers is very low, reduced labour demand for COW is more important than onboard ships with more crewmembers at hand.

It is difficult to indicate preferences and give general advice with respect to what type of machines to choose. The types mentioned have all proved that acceptable cleanliness can be obtained. The important point is that decisions are made after thorough and realistic evaluation of all the relevant aspects involved.

10.4.5 Nozzle diameter

The nozzle diameters for COW machines are usually varying between 20 and 40 mm. The size will, of course, have an influence on the jet length and throughput (capacity); the capacity increases proportionally with the nozzle area. The two diagrams, figure 13 and 14, show typical jet lengths and throughputs as a function of pressure for different nozzle diameters for a single nozzle machine.

When the number of COW machines to be operated simultaneously has been decided, the nozzle diameter will be influenced by the following factors:

- size of the tank and intended distance to be covered by one machine
- pumping and stripping capacities
- dimensions of piping (pressure drop)

Experience, so far, indicates that bigger nozzles give better washing results under similar conditions. Experiments with the same number of single nozzle programmable COW machines but with big nozzle diameter in one tank and smaller diameter in another similar wing tank, support this.

Based on this, larger nozzle diameters should be preferred but always provided the pressure can be maintained. However, where one or more of the above mentioned factors restrict the
diameter, this normally will have to be compensated by increased washing time or if convenient with higher pumping pressure from supply pump. An alternative is also to reduce the total number of COW machines intended for simultaneous operation.

10.4.6 Number and location of the tank washing machines/shadow diagrams

According to the IMO specifications the number and location of washing machines must be determined by the maximum allowable total area shielded from direct impingement by internal structure of the tanks: 15 and 10 per cent shadows for vertical and horizontal areas. The number and location of the machines in each cargo tank shall be such that all horizontal and vertical areas are washed by direct impingement or effectively by deflection or splashing of the impinging jet. In assessing an acceptable degree of jet deflection and splashing, particular attention shall be paid to the washing of upward facing horizontal areas and the following parameters shall be used:

- For horizontal areas of a tank bottom and the upper surfaces of a tank’s stringers and other large primary structural members, the total area shielded from direct impingement by deck or bottom transverses, main girders, stringers or similar large primary structural members shall not exceed 10 per cent of the total horizontal area of tank bottom, the upper surface of stringers, and other large primary structural members.

- For vertical areas of the sides of a tank, the total area of the tank’s sides shielded from direct impingement by deck or bottom transverses, main girders, stringers or similar large primary structural members shall not exceed 15 per cent of the total area of the tank's sides.

In some installations it may be necessary to consider the fitting of more than one type of tank washing machine in order to effect adequate coverage
SHADOW DIAGRAM TYPICAL WING TANK

FIG. 15

SHADOW DIAGRAM TYPICAL WING TANK

FIG. 16

(SHADOW DIAGRAMS)
10.5 PUMPS

Pumps
The pumps supplying crude oil to the tank cleaning machines shall be either the cargo pumps or pumps specifically provided for the purpose. The capacity of the pumps shall be sufficient to provide the necessary throughput at the required pressure for the maximum number of tank cleaning machines required to be operated simultaneously as specified in the Operations and Equipment Manual. In addition to the above requirement, the pumps shall if an eductor system is fitted for tank stripping, be capable of supplying the eductor sufficient driving fluid such that the bottom of the tank being cleaned is kept free of accumulations of oil and sediment towards completion of the tank washing process.

The pumping and piping arrangements shall be such that the crude oil washing system can be effectively operated with any one pump out of use and the carriage of more than one grade of cargo shall not prevent crude oil washing of tanks.

The two main principles for oil supply to the COW system are:

1. bleed-off from main(s) (see figure 1)
2. separate pump (a designated cargo pump or a dedicated COW pump, see figure 1 and 2)

In the first case, sufficient washing pressure is achieved by throttling the manifold valve(s) when the backpressure from the shore side is below recommended washing pressure. Terminal backpressure may vary between 4 and 10 bar and recommended washing pressure is usually from 8 to 12 bar. When throttling, the discharging capacity is then correspondingly reduced. This will increase time for cargo discharge if the ship is allowed to discharge with maximum pumping capacity. The cargo discharging capacity will be seriously affected for the arrangement shown in figure 3 in particular.

To achieve a steady washing pressure, the throttled valve will have to be more or less frequently adjusted depending on different circumstances on the shore side and onboard. The pressure will then need continuous attention and frequent adjustment. It is therefore recommended to have a manometer, indicating washing pressure, which can be easily observed from the position where the valve is throttled.
The use of butterfly valves for throttling is usually not recommended, and such valves have been damaged because they were not intended for throttling. The necessity of replacing butterfly valves with, for instance sluice valves should be considered.

OIL SUPPLY TO COW MAIN:

ALT. I: BLEED OFF FROM CARGO MAINS
ALT. II: SEPARATION OF ONE CARGO PUMP, CLOSING OF CORRESPONDING MANIFOLD VALVE

DEDICATED PUMP FOR OIL SUPPLY TO COW SYSTEM

Fig. 1

Fig. 2
The best arrangement seems to be a separate pump for COW, and driving fluid for stripping eductor(s) where arranged. Then the COW procedure, including stripping, can be performed independently of pressure fluctuations in the cargo lines, and it is easier to continue COW when cargo discharge is stopped temporarily. It is required that at least two pumps must be capable of supplying crude oil for washing. Flexibility, especially for multigrade cargoes, is usually achieved if any one cargo pump can be isolated and used exclusively for COW and stripping eductor(s). However, the best solution from an operational and efficiency point of view is a dedicated pump for COW and stripping eductor(s) (see fig. 2). This arrangement will have least influence on discharging capacity. The costs of retrofitting a dedicated washing pump will of course, have to be weighed against the advantages achieved. This solution is probably most attractive for ships having only two or three cargo pumps.

Figure 4 indicates simple modifications of the arrangement in figure 3 to achieve a more efficient and flexible arrangement for COW.

The figures 5-7 are showing different typical piping arrangements.
MODIFICATION OF ARRANGEMENT

Figure 4

TYPICAL DISCHARGE MAINS WITH GOOD POSSIBILITIES
TO BLEED OFF WHEN COW IS PERFORMED DURING DISCHARGE

Fig. 5
TYPICAL DISCHARGE MAINS WITH GOOD, BUT RESTRICTED, POSSIBILITIES TO BLEED OFF FOR COW DURING DISCHARGE

Fig. 6

TYPICAL DISCHARGE MAINS WITH POOR POSSIBILITIES TO BLEED OFF WHEN COW IS PERFORMED DURING DISCHARGE

Fig. 7
10.6 STRIPPING SYSTEMS

The design of the system for stripping crude oil from the bottom of every cargo tank shall be to the satisfaction of the Administration.

The design and capacity of the tank stripping system shall be such that the bottom of the tank being cleaned is kept free of accumulations of oil and sediment towards completion of the tank washing process.

The stripping system shall be capable of removing oil at a rate of 1.25 times the total throughput of all the tank cleaning machines to be operated simultaneously when washing the bottom of the cargo tanks as described in the ship's Operations and Equipment Manual.

Means such as level gauges; hand dipping and stripping system performance gauges shall be provided for checking that the bottom of every cargo tank is dry after crude oil washing.

Where a stripping pump is provided, the monitoring equipment shall include, as appropriate, a flow indicator, or a stroke counter or a revolution counter, and pressure gauges at the inlet and discharge connections of the pump or equivalent.

Where eductors are provided, the monitoring equipment shall include pressure gauges at the driving fluid intake and at the discharge and a pressure/vacuum gauge at the suction intake.

Suitable arrangements for hand dipping must be provided at the aftermost portion of a cargo tank and in three other suitable locations unless other approved means are fitted for efficiently ascertaining that the bottom of every cargo tank is dry. For the purpose of this paragraph, the cargo tank bottom shall be considered "dry" if there is no more than a small quantity of oil near the stripping suction with no accumulation of oil elsewhere in the tank.

Means shall be provided to drain all cargo pumps and lines at the completion of cargo discharge, where necessary, by connection to a stripping device. The line and pump draining shall be capable of being discharged both to a cargo tank and ashore. For discharge ashore a special small diameter line shall be provided for that purpose and connected outboard of the ship's manifold valve. For new oil tankers or existing oil tankers not already fitted with such a line the cross-sectional area of this line shall not exceed 10 per cent of that of a main cargo discharge line.

Where such a line is already fitted on an existing tanker, a cross-sectional area of not more than 25 per cent of that of a main cargo discharge line may be accepted.

10.6.1 Ballast lines

Where a separate ballast water system for ballasting cargo tanks is not provided, the arrangement shall be such that the cargo pump, manifolds and pipes used for ballasting can be safely and effectively drained of oil before ballasting.

10.7 QUALIFICATION OF PERSONNEL

The training requirements of ships' personnel engaged in the crude oil washing of tankers shall be to the satisfaction of the Administration.

10.7.1 Formal qualification requirements.

Where a person such as the master, the chief officer or the cargo control officer assumes overall charge of a crude oil wash he shall:
• Have at least one year’s experience on oil tankers where his duties have included the discharge of cargo and associated crude washing.

• Where his duties have not included crude oil washing operations, he shall have completed a training programme in crude oil washing in accordance with Appendix H to these Specifications and satisfactory to the Administration;

• Have participated at least twice in crude oil wash programmes one of which shall be on the particular ship for which he is required to undertake the responsibility of cargo discharge. Alternatively, this latter participation may be acceptable if undertaken on a ship that is similar in all relevant respects; and

• Be fully knowledgeable of the contents of the Operations and Equipment Manual.

• Where other nominated persons are intended to have particular responsibilities as defined in the Operations and Equipment Manual they shall have at least 6 months experience on oil tankers where, in the course of their duties, they should have been involved in the cargo discharge operation. In addition, they should have been instructed in the crude oil washing operation in the particular ship for which they are required to undertake this responsibility and be fully knowledgeable of the contents of the Operations and Equipment Manual.

10.8 OPERATIONS

10.8.1 Tankage to be Crude Oil Washed

Paragraph 6.1 of the Specifications requires that the following tanks are crude oil washed:

1) All departure and arrival ballast tanks permitting compliance with trim and draught requirements of Regulation 13 (2) (a), (b) and (c) of Annex I of MARPOL Protocol (see figure 17).

2) In addition about 1/4 of the remaining cargo tanks on rotational basis, for sludge control. However, for sludge control no tank need be crude oil washed more than once every four months.

3) Cargo tanks that may contain “heavy weather ballast” during the subsequent ballast voyage must always be crude oil washed. This (these) tank may be included in the tanks under 2.

Regulation 13 of MARPOL 73/78, Annex I
(2) The capacity of the segregated ballast tanks shall be so determined that the ship may operate safely on ballast voyages without recourse to the use of oil tanks for water ballast except as provided for in paragraph (3) of this Regulation. In all cases, however, the capacity of segregated ballast tanks shall be at least such that in any ballast condition at any part of the
voyage; including the conditions consisting of lightweight plus segregated ballast only, the ship's draughts and trim can meet each of the following requirements:
(a) the moulded draught amidships (dm) in metres (without taking into account any ship's deformation) shall not be less than:
\[ dm = 2.0 + 0.02 L; \]

(b) the draughts at the forward and after perpendiculars shall correspond to those determined by the draught amidships (dm), as specified in subparagraph (a) of this paragraph, in association with the trim by the stem of not greater than 0.015L; and

(c) in any case the draught at the after perpendicular shall not be less than that which is necessary to obtain full immersion of the propeller(s).

In no case shall ballast water be carried in oil tanks except in weather conditions so severe that, in the opinion of the Master, it is necessary to carry additional ballast water in oil tanks for the safety of the ship. Such additional ballast water shall be processed and discharged in compliance with Regulation 9 and in accordance with the requirements of Regulation 15 of this Annex, and entry shall be made in the Oil Record Book referred to in Regulation 20 of this Annex.

These are minimum requirements. More tanks may of course, be crude oil washed. E.g. it is recommended that at least the bottom of the aftermost centre tank is washed after every cargo discharge if this tank has a lot of pipelines passing through, thereby reducing the washing efficiency considerably. This may be compensated by more frequent washing.

10.8.2 Use and control of inert gas

In general reference is given to the Inert Gas part of this Course. The main mention here is that COW must never be performed unless the IGS is in proper operation. If the oxygen content of the tanks exceeds 8 per cent in volume, no COW is allowed. (Paragraph 6.6 of the Specifications).
10.8.3 Precautions against electrostatic generation

Presence of water in the fluid for COW may result in excessive electrostatic generation. To avoid this, any tank supplying crude to the COW system must first be discharged by at least 1 metre. If slop tank is to be used, it must be completely discharged and refilled with dry crude before supply to the COW system is started.

10.8.4 COW at Sea

COW must be completed before the ship leaves its final port of discharge. Any tank being washed between multiple discharge ports is required by the Specifications to be left empty and available for inspection at the next discharge port before commencing the next ballast voyage. This inspection may consist of multiple sounding/dipping of the tank when the tank is empty. (Paragraph 6.4 of the Specifications). See also 6.5.

10.8.5 Operations and Equipment Manual

The IMO Specifications, chapter 7, deals in detail with the content of the Manual. The outline of the content of this Manual has been included in the following pages.

The Manual is required to contain general information, common for all tankers. However, most of the content will comprise specific details for each particular ship. The Manual must therefore be tailor-made, and may very well reflect the company’s practice and intentions with COW within the framework of the Specifications.

The parts of the Manual dealing with normal operation of COW will contain instructions, which must always be complied with, and also guidance and recommendations for typical operations. Because no cargo discharge/COW operations are similar in all respects, it is impossible to describe detailed procedures, always to be followed, for these operations. It should be in interest of all parties involved to make the Manual as useful as possible. To take full advantage of the benefits of COW, efforts should be made not only to comply with IMO’s minimum requirement for the content of the Manual, but also to include specific description of principles for planning and how to accomplish an optimum COW operation under different cargo discharging conditions for that particular ship. The result of tank inspection and the other tests described may influence the content of the Manual.

10.8.6 Initial approval of Cow systems

Approval of a COW system involves different activities described by the IMO Specifications. Practice may differ slightly from one certifying authority to the other. However, the main features of today’s practice are listed below.

10.8.7 Extent of Approval

i) Approval of plans and documentation.

ii) General inspection of piping system equipment and arrangements on board.
iii) Hydraulic pressure testing of the piping system after installation to 1.5 times the working pressure.

iv) Inspection of typical cargo tanks after COW, but prior to water washing (normally 3-5 tanks).

v) Measurement of the oil floating on top of the departure ballast.

vi) Measurement of the oil content in the arrival ballast (not for segregated ballast tankers).

vii) Approval of the “Operations and Equipment Manual”.

Approval of drawings and documentation and general inspection of the COW system items 1-3, are in principle similar to general classification practice and will not be dealt with here. The documentation should describe the complete COW system and all relevant parameters, and as far as practical clearly indicate that the COW Specifications are complied with. The documentation to be evaluated also comprises shadow diagrams for all cargo tanks including slop tank(s).

The ship should pass the inspection/tests listed in items 4-6 after COW and ballast handling procedures typical for that particular company and ship. These typical procedures, including modifications deemed necessary after the results of the inspection/tests, should be included in the Manual and are assumed to influence to some extent the operation in the future. It is therefore important that the crew onboard has the best possible idea of and experience on the operational procedures that generally are to be followed before the inspection/tests for final approval are carried out.

10.8.8 Tank Inspection after COW

The Specifications require tank inspections to be carried out after COW, but prior to water washing in connection with initial approval of the system. This is usually the most time consuming and sometimes, most complicated part of the approval procedure, especially gas freeing and control of the tank atmosphere. The surveyor normally visits the ship before cargo discharge commences and then joins the ship on the subsequent ballast voyage until the inspections and tests have been carried out.

10.8.9 “Oil-on-top” Test

The amount of oil remaining in the tanks, intended for departure ballast, after COW and final stripping should not exceed 0.085 per cent of the total volume, of the tanks. After filling departure ballast tanks, samples are taken, after 10 hours or more, of the oil layer floating on top of the ballast water. This is done by means of a special test-tube provided by the surveyor. For a tank of average proportions, the thickness of the oil layer must not exceed about 20 mm.

For ships with SBT, this test is to include the “heavy weather ballast tanks” and the other cargo tanks being inspected.
10.8.10 Oil Content in the Arrival Ballast

The last test normally carried out for initial approval of the COW system is control of the oil content in the arrival ballast.

When the arrival ballast after a typical ballast voyage is discharged, the oil content should not exceed 15 PPM (parts per million).

Before filling arrival ballast, the tanks must have been crude oil washed and “water rinsed” in accordance with procedures, described in the Manual. This test may easily be carried out on board ships already fitted with an approved oily water monitoring system.

A sampling point in the discharge line must be provided. If this does not already exist, a small piece of pipe and a valve may be, used.

10.9 Wash Strategy

10.9.1 Top washing

It is recommended to start the top washing, as soon as possible, when about ¾ of the tank is discharged. Top washing is simpler than bottom washing and may be done simultaneously as the discharging takes place in full rate. To start the top washing a bleed off from one of the discharging lines is lead to the cow main line, and from there, to the cow machines being used. Make sure that the recommended pressure for cow lines and cow machines is kept during the operation.

If the specific ship is equipped with ullage tapes, remember to crank them up before starting.

In the example above, the top washing starts and is programmed to cycle from 120° down to 45°, up to 120° and so on. The loss of time during top washing comes from the time associated with the re-circulated cargo, which could have been discharged to shore instead.

10.9.2 Bottom washing

Usually bottom washing starts with a small amount of cargo in the tank. The amount in the tank is checked before the bottom washing starts. If sounding (dipping) is used for the check,
remember to use a sounding (dipping) rod and a line of material, which does not collect static electricity. It is not possible to sound when the crude oil washing is in process. If so, check the manometer on the suction side of the stripping system.

Make sure that the bottom-washing cycle overlaps the top-washing cycle. In the washing process, each tank depends on the tank construction, the oil’s composition, time since last washing, the equipment’s function and the skill of the operator. If the stripping is internal, it is extremely important to keep an accurate record of the level at the receiving tank. It is recommended to strip directly ashore if the ship is fitted with equipment to do so (vacuum strip). This saves a lot of time and also avoids moving the washing liquid and residues from tank to tank internally.

By the end of the bottom washing, remember that liquid will continue to flow toward the suction for some time. Therefore, some final stripping is necessary. When the bottom washing is completed, remember to properly shut all of the cow machine’s delivery valves.

The drawing above shows a bottom washing example, where the cycling is $0^\circ - 45^\circ - 0^\circ$.

10.9.3 Washing strategy

Washing strategy means that the crude oil washing is well planned and executed in such a way that unnecessary time loss and complications are avoided. It is very important that the crude oil washing starts, as soon as possible. At the end of the cow operation the time is running out. So it is extremely important to have a well-planned operation. For instance, the bottom washing should not get left behind when the ship is almost finished discharging.

10.9.4 Washing efficiency

When using the re-circulation method, which means that the tank that delivers washing liquid is the same tank, which receives liquid from the tank being washed. It is of great interest to have a good indication of the washing efficiency. Provided that it is possible to record the
ullage accurately, frequent ullage readings will give a good indication of the efficiency from the following:

1. Ullage that is decreasing means that liquid and residue is being washed out and transferred from the tank being washed.

2. No ullage change means that there are no more liquid and residues in the tank being washed. The tank is finished.

3. Ullage that is increasing means that the stripping efficiency is bad. In other words, the tank is supplied with more liquid than the stripping process is able to strip and a build up of fluid is occurring in the tank being washed.

By using re-circulation in crude oil washing, residue is transferred internally although it is preferred to strip all directly ashore. This is also done if the equipment is able to do so. Usually sounding (dipping) can check the efficiency. This check must of course not be done when the crude oil washing is in progress.

**10.9.5 Checklists**

The following lists are recommended by the IMO for use in discharging operations, including crude oil washing.

- Pre-arrival checklist at discharge port.
- Before crude oil wash operation.
- During crude oil wash operation.
- After crude oil wash operation.

Examples of various checklists follow on the next few pages.
This Appendix comprises the Ship/Shore Safety Check List (Parts A & C), Guidelines relating to the Check List and a specimen letter for issue by the terminal representative to masters of tankers at terminals.

Ship/Shore Safety Check List

<table>
<thead>
<tr>
<th>Ship's Name</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Berth</td>
<td>Port</td>
</tr>
<tr>
<td>Date of Arrival</td>
<td>Time of Arrival</td>
</tr>
</tbody>
</table>

Instructions for completion

The safety of operations requires that all questions should be answered affirmatively by clearly ticking (✓) the appropriate box. If an affirmative answer is not possible, the reason should be given and agreement reached upon appropriate precautions to be taken between the ship and the terminal. Where any question is considered to be not applicable, then a note to that effect should be inserted in the remarks column.

A box in the columns ‘ship’ and ‘terminal’ indicates that checks should be carried out by the party concerned.

The presence of the letters A, P or R in the column ‘Code’ indicates the following:

A - any referenced procedures and agreements should be in writing in the remarks column of this check list or other mutually acceptable form. In either case, the signature of both parties should be required.

P - in the case of a negative answer the operation should not be carried out without the permission of the Port Authority.

R - indicates items to be rechecked at intervals not exceeding that agreed in the declaration.
### Part A Bulk Liquid General

<table>
<thead>
<tr>
<th>General</th>
<th>Ship</th>
<th>Terminal</th>
<th>Code</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1  Is the ship securely moored?</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stop cargo at: kts wind vel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Disconnect at: kts wind vel.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Unberth at: kts wind vel.</td>
</tr>
<tr>
<td>2  Are emergency towing wires correctly positioned?</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>3  Is there safe access between ship and shore?</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>4  Is the ship ready to move under its own power?</td>
<td></td>
<td></td>
<td></td>
<td>PR</td>
</tr>
<tr>
<td>5  Is there an effective deck watch in attendance on board and adequate supervision on the terminal and on the ship?</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>6  Is the agreed ship/shore communication system operative?</td>
<td></td>
<td></td>
<td></td>
<td>AR</td>
</tr>
<tr>
<td>7  Has the emergency signal to be used by the ship and shore been explained and understood?</td>
<td></td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>8  Have the procedures for cargo, bunker and ballast handling been agreed?</td>
<td></td>
<td></td>
<td></td>
<td>AR</td>
</tr>
<tr>
<td>9  Have the hazards associated with toxic substances in the cargo being handled been identified and understood?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10 Has the emergency shutdown procedure been agreed?</td>
<td></td>
<td></td>
<td></td>
<td>A</td>
</tr>
<tr>
<td>11 Are fire hoses and firefighting equipment on board and ashore positioned and ready for immediate use?</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>12 Are cargo and bunker hoses/arms in good condition, properly rigged and appropriate for the service intended?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13 Are scuppers effectively plugged and drip traps in position, both on board and ashore?</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>14 Are unused cargo and bunker connections properly secured with blank flanges fully bolted?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 Are sea and overboard discharge valves, when not in use, closed and visibly secured?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 Are all cargo and bunker tank lids closed?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 Is the agreed tank venting system being used?</td>
<td></td>
<td></td>
<td></td>
<td>AR</td>
</tr>
<tr>
<td>18 Have the PTV vents been operated using the checklist facility, and the operation of the vent verified?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 Are hand torches of an approved type?</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>20 Are portable VHF/UHF transceivers of an approved type?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 Are the ship's main radio transmitter aerials earthed and radars switched off?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 Are electric cables to portable electrical equipment disconnected from power?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23 Are all external doors and ports in the accommodation closed?</td>
<td></td>
<td></td>
<td></td>
<td>R</td>
</tr>
<tr>
<td>24 Are window-type air conditioning units disconnected?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25 Are air conditioning intakes which may permit the entry of cargo vapours closed?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26 Are the requirements for use of galley equipment and other cooking appliances being observed?</td>
<td></td>
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</tr>
<tr>
<td>General</td>
<td>Ship</td>
<td>Terminal</td>
<td>Code</td>
<td>Remarks</td>
</tr>
<tr>
<td>---------</td>
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<td>---------</td>
</tr>
<tr>
<td>27 Are smoking requirements being observed?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>28 Are naked light requirements being observed?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29 Is there provision for an emergency escape?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30 Are sufficient personnel on board and ashore to deal with an emergency?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>31 Are adequate insulating means in place in the ship/shore connection?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>32 Have measures been taken to ensure sufficient pumproom ventilation?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>33 If the ship is capable of &quot;closed loading&quot;, have the requirements for closed operations been agreed?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>34 Has a vapour return line been connected?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>35 If a vapour return line is connected, have operating parameters been agreed?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>36 Are ship emergency fire control plans located externally?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

If the ship is fitted, or required to be fitted, with an inert Gas System, the following questions should be answered.

<table>
<thead>
<tr>
<th>General</th>
<th>Ship</th>
<th>Terminal</th>
<th>Code</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>37 Is the Inert Gas System fully operational and in good working order?</td>
<td>☐</td>
<td>☐</td>
<td>P</td>
<td></td>
</tr>
<tr>
<td>38 Are deck deals in good working order?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>39 Are liquid levels in P/V breakers correct?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>40 Have the fixed and portable oxygen analysers been calibrated and are they working properly?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>41 Are fixed IG pressure and oxygen content recorders working?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>42 Are all cargo tank atmospheres at positive pressure with an oxygen content of 8% or less by volume?</td>
<td>☐</td>
<td>☐</td>
<td>PR</td>
<td></td>
</tr>
<tr>
<td>43 Are all the individual tank IG valves (if fitted) correctly set and locked?</td>
<td>☐</td>
<td>☐</td>
<td>R</td>
<td></td>
</tr>
<tr>
<td>44 Are all the persons in charge of cargo operations aware that in the case of failure of the Inert Gas Plant, discharge operations should cease and the terminal be advised?</td>
<td>☐</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank Cleaning</th>
<th>Ship</th>
<th>Shore</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Are tank cleaning operations planned during the ship's stay alongside the shore installation?</td>
<td>☐</td>
<td></td>
<td>Yes/No*</td>
</tr>
<tr>
<td>If so, have the Port Authority and terminal authority been informed?</td>
<td>☐</td>
<td>Yes/No*</td>
<td>Yes/No*</td>
</tr>
</tbody>
</table>

* Delete Yes or No as appropriate
### Part C  Bulk Liquefied Gases

<table>
<thead>
<tr>
<th>Bulk Liquefied Gases</th>
<th>Ship</th>
<th>Terminal</th>
<th>Code</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Is information available giving the necessary data for the safe handling of the cargo including, as applicable, a manufacturer's inhibition certificate?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Is the water spray system ready for use?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Is sufficient suitable protective equipment (including self-contained breathing apparatus) and protective clothing ready for immediate use?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Are hold and inter-barrier spaces properly inerted or filled with dry air as required?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Are all remote control valves in working order?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Are the required cargo pumps and compressors in good order, and have maximum working pressures been agreed between ship and shore?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>7. Is refrigeration or boil off control equipment in good order?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Is the gas detection equipment properly set for the cargo, calibrated and in good order?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Are cargo system gauges and alarms correctly set and in good order?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Are emergency shutdown systems working properly?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Does the shore know the closing rate of ship’s automatic valves, does the ship have similar details of shore system?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>Ship</td>
</tr>
<tr>
<td>12. Has information been exchanged between ship and shore on the maximum/minimum temperatures/pressures of the cargo to be handled?</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>13. Are cargo tanks protected against inadvertent overfilling at all times while any cargo operations are in progress?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14. Is the compressor room properly ventilated; the electrical motor room properly pressurised and the alarm system working?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15. Are cargo tank relief valves set correctly and actual relief valve settings clearly and visibly displayed?</td>
<td>☐</td>
<td>☐</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank No 1</th>
<th>Tank No 5</th>
<th>Tank No 8</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank No 2</th>
<th>Tank No 6</th>
<th>Tank No 9</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tank No 3</th>
<th>Tank No 7</th>
<th>Tank No 10</th>
</tr>
</thead>
<tbody>
<tr>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>
**Declaration**

We the undersigned have checked, where appropriate jointly, the items on this check list and have satisfied ourselves that the entries we have made are correct to the best of our knowledge.

We have also made arrangements to carry out repetitive checks as necessary and agreed that those items with the letter "R" in the column "Code" should be re-checked at intervals not exceeding __________ hours

<table>
<thead>
<tr>
<th>For Ship</th>
<th>For Shore</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name:</td>
<td>Name:</td>
</tr>
<tr>
<td>Rank:</td>
<td>Position:</td>
</tr>
<tr>
<td>Signature:</td>
<td>Signature:</td>
</tr>
<tr>
<td>Date:</td>
<td></td>
</tr>
<tr>
<td>Time:</td>
<td></td>
</tr>
</tbody>
</table>
Before crude oil wash operation

1. Are all pre-arrival checks and conditions in order?

2. Has discharge/crude oil washing operation been discussed with both ship and shore staff and is agreed plan readily available for easy reference?

3. Has communication link between deck/control station and control station/shore been set up and is it working properly?

4. Have crude oil wash abort condition and procedures been discussed and agreed to by both ship and shore staff?

5. Have fixed and portable oxygen analysers been checked and are they working properly?

6. Is the inert gas system working properly and is the oxygen content of inert gas being delivered below 5 percent by volume?

7. Is oxygen content of tank(s) to be crude oil washed below 8 percent by volume?

8. Have all cargo tanks positive inert gas pressure?

9. Has a responsible person been assigned to check all deck lines for leaks as soon as washing starts?

10. Are the fixed machines set for the required washing method and are portable drive units, if fitted, mounted and set?

11. Have valves and lines both in pump room and on deck been checked?

During crude oil washing

1. Is the quality of inert gas being delivered frequently checked and recorded?

2. Are all deck lines and machines being frequently checked for leaks?

3. Is the crude oil washing in progress in designated cargo tanks only?

4. Is the pressure in the tank wash line as specified in the Manual?

5. Are cycle times of tank washing machines as specified in the Manual?

6. Are the washing machines in operation, together with their drive units if applicable, frequently checked and are they working properly?

7. Is a responsible person stationed continuously on deck?
8. Will trim be satisfactory when bottom washing is in progress as specified in this Manual?

9. Will the recommended tank draining method be followed?

10. Have ullage gauge floats been raised and housed in tanks that are being crude oil washed?

11. Is level in holding tank for tank washings frequently checked to prevent any possibility of an overflow?

After crude oil wash operation.

1. Are all valves between discharge line and tank wash line closed?

2. Has tank wash line been drained of crude oil?

3. Are all valves to washing machines closed?

4. Are cargo pumps, tanks and pipelines properly drained as specified in the Manual?

It is very important to drain the crude oil washing lines as soon as possible after completing washing. This gives the oil time to run dry before the discharge is terminated by use of the stripping pump through the small diameter line. The preceding lists are recommended by IMO regarding content. The ship, company and local authorities may also have additions to the content. Also remember to record the crude oil washing operation in the “cow-log”.

Remember to register the operations in the Oil Record Book!
10.9.6 Discharge plan including COW

We are now ready to work out a discharging plan including COW. This plan is worked out based upon the obtained information described in chapter 1, page 3. At some points in the plan it has been chosen to show the vessel’s condition figuratively. Following is the information obtained:

- Cargo: 186630 metric tonnes.
- SBT: WT3 s/p and FPT.
- CBT: WT2 s/p and WT5 s/p, departure ballast tanks. CT2, CT4, arrival ballast tanks. Ballast tanks (SBT and CBT) can be filled with the separated ballast system.
- Slop: WT6 s/p can receive liquid from ejector and there are connections between WT6 port and CT4.
- Stripping: Steam stripping pump. Stripping has to be carried out through discharging line, because the vessel is not fitted with separate stripping lines. The vessel is equipped with vacuum stripping system.
- Cargo pumps: 4, each with a capacity of 4000 m$^3$/hour at 120mlc.
- Stripping pump: 1 steam driven piston pump with a capacity of 315m$^3$/hour by 150spm.
- Ejector: 1 ejector with a capacity of 950 m$^3$/hour by 8bars pressure.
- Ballast pump: 1 ballast pump with a capacity of 4000 m$^3$/hour by 120mlc.
- Cow machines: 6 pcs. in each cargo tank except in WT6s/p where they are 2 in each. The flow capacity of each cow machine is 110 m$^3$/hour by 8bars pressure.
- Top washing: Cycle between 115°/45° in 25 min.
- Bottom washing: Cycle between 45° - 0° - 45° in 45 min.

In this discharging plan the vacuum system is used for stripping and ejector stripping if needed. We can use 6 cow machines simultaneously to maintain the demand of stripping capacity according to IMO.

In the plan “TW” means top washing, “BW” means bottom washing and “P/V” means prime/vacuum stripping.
## Discharge plan incl. COW

<table>
<thead>
<tr>
<th>Post</th>
<th>Hour from start</th>
<th>Disch. from tank no.</th>
<th>Pumps in use</th>
<th>Ullage</th>
<th>Trim astern</th>
<th>Cow tank no.</th>
<th>Pump for cow.</th>
<th>Remarks:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1,0</td>
<td>All</td>
<td>All</td>
<td>1,60m</td>
<td>0,76m</td>
<td></td>
<td></td>
<td>Disch. approx. 1m from each tank.</td>
</tr>
<tr>
<td>2</td>
<td>4,2</td>
<td>CT2</td>
<td>All</td>
<td>10,21m</td>
<td>10,13m</td>
<td></td>
<td></td>
<td>Disch. to WT1s/p &amp; WT6s/p are on approx. ullage 10m.</td>
</tr>
<tr>
<td>3</td>
<td>7,0</td>
<td>CT2</td>
<td>All</td>
<td>20,12m</td>
<td>20,12m</td>
<td></td>
<td></td>
<td>Disch. to WT2s/p, WT5s/p, and CT2 are on approx. 20m ullage and ready to TW.</td>
</tr>
<tr>
<td>4</td>
<td>8,0</td>
<td>WT5s/p</td>
<td>1 2 3 4</td>
<td>22,12m</td>
<td>21,42m</td>
<td>5,37n</td>
<td>TW WT2s/p WT5s/p CT2</td>
<td>2 Open CT4. Close all crossover valves.</td>
</tr>
<tr>
<td>5</td>
<td>10,0</td>
<td>WT5s/p</td>
<td>1 2 3 4</td>
<td>24,06m</td>
<td>23,13m</td>
<td>4,71m</td>
<td>BW WT2s/p</td>
<td>2 Commence ballasting WT3s/p. BW, WT2s/p.</td>
</tr>
<tr>
<td>6</td>
<td>12,0</td>
<td>WT5s/p</td>
<td>1 2 3 4</td>
<td>P/V</td>
<td>12,76m</td>
<td>4,91m</td>
<td>BW WT5s/p</td>
<td>2 WT2s/b finished BW. Open CT3, close WT2s/p. Open WT1s/p close CT4.</td>
</tr>
<tr>
<td>7</td>
<td>14,0</td>
<td>CT1</td>
<td>1 2 3 4</td>
<td>6,56m</td>
<td>9,97m</td>
<td>5,22m</td>
<td>BW CT2</td>
<td>1 WT5s/p finished BW. Open CT1, close WT5s/p. CT2 ready for BW. Open CT4, close WT1s/p. Commence ballasting on WT2s/p and WT5s/p.</td>
</tr>
<tr>
<td>8</td>
<td>15,4</td>
<td>WT1s/p</td>
<td>1 2 3 4</td>
<td>12,76m</td>
<td>9,78m</td>
<td>5,22m</td>
<td></td>
<td>CT2 finished BW. Drop cargo from WT4s/p to CT2 stop on ullage 19,80m. Open crossover valves between line 1&amp;2, close CT1. Open WT1s/p, close CT4.</td>
</tr>
<tr>
<td>Page</td>
<td>Time</td>
<td>Action</td>
<td>Details</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>------</td>
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<td>--------</td>
<td>---------</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 9    | 17,0 | Open CT1. Close crossover valves between line 1&2. | CT1
     |      | | WT1s/p
     |      | | WT6s/p
     |      | | WT4s/p
     |      | | 9,28m
     |      | | 23,85m
     |      | | P/V
     |      | | 15,15m
     |      | | 5,50m
     |      | | TW
     |      | | WT6s/p
     |      | | WT1s/p
     |      | | BW
     |      | | WT6s/p |
| 10   | 19,0 | WT6s/p finished BW. WT 1s/p ready for BW. Open CT3, close WT6s/p. | CT1
     |      | | WT1s/p
     |      | | CT3
     |      | | WT4s/p
     |      | | 10,46m
     |      | | P/V
     |      | | 14,12m
     |      | | 18,82m
     |      | | 5,54m
     |      | | BW
     |      | | WT1s/p
     |      | | TW
     |      | | WT4s/p |
| 11   | 21,0 | WT1s/p finished BW. Open CT4, close WT1s/p. TW of WT4s/p. | CT1
     |      | | CT4
     |      | | CT3
     |      | | WT4s/p
     |      | | 16,21m
     |      | | P/V
     |      | | 20,65m
     |      | | 21,65m
     |      | | 5,40m
     |      | | TW
     |      | | WT4s/p |
| 12   | 23,5 | WT4s/p finished TW. Disch. to WT4s/p is ready for BW. | CT1
     |      | | CT4
     |      | | CT3
     |      | | WT4s/p
     |      | | 19,08m
     |      | | P/V
     |      | | 18,73m
     |      | | 23,26m
     |      | | 5,35
     |      | | BW
     |      | | WT4s/p |
| 13   | 24,5 | BW of WT4s/p. | CT1
     |      | | CT4
     |      | | CT3
     |      | | WT4s/p
     |      | | 21,66m
     |      | | P/V
     |      | | 21,24m
     |      | | 24,83m
     |      | | 19,82m
     |      | | 5,52m
     |      | | TW
     |      | | CT3
     |      | | CT4
     |      | | CT1
     |      | | 4
     |      | | CT2
     |      | | CT1
     |      | | CT4
     |      | | CT3
     |      | | CT2
     |      | | 23,28m
     |      | | P/V
     |      | | 24,64m
     |      | | 20,50m
     |      | | 4,70m
     |      | | BW
     |      | | CT3
     |      | | 4
     |      | | CT3
     |      | | CT4
     |      | | CT1 finished TW, BW of CT3. |
| 14   | 26,5 | WT4s/p finished BW. Open CT2, close WT4s/p. | CT1
     |      | | CT4
     |      | | CT3
     |      | | CT2
     |      | | 24,40m
     |      | | P/V
     |      | | 21,71
     |      | | 5,81m
     |      | | BW
     |      | | CT4
     |      | | 4
     |      | | CT3 finished BW. Close CT3, stop COP 3. |
| 15   | 27,8 | CT3, CT4, CT1 finished TW, BW of CT3. | CT1
     |      | | CT4
     |      | | CT3
     |      | | CT2
     |      | | 24,40m
     |      | | P/V
     |      | | 22,79
     |      | | 4,95m
     |      | | BW
     |      | | CT4
     |      | | 4
     |      | | CT4 finished BW. Close CT4, stop COP 2. |
| 16   | 29,3 | CT3 finished BW. Close CT3, stop COP 3. | CT2
     |      | | CT4
     |      | | CT2
     |      | | 23,81
     |      | | 5,39m
     |      | | CT1 finished BW. Close CT1, stop COP 1. Cow-operation completed. |
| 17   | 30,5 | CT2 finished discharged. Stop COP 4. Stripping ashore through small diameter line. | Pumps
     |      | | lines
     |      | | Str. pump
     |      | | 3,80m
     |      | | Stop stripping pump. Finished ballasting. |
| 18   | 31,7 | Compl. discharge. | Compl.
     |      | | discharge. |
| 19   | 34   | Stop stripping pump. Finished ballasting. | Str. pump |
| 20   | 36   | Stop stripping pump. Finished ballasting. | Str. pump |
On arrival the following quantity of bunkers, water, stores etc. are on board:

- Total heavy fuel oil: 510 metric tonnes.
- Total diesel oil: 118 metric tonnes.
- Water, stores etc.: 512 metric tonnes.
- Total = **1140** metric tonnes.
Comments on Discharging Plan with COW

Post 1:
After all safety checks have been carried out, commence discharging with all cargo pumps. Discharge approximately 1m from each tank to get rid of possible water and to eliminate the risk of static electricity. Start the inert gas plant. Check the quality of supplied inert gas and make sure that all tanks have positive pressure. All crossover valves are open.

Post 2:
Close CT1, CT3, CT4, and WT4s/p. Continue disch. on the other tanks with all cargo pumps. Close WT1s/p at ullage 10,0m due to attained trim. Close WT6s/p also at ullage 10,0m.
Post 3:
Continue disch. from WT2s/p, WT5s/p and CT2 with all cargo pumps, reaching ullage 20,0m, where we start top washing. Choose to top wash WT2s/p and WT5s/p first because these tanks are to be used for departure ballast. When these departure ballast tanks are finished washing, continue washing CT2, which shall be refilled with fresh crude from WT4s/p and used for final washing.

Post 4:
WT2s/p, WT5s/p, CT2 are ready for top washing. Open CT4, close all crossover valves. Crude oil washing starts after all check points in checklist “before crude oil washing” have been carried out. During the cow-operation the checkpoints in checklist “during crude oil washing” follows continuously.

- COP 1 disch. from WT5s/p.
- COP 2 disch. l from CT4, deliver to cow.
- COP 3 disch. /stripp. WT2s/p.
- COP 4 disch. from CT2.
- Adjust so WT2s/p will be the first tanks ready for BW.

Post 5:
WT2s/p are ready for BW. Commence ballasting of WT3s/p. Use the ballast to adjust trim and list when necessary.

- COP 1 disch. from WT5s/p. Adjust so these two tanks are ready for BW when WT2s/p are finished BW.
- COP 2 disch. from CT4, deliver to cow.
- COP 3 disch./stripp. WT2s/b.
- COP 4 disch. from CT2.
- Stripp WT2s/p alternately to get these tanks as empty as possible.

Post 6:
WT2s/p are finished washing. Open CT3, close WT2s/p. Open WT1s/p, and close CT4. WT5s/p are ready for BW. Adjust CT2 so this tank will be ready for BW when WT5s/p are finished BW. At this stage in the operation request for dry certificate on WT2s/p and on WT5s/p as soon as WT5s/p are finished BW and stripped.

- COP 1 disch./stripp. from WT5s/p.
- COP 2 disch. from WT1s/p, deliver to cow.
- COP 3 disch. from CT3.
- COP 4 disch. from CT2.
Post 7:
WT5s/p are finished washing. Open CT1, close WT5s/p. Open CT4, close WT1s/p. CT2 is ready for BW. Receive dry certificate, commence ballasting WT2s/p and WT5s/p. using the ballast to adjust trim and list when necessary.
- COP 1 disch. from CT 1, deliver to cow.
- COP 2 disch. from CT4.
- COP 3 disch. from CT3.
- COP 4 disch./stripp. CT2.
Post 8:
CT2 is finished washing. Refill CT2 with fresh crude from WT4s/p to use for finial washing, stop on ullage approx. 19,80m. Open WT6s/p, close CT3. Open WT1s/p, close CT4. Open crossover valves between line 1&2. Close CT1.
- COP 1 and COP 2 disch. from WT1s/p.
- COP 3 disch. from WT6s/p.
- COP 4 disch. from WT4s/p.

Post 9:
WT6s/p are ready for TW, and on these two tanks the BW–ing continues in the lengthening of the TW due to the size of the tanks (small). WT1s/p are also ready for TW. Open CT1, close crossover valves between line 1&2.
- COP 1 disch. from CT1, deliver to cow.
- COP 2 disch. from WT1s/p.
- COP 3 disch./stripp. from WT6s/p.
- COP 4 disch. from WT4s/p.
Post 10:
WT6s/p are finished washed. Open CT3, close WT6s/p. WT1s/p are finished TW and ready for BW.
• COP 1 disch. from CT1, deliver to cow.
• COP 2 disch./stripp. WT1s/p.
• COP 3 disch. from CT3.
• COP 4 disch. from WT4s/p.

Post 11:
WT1s/p are finished washing. Open CT4, close WT1s/p. WT4s/p are ready for TW. Complied ballasting on WT3s/p.
• COP 1 disch. from CT1, deliver to cow.
• COP 2 disch. from CT4.
• COP 3 disch. from CT3.
• COP 4 disch. from WT4s/p.

Post 12:
WT4s/p are finished washing. Continue discharging on WT4s/p until these tanks are ready for BW.
• COP 1 disch. from CT1.
• COP 2 disch. from CT4.
• COP 3 disch. from CT3.
• COP 4 disch. from WT4s/p.

Post 13:
WT4s/p are ready for BW.
• COP 1 disch. from CT1, deliver to cow.
• COP 2 disch. from CT4.
• COP 3 disch. from CT3.
• COP 4 disch/stripp. from WT4s/p.

Post 14:
WT4s/p are finished washing. Open CT2, close WT4s/p. CT1, CT3, CT4, are ready for TW.
• COP 1 disch. from CT1.
• COP 2 disch. from CT2.
• COP 3 disch. from CT3.
• COP 4 disch. from CT2, deliver to cow.

Post 15:
CT1, CT3, CT4 are finished TW. CT3 is ready for BW. Adjust so CT4 is ready for BW when CT3 is finished BW. Commence ballasting on FPT, adjust with ballast tanks for trim when necessary.
• COP 1 disch. from CT1.
• COP 2 disch. from CT4.
• COP 3 disch./stripp. from CT3.
• COP 4 disch. from CT2, deliver to cow.

Post 16:
CT3 is finished washing. Close CT3, stop COP 3. CT4 is ready for BW. At this point reduce a little on the ballasting to the FPT to achieve satisfactory trim.
• COP 1 disch. from CT1.
• COP 2 disch./stripp. from CT4.
• COP 4 disch. from CT2, deliver to cow.
Post 17:
CT4 is finished washing. Close CT4, stop COP 2. CT1 is ready for BW. Complete ballasting on WT5s/p.
- COP 1 disch./stripp CT1.
- COP 4 disch. from CT2, deliver to cow.

Post 18:
CT1 is finished washing. The cow operation is completed. Go through the checklist “after cow”. Close CT1, stop COP 1. Continue discharging the balance cargo ashore from CT2, and also commence stripping lines and cargo pumps ashore through the small diameter line.
- COP 4 disch. from CT2.
- Stripping pump stripp COP 1-2-3, and lines 1 - 2 - 3 ashore.

Post 19:
CT2 is empty, close CT2, and stop COP 4. Continue stripping cargo pumps and lines ashore. Complete ballasting on WT2s/p, continue filling ballast on FPT.

Post 20:
Stop ballast pump, ballast completed. Stop stripping pump, the vessel is finished discharging. The wanted departure draft and trim are attained. Departure bunkering is completed.
Now a discharging plan is worked out including 100% cow (100% cow means that all tanks are to be crude oil washed), and everything is ready for discharge of the cargo in Fos, France. According to the plan, ballasting of the departure ballast is to take place during the discharging operation. When planning, consideration of this departure ballast is taken regarding where to put and how much. This is shown after post no.20, based on the following process:

Before departure the vessel is to be bunkered with fuel and diesel. The following quantities are on board when departure:

- Total fuel oil: 3390 metric tonnes.
- Total diesel: 235 metric tonnes.
- Water, stores etc: 320 metric tonnes:
- Total: 3945 metric tonnes.

In accordance to Regulation 13 (2), a, b and c in Annex I of MARPOL 73/78 the departure draught and trim of the vessel shall be:

a. the moulded draught amidships ($d_m$) in metres (without taking into account any ships deformation) shall not be less than:

$$d_m = 2m + (0.02 \times L)$$

- $d_m = $ draft amidships.
- $L$ = Length between perpendiculars (LPP). On M/T Seagull this length is 295 metres.
- $d_m = 2 \times 2 + (0.02 \times 295)$ m.
- $d_m = 2 \times 2 + 5.90$ m.
- $d_m = 7.90$ m.

The vessel’s departure draft amidships according to this regulations is to be minimum 7.90m.

b. the draughts at the forward and after perpendiculars shall correspond to those determined by the draught amidships ($d_m$) as specified in subparagraph (a) of this paragraph, in association with the trim by stern of not greater than:

$$\text{Trim} = 0.015 \times L$$

- trim = 0.015 x L
- trim = 0.015 x 295 m.
- trim = 4.425 m.

The vessel’s departure trim shall not be greater than 4.425 metres.
c. in any case the draught at the after perpendicular shall not be less than that which is necessary to obtain full immersion of the propeller(s).

Be also aware of local regulations on departure, for example channels, bridges etc.

**Calculation of departure ballast based upon following data:**

Water density: **1025**.

- Fuel, diesel, water, stores etc: 3945 metric tonnes.
- Ballast on FPT (SBT): 9500 metric tonnes.
- Ballast on WT3s/p (SBT): 10508 metric tonnes.
- Total: **23953 metric tonnes**.
- Vessel’s DW (dead-weight) with dm = 7.90m: 54765 metric tonnes.
- Minus SBT, fuel, diesel, stores etc: 23953 metric tonnes.
- Quantity of dirty ballast: **30812 metric tonnes**.

Before departure, we have to ballast 30812 metric tonnes dirty ballast, which will be distributed, as follow:

- WT2s/p = 7215 metric tonnes.
- WT2s/p = 7215 metric tonnes.
- WT5s/p = 8191 metric tonnes.
- WT5s/p = 8191 metric tonnes.
- Dirty ballast: **30812 metric tonnes**.

After completed discharging, ballasting and bunkering, the vessel’s departure draught amidships is 7,915 metres, the trim is 1,84 metres by stern and the propeller is well in the water. There are no special local regulations in Fos, so this will be the vessel’s departure condition.

Before filling of dirty ballast, the tanks to be used for this propose must have been crude oil washed, well-stripped and dry certificate issued. It is important to give notice in good time to minimise loss of time. If you are on a vessel where it is impossible to ballast simultaneously with discharging, you might have to stop the discharging operation for ballasting. If so, the procedure is to empty the departure ballast tanks, strip cargo pumps and lines which are to be used for ballasting. The routines for such a operation are found in the vessel’s cow-manual, and will also need to be approved by the terminal. All operations need to be clarified with the terminals representative(s) before commence discharging.

Companies and ships usually have their own formula for the planning of operations etc. The next page shows a sketch of a departure formula.

The ship is along side and well moored, fire fighting equipment is ready, discharging arms are connected. Cargo pump, stripping pump and inert gas plant are ready for use.
Departure

Arrival

Vessel: ____________________________   Voy. no. ______________
Port: _______________________________   Date: ________________
Terminal: ____________________________

<table>
<thead>
<tr>
<th>FUEL</th>
<th>MET.T.</th>
<th>DIESEL MET.T.</th>
<th>FW,ETC. MET.T.</th>
</tr>
</thead>
<tbody>
<tr>
<td>FWD</td>
<td>0</td>
<td>Storage 95</td>
<td>Freshw. 185</td>
</tr>
<tr>
<td>Aft</td>
<td>2940</td>
<td>Setl.t 93</td>
<td>Stores 75</td>
</tr>
<tr>
<td>Setl.t</td>
<td>310</td>
<td>Serv.t 47</td>
<td>Lub.oil 60</td>
</tr>
<tr>
<td>Serv.t</td>
<td>140</td>
<td>Total 235</td>
<td>Total 320</td>
</tr>
<tr>
<td>Total</td>
<td>3390</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SBT</th>
<th>BALLAST</th>
<th>DIRTY</th>
<th>BALLAST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tank no.</td>
<td>WT3 stb.</td>
<td>5254</td>
<td>WT2 stb.</td>
</tr>
<tr>
<td></td>
<td>WT3 port.</td>
<td>5254</td>
<td>WT2 port.</td>
</tr>
<tr>
<td></td>
<td>FPT</td>
<td>9500</td>
<td>WT5 stb.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>WT5 port.</td>
</tr>
<tr>
<td>Total</td>
<td>20008</td>
<td></td>
<td>Total 30812</td>
</tr>
</tbody>
</table>

Total ballast = **50820 metric tonnes**.

Total bunkers, stores etc: 3945 metric tonnes.
Total ballast: **50820 metric tonnes**.
Dead-weight (DW) on dep: **54765 metric tonnes**
LS (light ship): 29555 metric tonnes.
Displacement on dep: **84320 metric tonnes**

**Draught:**
Fwd: **6,995m**  Mean: **7,915m**  Aft: **8,835m**
Trim: **1,84m**

Surveyors sign.  Chief-officer sign.

sign.
10.9.7 Survey

Representative(s) for the terminal, cargo owner etc. (surveyors) comes on board. Together with the vessel's cargo handling officer, surveying of the cargo tanks takes place: ullaging, measurement of temperature, cargo sampling and water detecting.

Based on the survey results, the “survey ullage report” is filled in. These quantities should correspond to the quantity after departure loading port.

The discharging plan incl. cow is gone over with the terminal’s representative, also “ship/shore check list”, discharging limits (if any), agreed discharging rate and all other information with importance to the operation.

Agreement on ship/shore communications is established. This can vary from port to port, for example specific channel on VHF, the terminal’s radio set. Agreed emergency signal test will be carried out. It is extremely important that involved operation personnel are aware of all communication agreements.

In this stage of the operation, lines, valves etc. are ready for use, except the manifold valves and delivery valves on cargo pumps, which are closed. The inert gas plant is ready for use.

Message is given to the terminal or to the terminal’s representative on board that the vessel is ready to commence discharge.

The drawing shows an interface detector, an instrument used for the surveying mention above.

10.9.8 Interface Detector.

Interface detector is available as fixed and mobile installations. Surveying should take place in a closed system. The drawing shows mobile equipment. The unit is connected to a measuring point on the actual tank via a quick release coupling. After the unit is connected, a ball valve is set open to the tank, and the bar solder is sunken into the cargo.

Mobile units consist of a metal tape, ampere meter and a bar solder. With a switch selector it decides what is measured, temperature, ullage or water amounts. The result is read digitally on the unit.
10.9.9  Line displacement

The discharging normally starts with line displacement. The purpose of this line displacement is to check that the vessel’s measuring method is corresponding with the measuring method in use by the terminal. Normally this line displacement ends with a shore stop. The recommendation is to discharge from a tank, which more or less, brings the ship approximately straight up. This eases the surveying after completion of the line displacement regarding trim and list corrections. When to stop the line displacement is received, a survey is taken of the tank(s) it is discharged from. The discharged quantity is calculated and compared with the terminal figure. The inert gas plant also runs during this line displacement.

After completing line displacement, the discharging commences with a slow rate. Start the inert gas plant, make sure that there is positive pressure on the cargo tanks during the whole operation. Check the quality on supplied inert gas. Increase the rate up to full or agreed rate. Our discharging plan will now be followed up to complete discharging.

**Important!** Remember to log down all happenings during the operation such as timesheet, pumping log, cow log etc.

Have a pleasant stay and successful operation!
2 BASIC PROPERTIES OF PETROLEUM AND ITS HAZARDS

(STCW Code, section A-V/1 paragraph 11)

Learning Objectives:
On completion of this section the trainee should have a good knowledge of:
  Basic physics
  Properties of petroleum
  Hazards associated with the handling and carriage of petroleum
  Toxicity
  Oxygen deficiency
  Flammability
  Toxicity of inert gas
  Hazards to the marine environment

2.1 BASIC PHYSICS – REVISION

Physics is the learning of different substances and property forces and their energy form.

Chemistry is the learning of different substance’s composition and the substantial or permanent changes these substances may undergo.

The theory about atoms and molecules understands that substances are able to divide into smaller parts, atoms and molecules.

2.1.1 The three aggregate states

Normally, here on earth, we find matter in one of three states:
  • Solid, or frozen, like ice.
  • Liquid, like water.
  • Gas or vapour, like steam.

We can change a solid to liquid, or a liquid to a gas, by adding a lot of energy to it, we heat it up. The energy makes the atoms move around.
  • In a solid, the atoms don't move, they just vibrate, as they get hot. When they get hot enough to actually start moving around, the solid melts!
  • In a liquid, the atoms move around each other, but they stay about the same distance from each other. When we heat them up, the atoms vibrate and move more. When they get hot enough to start moving apart, the liquid evaporates!
  • In a gas, the atoms bounce all over the place, like ping-pong balls in a box that is being shaken up. When we heat a gas, the atoms move farther apart, and the gas expands.

Now suppose we take something and really heat it up, hotter than most anything you would find on earth, as hot as the sun! The electrons in the atom come unglued and start bouncing
around with the atoms, so we have a soup of electrons and positively charged atom nuclei. We call this \textit{plasma}. It is a fourth state of matter that we don't see here on earth very often, but it is the most common state of matter in outer space!

2.1.2 Solid Substances
A solid substance has a fixed form and fixed volume. An iron bar resists being lengthened or pressed together. The molecules in the iron bar will try hard to keep a certain mutual distance to each other. The iron bar is resistant to rubbing and bending. In solid substances the molecules have fixed places according to each other, and the same applies to the substance’s volume and form. This is because the cohesion and expansive force is very large.

2.1.3 Fluids
Fluids have a fixed volume, but do not have any fixed form. To squeeze water in a cylinder with tight-fitting piston is hard without using large power. Similar to the molecules in solid substances, the molecules in a liquid substance have a certain mutual distance between each other. The liquid molecules on the other hand have no fixed positions according to each other. Liquid will always be shaped based on where the liquid is stored. The cohesion force in liquids is not powerful enough to prevent the molecules from moving freely according to each other. However, the force is still strong enough to maintain the distance between each of the fixed molecules. The expansion force is equal as in solid substances.

2.1.4 Gases
Gases have no fixed volume or fixed form. A gas will always try to fill as great a volume as possible, and will therefore fill the room, the tank and so on, where the gas is stored. The cohesion force in gas is too small to prevent the molecules from changing both the distance and the position in accordance with each other. The expansion force gets free scope and the gas expansion is total and unlimited. By exposing gas to forces greater than the expansive force itself, the gas will be compressed.

2.1.5 Phase changes
Any substance can be transformed from one condition to another, by means of temperature changes or varying temperatures and pressure. Ice, water and water vapour are the same substance in different forms. The transformation between cohesion and expansion with water molecules goes through these three phases - solid substances, liquids and gases.
2.1.6 Melting

When a solid, pure crystal substance is continuously supplied with heat, the substance will melt. For example:
1 kg of ice with a temperature of minus 20 degrees Celsius exposed to heat (the pressure is 1 atm). A thermometer placed in the ice will show a rise in temperature up to 0 degrees Celsius, which is melting point of the ice. The heat supplied after the melting point is achieved will have no effect to any temperature rising, as long as the ice is present.

During the melting, the temperature is invariable, and the heat supplied during the melting process is consumed in melting the ice. When all the ice is melted, the temperature in the water will rise. So, the amount of heat supplied to 1 kg of the solid substance, in order to reach the melting point where the change from solid to liquid form occurs, is called the “melting heat”.

The heat needed to transform a solid substance at a given temperature, into a liquid substance with the same temperature, is called the “specific melting heat”. The unit for specific melting heat is Joule/kg.

The heat necessary to evaporate one kilo of a certain liquid substance is called “specific melting heat”, abbreviated “r”. The unit for specific evaporation heat is J/k.

2.1.7 Enthalpy

A substance’s total energy consists of the external energy (work) plus the internal energy. Enthalpy is an expression for a substance’s internal energy abbreviated “h”. This enthalpy is an expression of how much energy is tied up in one kilo of the substance. The unit for enthalpy is Joule/kg. IK. The comparison of enthalpy to temperature change of gradients shows how much energy is needed to be supplied to bring ice through the three different stages.

2.1.8 Evaporation

A liquid change to gas is called evaporation. This may happen by evaporation or boiling. To achieve evaporation, heat of evaporation is needed. Some liquids evaporate very quickly, such as gasoline and ether. Other liquid substances evaporate very slowly, such as in crude oil. Evaporation is vapour formed out of the liquid surface and occurs at all temperatures.
This is explained by some of the liquid’s surface molecules being sent into the air, which is strongest at high temperatures, dry air and fresh wind. The specific temperature calls the amount of heat needed for one kilo of liquid with fixed temperature to form into one kilo of steam with the same temperature”. The heat from evaporation is set free when the steam forms to liquid again, or condenses.

The heat necessary to evaporate one kilo of a certain liquid is called “specific heat of evaporation”, abbreviated as \( (r) \). The unit for specific heat of evaporation is J/kg.

### 2.1.9 Boiling

Boiling is steam formed internally in the liquid. The boiling occurs at a certain temperature, called “the boiling point”. Water is heated in normal atmospheric pressure (1 atm), in an open container. In common, some parts of air are always dissolved. The rise in temperature is read from a thermometer placed in the liquid’s surface. When the temperature has reached 100 degrees Celsius, steam bubbles will form inside the liquid substance, especially in the bottom of the container. With continuous heat supply, the bubbling will rise like a stream towards the surface and further up into the air. The water is boiling. The formation of bubbling steam can be explained as follows: During the heating, the water molecule’s kinetic energy increases; consequently the molecules demand more space. During the boiling, as long as there is in water in the container, the temperature will be 100 degrees C.

The boiling point is dependent upon the pressure. If the steam or the atmospheric pressure increases above liquid substance, the boiling point will also rise. If the surface temperature is just below the boiling temperature, then the water steam will evaporate on the surface. The evaporation point and the boiling point will be the same accordingly.
The pressure from the surrounding liquid is the total amount of pressure above the liquid, Pa, plus the static liquid pressure.

\[ P = p_a + (\rho \times g \times h) \]

- \( P \) = pressure in Pascal \((100 \,000 \, Pa + 1 \, \text{bar})\)
- \( p_a \) = barometer pressure
- \( \rho \) = the liquid density in kg/m\(^3\)
- \( g \) = force of gravity acceleration \((9.81 \, m/s^2)\)
- \( h \) = liquid column in meter.

When reducing the pressure above the liquid, the boiling point will also be reduced. A practical use of this characteristic is the production of fresh water on board (fresh water generator).

### 2.1.10 Condensation

Condensation is the opposite of evaporation. If a gas is to be changed to liquid at the same temperature, we must remove the heat of evaporation from the gas. A gas can be condensed at all temperatures below the critical temperature. By cooling a gas, the molecule speed decreases hence the kinetic speed. The internal energy decreases, as well as, the molecule units and liquid forms.

### 2.1.11 Distillation

Distillation is a transferring of liquid to vapour, hence the following condensing of vapour to liquid. Substances, which were dissolved in the liquid, will remain as solid substance. With distillation it is possible to separate what has been dissolved from the substance, which was being dissolved. When a mixture of two liquids with different boiling point is heated, will the most volatile liquid evaporate first while the remaining becomes richer on the less volatile? On board, for instance, seawater is distillate by use of an evaporator.

### 2.1.12 Saturated and unsaturated or superheated steam

Let us imagine boiling water, releasing vapour from a container, and leading the steam into a cylinder that is equipped with a tightening piston, a manometer and two valves. The steam flows through the cylinder and passes the valves, whereon the valves are closing. There now is a limited and fixed volume of steam in the cylinder. Around this cylinder a heating element is fitted. Vapour from the container is constantly sent through this heating element to ensure that the temperature is maintained constant.

The piston is pressed inwards, and now the manometer should show a rise in pressure. But, the manometer shows an unchanged pressure regardless how much the volume is reduced.
What’s happening is, the further the piston is pressed inwards, some parts of the steam is condensed more, and using less volume. The vapour from the heating element removes the condensed heat, which is liberated during the condensation process.

We find that the amount of steam, which is possible to contain per volume unit, remains constant when the steam’s temperature is equal to the condensation point at the set pressure. The room cannot absorb more vapour, it is saturated with steam and called “saturated”. If the piston is pressed outwards, the pressure will still show constant. The conclusion is:

- With temperature equal to the condensation point by set pressure, steam is saturated.
- Steam above boiling water is saturated.
- Saturated steam with a set temperature has a set pressure. This is called saturation pressure.
- With constant temperature saturated steam cannot be compressed.

This also concerns vapour as saturated steam of other gases. Using the same cylinder arrangement as before.

The cylinder contains saturated steam, no water. The piston is drawn outward. When no water exists over the piston no new steam will be supplied underneath. The manometer will now show reduced (falling) pressure as the steam expands. When saturated steam expands without supplying new steam, it is called unsaturated steam. The room has capacity to collect more steam.

So: Unsaturated steam contains lower pressure than saturated steam at the same temperature. The unsaturated steam in the cylinder can be made saturated again in two ways. Either by pushing the piston inward to the originated position, or let the unsaturated steam be sufficiently cooled down. When the temperature is reduced, the saturation pressure will reduce. Unsaturated steam will, in other words, have a too high temperature to be saturated with the temperature it originally had. Therefore, this often is referred to as superheated steam.

2.2 Properties of Petroleum

General

Crude oil is a liquid that comes from reservoirs below the earth's surface. It is called crude oil because it must be processed or "refined" into useable products like gasoline. Natural gas is a gas or vapour that is also stored in reservoirs below the ground. Crude oil and natural gas are often referred to as petroleum.

Crude oil and natural gas are composed of molecules containing carbon and hydrogen atoms. Hydrogen is most commonly found in water, which is composed of two hydrogen atoms and one oxygen atom. The chemical formula for water is written as \( H_2O \). The carbon atom, represented by the letter \( C \), is found in the mineral coal or in the carbon dioxide, which we exhale when we breathe. Carbon dioxide is composed of two atoms of oxygen and one atom of carbon. The chemical formula for carbon dioxide is written \( CO_2 \).
Molecules that are formed by the union of carbon and hydrogen atoms are called hydrocarbons ("hydrogen" and "carbons"). Large hydrocarbon molecules, such as those found in petroleum, are formed by joining or bonding of many hydrogen and carbon atoms. The properties of these hydrocarbons depend upon the number of and arrangement of the carbon atoms in their molecules. Crude oil is composed of not just one molecule but a mixture of many molecules composed of different numbers of carbon and hydrogen atoms.

The simplest hydrocarbon is composed of one carbon atom and four hydrogen atoms, CH₄. This molecule is called methane and is the principal component of natural gas. As more carbon atoms are added to the methane molecule, a carbon chain, C-C, starts to form. The next molecule in the series is ethane, which has two carbons and six hydrogen atoms, C₂H₆. Ethane is a very important chemical because it is used to make ethylene. Ethylene is composed of two carbon atoms but only four hydrogen atoms. The difference between these two molecules is that in the case of ethane the carbon atoms are tied together with a single atomic bond while in the case of ethylene the carbon atoms are joined by a double bond. Compounds consisting solely of carbon and hydrogen atoms joined together by single bonds are called saturated hydrocarbons. Those that are tied together by double bonds are called unsaturated. Ethylene is used as an important chemical building block to make plastics such as polyvinyl chloride for PVC piping, ethylene glycol for automotive antifreeze, and acetic acid for medicine.

As more carbon atoms are added, the molecule's weight and properties change. A hydrocarbon with three carbon atoms is called propane, C₃H₈, which is used for heating and
cooking. Many of us have had hamburgers and hot dogs cooked on propane grills. Four carbon atom chains form butane, \( \text{C}_4\text{H}_{10} \), molecules.

As we add more carbons the hydrocarbon becomes heavier and heavier and its properties change. We move from methane, which is a gas to hexane, which is a liquid. The components of crude oil include heavier hydrocarbons. We separate crude oil into fractions by distillation. As the hydrocarbons become heavier their boiling point increases and they produce more heat when they are burned. In distillation, fractions boiling at different temperatures are separated. Ethane boils at lower temperature than hexane. The distillation process allows use to refine crude oil into its different fractions to produce products like gasoline, jet fuel, diesel oil, home heating oil, residual fuel oil, lubricating oils, and asphalt.

If a crude contains high levels of sulphur, it is called a sour crude and if it has little or no sulphur it is called a sweet crude. Crude oil also contains metals such as nickel and vanadium. Natural gas also contains sulphur, oxygen, and nitrogen that are removed before the gas is sold.

2.2.1 True Vapor Pressure

All crude oils and the usual petroleum products are essentially mixtures of a wide range of hydrocarbon compounds (i.e. chemical compounds of hydrogen and carbon). The boiling points of these compounds range from -162°C (methane) to well in excess of +400°C, and the volatility of any particular mixture of compounds depends primarily on the quantities of the more volatile constituents (i.e. those with a lower boiling point). The volatility (i.e. the tendency of a crude oil or petroleum product to produce gas) is characterized by the vapor pressure. When a petroleum mixture is transferred to a gas free tank or container it commences to vaporize, that is, it liberates gas into the space above it. There is also a tendency for this gas to re-dissolve in the liquid, and equilibrium is ultimately reached with a certain amount of gas evenly distributed throughout the space. The pressure exerted by this gas is called the equilibrium vapor pressure of the liquid, usually referred to simply as the vapor pressure.

The vapor pressure of a pure compound depends only upon its temperature. The vapor pressure of a mixture depends on its temperature, constituents and the volume of the gas space in which vaporization occurs; that is, it depends upon the ratio of gas to liquid by volume. The True Vapor Pressure (TVP) or bubble point vapor pressure is the equilibrium vapor pressure of a mixture when the gas/liquid ratio is effectively zero. It is the highest vapor pressure, which is possible at any specified temperature. As the temperature of a petroleum mixture increases its TVP also increases. If the TVP exceeds atmospheric pressure the liquid commences to boil. The TVP of a petroleum mixture provides a good indication of its ability to give rise to gas. Unfortunately it is a property, which is extremely difficult to measure, although it can be calculated from a detailed knowledge of the composition of the liquid. For crude oils it can also be estimated from the stabilization conditions, making allowance for any subsequent changes of temperature or composition. In the case of products, reliable correlations exist for deriving TVP from the more readily measured Reid Vapor Pressure and temperature.

2.2.2 Reid Vapor Pressure

The Reid Vapor Pressure (RVP) test is a simple and generally used method for measuring the volatility of petroleum liquids. It is conducted in a standard apparatus and in a closely defined way. A sample of the liquid is introduced into the test container at atmospheric pressure so that the volume of the liquid is one fifth of the total internal volume of the container. The container is sealed and immersed in a water bath where it is heated to 37.8°C. After the container has been shaken to bring about equilibrium conditions rapidly, the rise in pressure
due to vaporization is read on an attached pressure gauge. This pressure gauge reading gives a close approximation, in bars, to the vapor pressure of the liquid at 37.8°C. RVP is useful for comparing the volatilities of a wide range of petroleum liquids in a general way. It is, however, of little value in itself as a means of estimating the likely gas evolution in specific situations, mainly because the measurement is made at the standard temperature of 37.8°C and at a fixed gas/liquid ratio. For this purpose TVP is much more useful; as already mentioned, in some cases correlations exist between TVP, RVP and temperature.

2.2.3 Hydrocarbon groups

Hydrocarbon is a common expression for all chemical compounds that includes carbon and hydrogen.

You find the element carbon in only two different natural conditions, as graphite and as diamond. Carbon is the element that naturally forms most natural chemical compounds. It is not reactive in room temperature, but it will when heated up react more easily with, for example, the oxygen in air. We say that the carbon is combustible. The combustion is exothermic, which is a reaction that produces heat.

Hydrogen is the smallest main element. The gas (H₂), is light and is flammable in air. There are small quantities of hydrogen in free natural form on earth. Hydrogen is strongly widespread, first of all in form of water and naturally compounds together with carbon. Crude oil and natural gas consist mainly of a mixture with various unequal hydrocarbon compounds. Following sketch indicates an example of a natural gas’ composition:

<table>
<thead>
<tr>
<th>Natural gas from Well</th>
<th>Hydrocarbons</th>
<th>Gas</th>
<th>Methane</th>
<th>LNG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>(NGL)</td>
<td>Ethane, Propane</td>
<td>LPG</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Heavy fractions, min 5 C-atoms</td>
<td>Butane</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Non Hydrocarbons</td>
<td></td>
<td>Naphtha, Natural Gasoline and other, 5C+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water, carbondioxide etc.</td>
<td></td>
</tr>
</tbody>
</table>

Carbon has four electrons in the outer electron shell that can be divided with others. You may look at the four electrons as four “arms” that can connect to the hydrogen atom’s single “arm”, and creates hydrocarbon compounds.
Some of the hydrocarbon compounds are naturally created; other is only created in chemical controlled processes. To simplify the overview of these natural components, and all new hydrocarbon compounds that is created in the petrochemical industry, the different hydrocarbon compounds are grouped dependent of how the “arms” or the chemical bonding are between the two atoms. The most important hydrocarbon groups are:

- Alkanes, also called Paraffin’s
- Alkyls
- Alkenes, also called Olefins
- Alkynes, also called Acetylides
- Alkadienes, also called Di-olefins
- Cyclo-alkanes
- Arenes
- Alcohol
- Aldehyds
- Ketons

In addition to above listed hydrocarbon groups there are others like Carboxylic acid, Esters, Ethers etc.

2.2.4 Alkanes

Alkanes are saturated hydrocarbons. This means that there are only single bonds present in the structure of the molecule. There is a special way to name these molecules. This is done by identifying the number of carbon atoms in the longest continues chain. Remember carbon atoms can have four atom attached, and in hydrocarbons these atoms are hydrogen unless other wise stated.

Alkanes are the simplest hydrocarbon compounds and is the major part of crude oil and natural gas.

When there is one carbon the alkane is named methane. The formula for methane is CH₄

Methane CH₄
The carbon atom’s four arms are united to the hydrogen atoms’ single arm and has this general molecule-formula: \( \text{C}_n\text{H}_{2n+2} \), where “n” is a positive integer.

The gas methane is the smallest molecule, and is the main component in natural gas. A methane molecule consists of one carbon atom and four hydrogen atoms.

By adding one carbon atom and two hydrogen atoms to methane, we get ethane, which is the next component in this group.

\[
\text{Ethane } \text{C}_2\text{H}_6
\]

By adding carbon atoms and hydrogen atoms, and at the same time maintain the same simple form of binding, new alkanes are formed. The third component in the alkane group is propane, \( \text{C}_3\text{H}_8 \).

\[
\text{Propane } \text{C}_3\text{H}_8
\]

When the number of carbon atoms increase, the number of possible bonding between the atoms increase. You can arrange 20 carbon atoms and 42 hydrogen atoms in 366,319 different ways.

\[
\text{n-Butane, C}_4\text{H}_{10}
\]

Many materials may have the same molecule formula, but the properties (boiling point, density, etc.) are different because the atom structure is different. Such bonding is called isometric bonding. Normal-butane and iso-butane are examples of isomers where both have the same molecule formula, but different properties.
Chemical formulas and names are many times derived from each other. Pentane is derived from the Greek word “pent”. That means “five”, it refers to the number of carbon atoms in the material. Other names like methane and ethane are not following this system. These names are called trivial names.

In the following list, some of the most common alkanes are listed with melting- and boiling point at atmospheric pressure. Note that melting point and boiling point increase by the length of chain for the straight-chained hydrocarbons.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Formula</th>
<th>Melting point °C</th>
<th>Boiling point °C</th>
<th>Number of isomeric compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methane</td>
<td>CH₄</td>
<td>-182,5</td>
<td>-161,6</td>
<td>0</td>
</tr>
<tr>
<td>Ethane</td>
<td>C₂H₆</td>
<td>-183,2</td>
<td>-88,6</td>
<td>0</td>
</tr>
<tr>
<td>Propane</td>
<td>C₃H₈</td>
<td>-189,9</td>
<td>-42,5</td>
<td>0</td>
</tr>
<tr>
<td>n-Butane</td>
<td>C₄H₁₀</td>
<td>-135</td>
<td>-0,5</td>
<td>2</td>
</tr>
<tr>
<td>iso-Butane</td>
<td>C₄H₁₀</td>
<td>-145</td>
<td>-11,7</td>
<td>3</td>
</tr>
<tr>
<td>n-Pentane</td>
<td>C₅H₁₂</td>
<td>-130</td>
<td>36</td>
<td>3</td>
</tr>
<tr>
<td>n-Hexane</td>
<td>C₆H₁₄</td>
<td>-95</td>
<td>69</td>
<td>5</td>
</tr>
<tr>
<td>n-Heptane</td>
<td>C₇H₁₆</td>
<td>-56</td>
<td>98</td>
<td>9</td>
</tr>
<tr>
<td>n-Octane</td>
<td>C₈H₁₈</td>
<td>-57</td>
<td>126</td>
<td>18</td>
</tr>
<tr>
<td>n-Nonane</td>
<td>C₉H₂₀</td>
<td>-54</td>
<td>151</td>
<td>35</td>
</tr>
<tr>
<td>n-Decane</td>
<td>C₁₀H₂₂</td>
<td>-30</td>
<td>174</td>
<td>75</td>
</tr>
</tbody>
</table>

2.2.5 Alkenes
You do not find alkenes in the natural forms. These compounds are produced in a cracking process within the petrochemical industry. Alkenes are hydrocarbons with a double bonding between two of the carbon atoms. The general molecule formula for alkenes is: $C_nH_{2n}$

The simplest alkene is ethylene, $C_2H_4$ that is produced by cracking of for example propane, ethane, butane or naphtha.
The next alkene is propylene, C$_3$H$_6$, which is produced by cracking other hydrocarbons or naphtha.

The alkenes are so-called **unsaturated hydrocarbons**. The double bonding may easily loosen up, “arms” that are attached to several hydrogen atoms released, and the alkenes may change back to (chemical reaction) alkanes.

<table>
<thead>
<tr>
<th>Name:</th>
<th>Formula</th>
<th>Melting point °C</th>
<th>Boiling point °C</th>
<th>Number of isomeric compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene (ethene)</td>
<td>C$_2$H$_4$</td>
<td>-169</td>
<td>-103,7</td>
<td>0</td>
</tr>
<tr>
<td>Propylene (propene)</td>
<td>C$_3$H$_6$</td>
<td>-185,2</td>
<td>-47,7</td>
<td>0</td>
</tr>
<tr>
<td>1-Butene</td>
<td>C$_4$H$_8$</td>
<td>-185,4</td>
<td>-6,3</td>
<td>4</td>
</tr>
<tr>
<td>cis-2-Butene</td>
<td>C$_4$H$_8$</td>
<td>-138,9</td>
<td>3,7</td>
<td>4</td>
</tr>
<tr>
<td>trans-2-Butene</td>
<td>C$_4$H$_8$</td>
<td>-105,6</td>
<td>0,9</td>
<td>4</td>
</tr>
<tr>
<td>iso-Butene</td>
<td>C$_4$H$_8$</td>
<td>-140,4</td>
<td>-6,9</td>
<td>4</td>
</tr>
<tr>
<td>1-Pentene</td>
<td>C$<em>5$H$</em>{10}$</td>
<td></td>
<td></td>
<td>6</td>
</tr>
</tbody>
</table>

The number of isomeric compounds increases by the number of carbon atoms. Double bonding also gives additional possibilities for combination because the double bonding may be located on several different places inside the molecule.

**2.2.6 Chemical Reactions**

New products are continuously made in the petrochemical industry by allowing hydrocarbon compounds participate in chemical processes and reactions.
Unsaturated chemical compounds contain one or several double or triple bonding between the carbon atoms. They can easily saturate the vacant valences in a chemical reaction. A chemical reaction may take place:

- by mixing unsaturated compounds with another product.
- by increasing the temperature and pressure in the chemical compound, alone or together with other compounds.

To visualise an unsaturated compound, a solvent bromine and water can be used. If you mix bromine (Br) with saturated oil, the bromine-coloured water will disappear, because the double bonding is opened and bromine appears in every vacant valence. A chemical reaction has appeared between two compounds, and a new compound is created.

If you combine ethylene and bromine, this chemical reaction will take place:

\[
\text{H} - \text{H} + \text{Br}_2 = \text{H} - \text{Br} - \text{Br} - \text{H} - \text{H} - \text{H}
\]

When unsaturated chemical compounds are heated under pressure, the molecules react with each other and form large molecules, so-called macromolecules. This is called **polymerisation**. To start the reactions or to increase the velocity of reaction, a catalyst is often used. A catalyst is a material that increases the velocity of reaction in a chemical process without changing its own state.

Linear polyethylene is a plastic raw material, which is a **polymer** of ethylene produced by polymerising ethylene with a **peroxide** catalyst. Benzyl peroxide is an example of peroxide used as a catalyst for production of polyethylene.

Other types of polymers are made of ethylene or together with other hydrocarbon. The properties are different, and the plastic raw materials are used alone or together with others when producing plastic products.

Most plastic raw materials are produced like this. Molecules or mixture of molecules, which is capable of, polymerise, are called **monomers**. The number of monomers taking part of a polymerisation may be many thousand. A linear polyethylene has a molecular weight of more than 6000, others are considerably smaller. The molecular weight is controlled by temperature, concentration of catalyst or amount of ethylene.

It is not only the unsaturated hydrocarbon compound that may polymerise. In 1907, Baekeland managed to control three-step polymerising with phenol and formaldehyde. The product “Bakelite” was the first synthetic polymer that was produced, and has great significance even today.
The following list demonstrates some of the most common plastic materials today, and how they are produced:

<table>
<thead>
<tr>
<th>Polymer</th>
<th>Monomer:</th>
<th>Polymerisation:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polyethylene</td>
<td>(CH₂)ₙ</td>
<td>Ethylene</td>
</tr>
<tr>
<td>Polytetrafluoroethylene (PTFE)</td>
<td>(C₂F₄)ₙ</td>
<td>Tetrafluorethylene</td>
</tr>
<tr>
<td>Polyvinyl chloride (PVC)</td>
<td>(H₂CCHF)ₙ</td>
<td>Vinyl chloride</td>
</tr>
<tr>
<td>Polypropylene</td>
<td>(C₃H₆)ₙ</td>
<td>Propylene</td>
</tr>
<tr>
<td>Polystyrene</td>
<td>(C₆H₅CHCH₂)ₙ</td>
<td>Styrene monomer</td>
</tr>
</tbody>
</table>

### 2.2.7 Peroxides and inhibitors

Peroxides are highly explosive, and can form into unsaturated compounds, as for example butadiene and VCM if oxygen is present. They can appear as powder in pipes and tanks and are very unstable and can easily explode. The formation of peroxides in butadiene can entail polymerising with powerful heat generation.

To avoid such a chemical reaction, the content of oxygen in the tank atmosphere is kept as low as possible.

To assure that all oxygen is removed, an inhibitor is added to the individual cargo. An inhibitor is a material that itself, in low concentrations, reacts with the oxygen. Some types of inhibitors have the capability to react with radicals so that the velocity of reaction reduces or to cease up. Most inhibitors are very dangerous to our health, and must therefore, be handled with the utmost care.

Humidity and water will reduce the effect of inhibitors; in some cases water will accelerate a chemical reaction.

Cargo that is inhibited must have a certificate with:
- name and amount
- inhibitor date and for how long the inhibitor is efficient
- precautions, if the voyage lasts longer than the effect of the inhibitor
- eventual temperature limitation

The above mentioned inhibitors are only present in the liquid phase. In all probability, dangerous peroxides will be formed inside the lines of the cooling plant’s “condensate” system. It is recommended that these parts of the system are checked regularly, when the inhibited cargo is cooled. Further, it is recommended to circulate some inhibited liquid through the part of the system where “condensates” remains without the inhibitor.

Introductorily, we have said that polymerising can occur if the temperature is high enough. The following restriction of maximum outlet temperatures from the compressor are required:
- maximum 60°C for butadiene
- maximum 90°C for VCM

### 2.2.8 Reaction with other cargo and materials

Some cargo can react strongly with other cargo. This makes great demands for cleaning, before loading and full segregation against other cargo. Whenever cargo segregation is required, spool pieces must be used. It is important that all materials are compatible with
which the cargo can come in contact. The material must, for example, in all gaskets that can be in contact with propylene oxide be of PTFE or a similar approved material type.
2.3 HAZARDS ASSOCIATED WITH THE HANDLING AND CARRIAGE OF PETROLEUM

2.3.1 Toxicity in general
The toxic hazards to which personnel are exposed in tanker operations arise almost entirely from exposure to gases of various kinds. A number of indicators are used to measure the concentrations of toxic vapors and many substances have been assigned Permissible Exposure Limits (PELs) and/or Threshold Limit Values (TLVs). The term Threshold Limit Value has been in use within the industry for a number of years and is often expressed as a Time Weighted Average (TWA). The use of the term Permissible Exposure Limit is becoming more commonplace and refers to the maximum exposure to a toxic substance that is allowed by an appropriate regulatory body. The PEL is usually expressed as a Time Weighted Average, normally averaged over an eight-hour period, or as a Short Term Exposure Limit (STEL), normally expressed as a maximum airborne concentration averaged over a 15 minute period. The values are expressed as parts per million (ppm) by volume of gas in air.

2.3.2 Ingestion
The risk of swallowing significant quantities of liquid petroleum during normal tanker and terminal operations is very slight. Petroleum has low oral toxicity to man, but when swallowed it causes acute discomfort and nausea. There is then a possibility that liquid petroleum may be drawn into the lungs during vomiting and this can have serious consequences, especially with higher volatility products such as gasolines and kerosenes.

2.3.3 Skin Contact
Many petroleum products, especially the more volatile ones, cause skin irritation and remove essential oils from the skin, leading to dermatitis. They are also irritating to the eyes. Certain heavier oils can cause serious skin disorders on repeated and prolonged contact. Direct contact with petroleum should always be avoided by wearing the appropriate protective equipment, especially impervious gloves and goggles.

2.3.4 Petroleum gases
The main effect of petroleum gas on personnel is to produce narcosis. The symptoms include headache and eye irritation, with diminished responsibility and dizziness similar to drunkenness. At high concentrations these lead to paralysis, insensibility and death. The toxicity of petroleum gases can vary widely depending on the major hydrocarbon constituents of the gases. Toxicity can be greatly influenced by the presence of some minor components such as aromatic hydrocarbons (e.g. benzene) and hydrogen sulphide. A TLV of 300 ppm, corresponding to about 2% LFL, is established for gasoline vapours. Such a figure may be used as a general guide for petroleum gases but must not be taken as applicable to gas mixtures containing benzene or hydrogen sulphide. The human body can tolerate concentrations somewhat greater than the TLV for short periods. The following are typical effects at higher concentrations:
Typical Effects of Exposure to Petroleum Gases

<table>
<thead>
<tr>
<th>Concentration</th>
<th>% LEL</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1% vol (1,000ppm)</td>
<td>10%</td>
<td>Irritation of the eyes within one hour</td>
</tr>
<tr>
<td>0.2% vol (2,000ppm)</td>
<td>20%</td>
<td>Irritation of the eyes, nose and throat, dizziness and unsteadiness within half an hour</td>
</tr>
<tr>
<td>0.7% vol (7,000ppm)</td>
<td>70%</td>
<td>Symptoms of drunkenness within 15 minutes</td>
</tr>
<tr>
<td>1.0% vol (10,000ppm)</td>
<td>100%</td>
<td>Rapid onset of ‘drunkenness’ which may lead to unconsciousness and death if exposure continues</td>
</tr>
<tr>
<td>2.0% vol (20,000ppm)</td>
<td>200%</td>
<td>Paralysis and death occur very rapidly</td>
</tr>
</tbody>
</table>

Typical Effects of Exposure to Hydrogen Sulphide (H₂S)

The smell of petroleum gas mixtures is very variable, and in some cases the gases may dull the sense of smell. The impairment of smell is especially serious if the mixture contains hydrogen sulphide. The absence of smell should therefore never be taken to indicate the absence of gas. The TLV concentration is considerably below the lower flammable limit and combustible gas indicators cannot be expected to measure concentrations of this order accurately.

2.3.5 Hydrogen sulphide

Many crude oils come out of the well with high levels of hydrogen sulphide (H level is usually reduced by a stabilization process before the crude oil is delivered to the vessel. However, the amount of stabilization may be temporarily reduced at times. Thus a tanker may receive a cargo with a hydrogen sulphide content higher than usual. In addition, some crude oils are never stabilized and always contain a high hydrogen sulphide level. Hydrogen sulphide can also be encountered in other cargoes such as naphtha, fuel oil, bitumen’s and gas oils.

The Permissible Exposure Limit (PEL) of hydrogen sulphide expressed as a Time Weighted Average (TWA) is 10 ppm. The effects of the gas at concentrations in air in excess of the TWA are:

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>50-100 ppm</td>
<td>Eye and respiratory tract irritation after exposure of one hour.</td>
</tr>
<tr>
<td>200-300 ppm</td>
<td>Marked eye and respiratory tract irritation after exposure of one hour.</td>
</tr>
<tr>
<td>500-700 ppm</td>
<td>Dizziness, headache, nausea, etc. within 15 min, loss of consciousness and possible death after 30-60 minutes exposure</td>
</tr>
<tr>
<td>700-900 ppm</td>
<td>Rapid unconsciousness, death occurring a few minutes later.</td>
</tr>
<tr>
<td>1,000-2,000 ppm</td>
<td>Instantaneous collapse and cessation of breathing</td>
</tr>
</tbody>
</table>

Note: persons over exposed to H2S vapor should be removed to clean air as soon as possible. The adverse effects of H2S can be reversed and the probability of saving the person’s life improved if prompt action is taken.

It is important to distinguish between concentrations of hydrogen sulphide in the atmosphere expressed in ppm by volume and concentrations in liquid expressed in ppm by weight. For example a crude oil containing 70 ppm (by weight) hydrogen sulphide has been shown to produce a concentration of 7,000 ppm (by volume) in the gas stream leaving an ullage port.
above the cargo tank. Thus, it is not possible to predict the likely vapor concentration from known liquid concentrations.

2.3.6 Toxicity of inert gas

Inert Gas — General
Inert gas is principally used to control cargo tank atmospheres and so prevent the formation of flammable mixtures. The primary requirement for an inert gas is low oxygen content. Its composition can, however, be variable and the table below provides an indication of typical inert gas components expressed as a percentage by volume:

<table>
<thead>
<tr>
<th>Component</th>
<th>IG from main boiler flue gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N\textsubscript{2})</td>
<td>83%</td>
</tr>
<tr>
<td>Carbon dioxide (CO\textsubscript{2})</td>
<td>13%</td>
</tr>
<tr>
<td>Carbon monoxide (CO)</td>
<td>present</td>
</tr>
<tr>
<td>Oxygen (O\textsubscript{2})</td>
<td>4%</td>
</tr>
<tr>
<td>Sulphur dioxide (SO\textsubscript{2})</td>
<td>50 ppm</td>
</tr>
<tr>
<td>Oxides of Nitrogen (NO\textsubscript{X})</td>
<td>present</td>
</tr>
<tr>
<td>Water vapor (H\textsubscript{2}O)</td>
<td>present</td>
</tr>
<tr>
<td>Ash and soot (C)</td>
<td>present</td>
</tr>
<tr>
<td>Dew point</td>
<td>High if not dries</td>
</tr>
<tr>
<td>Density</td>
<td>1.044</td>
</tr>
</tbody>
</table>

*Inert Gas Composition*

2.3.7 Toxic Constituents

The main hazard associated with inert gas is its low oxygen content. However, inert gas produced by combustion either in a steam-raising boiler or in a separate inert gas generator contains trace amounts of various toxic gases, which may increase the hazard to personnel exposed to it.

2.3.8 Nitrogen Oxides

Fresh flue gases typically contain about 200 ppm by volume of mixed nitrogen oxides. The majority is nitric oxide (NO), which is not removed by water scrubbing. Nitric oxide reacts slowly with oxygen forming nitrogen dioxide (NO\textsubscript{2}). As the gas stands in tanks the total concentration of nitrogen oxide falls over a period of 1-2 days to a level of 10-20 ppm as the more soluble nitrogen dioxide goes into solution in free water, or by condensation, to give nitrous and nitric acids. Further decrease below this level is very slow. Nitric oxide is a colourless gas with little smell at its TLV of 25 ppm. Nitrogen dioxide is even more toxic with a TLV of 3 ppm.

2.3.9 Sulphur Dioxide

Flue gas produced by the combustion of high sulphur content fuel oils typically contains about 2,000 ppm of sulphur dioxide (SO\textsubscript{2}). Inert gas system water scrubbers remove this gas with an efficiency, which depends upon the design and operation of the scrubber, giving inert gas with sulphur dioxide content usually between 2 and 50 ppm.
Sulphur dioxide produces irritation of the eyes, nose and throat and may also cause breathing difficulties in sensitive people. It has a distinctive smell at its TLV of 2 ppm.

2.3.10 Oxygen deficiency

The oxygen content of the atmosphere in enclosed spaces may be low for several reasons. The most obvious one is if the space is in an inert condition, and the oxygen has been displaced by the inert gas. Also, oxygen can be removed by chemical reactions such as rusting or the hardening of paints or coatings.

As the amount of available oxygen decreases below the normal 21% by volume breathing tends to become faster and deeper. Symptoms indicating that an atmosphere is deficient in oxygen may give inadequate notice of danger. Most persons would fail to recognize the danger until they were too weak to be able to escape without help. This is especially so when escape involves the exertion of climbing.

While individuals vary in susceptibility, all will suffer impairment if the oxygen level falls to 16% by volume.

Exposure to an atmosphere containing less than 10% oxygen content by volume inevitably causes unconsciousness. The rapidity of onset of unconsciousness increases as the availability of oxygen diminishes, and death will result unless the victim is removed to the open air and resuscitated.

An atmosphere containing less than 5% oxygen by volume causes immediate unconsciousness with no warning other than a gasp for air. If resuscitation is delayed for more than a few minutes, irreversible damage is done to the brain even if life is subsequently restored.

Entry into oxygen deficient spaces must never be permitted without breathing apparatus until such spaces have been thoroughly ventilated and test readings indicate an oxygen level of 21% by volume throughout.

TEST...VENTILATE...TEST

DON'T BE A FOOL,

USE YOUR OXYGEN METER AS YOUR TOOL.

MAKE SURE IT’S SAFE!!

2.3.11 Flammability and explosives

General

In the process of burning, hydrocarbon gases react with the oxygen in the air to produce carbon dioxide and water. The reaction gives enough heat to form a flame, which travels through the mixture of hydrocarbon gas and air. When the gas above a liquid hydrocarbon is ignited the heat produced is usually enough to evaporate sufficient fresh gas to maintain the flame, and the liquid is said to burn; in fact it is the gas which is burning and is being continuously replenished from the liquid.
2.3.12 Flammable Limits

A mixture of hydrocarbon gas and air cannot be ignited and burn unless its composition lies within a range of gas in air concentrations known as the ‘flammable range’. The lower limit of this range, known as the lower flammable limit (LFL), is that hydrocarbon concentration below which there is insufficient hydrocarbon gas to support and propagate combustion. The upper limit of the range, known as the upper flammable limit (UFL), is that hydrocarbon concentration above which there is insufficient air to support and propagate combustion.

The flammable limits vary somewhat for different pure hydrocarbon gases and for the gas mixtures derived from different petroleum liquids. Very roughly the gas mixtures from crude oils, motor or aviation gasolines and natural gasoline type products can be represented respectively by the pure hydrocarbon gases propane, butane and pentane. Table below gives the flammable limits for these three gases. It also shows the amount of dilution with air needed to bring a mixture of 50% by volume of each of these gases in air down to its LFL; this type of information is very relevant to the ease with which vapours disperse to a non-flammable concentration in the atmosphere.

In practice the lower and upper flammable limits of oil cargoes carried in tankers can, for general purposes, be taken as 1% and 10% by volume respectively.

<table>
<thead>
<tr>
<th>Gas</th>
<th>Flammable limits % vol. Hydrocarbon in air</th>
<th>Number of dilutions by air to reduce 50% by volume mixture to LFL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Upper</td>
<td>Lower</td>
</tr>
<tr>
<td>Propane</td>
<td>9.5</td>
<td>2.2</td>
</tr>
<tr>
<td>Butane</td>
<td>8.5</td>
<td>1.9</td>
</tr>
<tr>
<td>Pentane</td>
<td>7.8</td>
<td>1.5</td>
</tr>
</tbody>
</table>

2.3.13 Effect of Inert Gas on Flammability

When an inert gas, typically flue gas, is added to a hydrocarbon gas/air mixture the result is to increase the lower flammable limit hydrocarbon concentration and to decrease the upper
flammable limit concentration. These effects are illustrated in the figure below, which should be regarded only as a guide to the principles involved.

Every point on the diagram represents a hydrocarbon gas/air/inert gas mixture, specified in terms of its hydrocarbon and oxygen contents. Hydrocarbon gas/air mixtures without inert gas lie on the line AB, the slope of which reflects the reduction in oxygen content as the hydrocarbon contents increases. Points to the left of AB represent mixtures with their oxygen content further reduced by the addition of inert gas.

The lower and upper flammability limit mixtures for hydrocarbon gas in air are represented by the points C and D. As the inert gas content increases, the flammable limit mixtures change as indicated by the lines CE and DE, which finally converge at the point E. Only those mixtures represented by points in the shaded area within the loop CED are capable of burning.

On such a diagram, changes of composition due to the addition of either air or inert gas are represented by movements along straight lines directed either towards the point A (pure air), or towards a point on the oxygen content axis corresponding to the composition of the added inert gas. Such lines are shown for the gas mixture represented by the point F.

It is evident from the flammability diagram that as inert gas is added to hydrocarbon gas/air mixtures the flammable range progressively decreases until the oxygen content reaches a level, generally taken to be about 11% by volume, when no mixture can burn. The figure of 8% by volume of oxygen specified in this guide for a safely inerted gas mixture allows a margin beyond this value.

When an inerted mixture, such as that represented by the point F, is diluted by air its composition moves along the line FA and therefore enters the shaded area of flammable mixtures. This means that all inerted mixtures in the region above the line GA go through a flammable condition as they are mixed with air, for example during a gas freeing operation. Those below the line GA, such as that represented by point H, do not become flammable on
dilution. Note that it is possible to move from a mixture such as F to one such as H by dilution with additional inert gas (i.e. purging to remove hydrocarbon gas).

2.3.14 Electrostatic hazards

Static electricity presents fire and explosion hazards during the handling of petroleum, and tanker operations. Certain operations can give rise to accumulations of electric charge which may be released suddenly in electrostatic discharges with sufficient energy to ignite flammable hydrocarbon gas/air n-fixtures; there is, of course, no risk of ignition unless a flammable fixture is present. There are three basic stages leading up to a potential static hazard: charge separation, charge accumulation and electrostatic discharge. All three of these stages are necessary for an electrostatic ignition.

Charge Separation

Whenever two dissimilar materials come into contact charge separation occurs at the interface. The interface may be between two solids, between a solid and a liquid or between two immiscible liquids. At the interface a charge of one sign (say positive) moves from material A to material B so that materials A and B become respectively negatively and positively charged. Whilst the materials stay in contact and immobile relative to one another, the charges are extremely close together. The voltage difference between the charges of opposite sign is then very small, and no hazard exists.

The charges can be widely separated by many processes, such as:

. 1 The flow of liquids (e.g. petroleum or mixtures of petroleum and water) through pipes or fine filters.

. 2 The settling of a solid or an immiscible liquid through a liquid (e.g. rust or water through petroleum).

. 3 The ejection of particles or droplets from a nozzle (e.g. steaming operations).
.4 The splashing or agitation of a liquid against a solid surface (e.g. water washing operations or the initial stages of filling a tank with oil).

.5 The vigorous rubbing together and subsequent separation of certain synthetic polymers (e.g. the sliding of a polypropylene rope through PVC gloved hands).

When the charges are separated, a large voltage difference develops between them. Also a voltage distribution is set up throughout the neighbouring space and this is known as an electrostatic field. As examples, the charge on a charged petroleum liquid in a tank produces an electrostatic field throughout the tank both in the liquid and in the ullage space, and the charge on a water mist by tank washing produces a field throughout the tank. If an unchanged conductor is present in an electrostatic field it has approximately the same voltage as the region it occupies. Furthermore the field causes a movement of charge within the conductor; a charge of one sign is attracted by the field to one end of the conductor and an equal charge of opposite sign is left at the opposite end. Charges separated in this way are known as induced charges and as long as they are kept separate by the presence of the field they are capable of contributing to an electrostatic charge.

2.3.15 Charge Accumulation

Charges, which have been separated attempt to recombine and to neutralise each other. This process is known as charge relaxation. If one, or both, of the separated materials carrying charge is a very poor electrical conductor, recombination is impeded and the material retains or accumulates the charge upon it. The period of time for which the charge is retained is characterised by the relaxation time of the material, which is related to its conductivity; the lower the conductivity the greater is the relaxation time.

If a material has a comparatively high conductivity, the recombination of charges is very rapid and can counteract the separation process, and consequently little or no static electricity accumulates on the material. Such a highly conducting material can only retain or accumulate charge if it is insulated by means of a poor conductor, and the rate of loss of charge is then dependent upon the relaxation time of this lesser conducting material.

The important factors governing relaxation are therefore the electrical conductivities of the separated materials and of any additional materials, which may be interposed between them after their separation.

2.3.16 Electrostatic Discharges

Electrostatic breakdown between any two points, giving rise to a discharge, is dependent upon the strength of the electrostatic field in the space between the points. This field strength, or voltage gradient, is given approximately by dividing the difference in voltage between the points by their distance apart. Field strength of about 3,000 kilovolts per metre is sufficient to cause breakdown of air or petroleum gases.

The field strength near protrusions is greater than the overall field strength in the vicinity and discharges therefore generally occur at protrusions. A discharge may occur between a protrusion and the space in its vicinity without reaching another object. These single electrode discharges are rarely, if ever, incentive in the context of normal tanker operations. The alternative is a discharge between two electrodes adjacent to each other. Examples are:

.1 Between sampling apparatus lowered into a tank and the surface of a charged petroleum liquid.
.2 Between an unearthed object floating on the surface of a charged liquid and the adjacent tank structure.

.3 Between unearthed equipment suspended in a tank and the adjacent tank structure.

Two-electrode discharges may be incentive if various requirements are met. These include:

.1 A discharge gap short enough to allow the discharge to take place with the voltage difference present, but not so short that any resulting flame is quenched.

.2 Sufficient electrical energy to supply the minimum amount of energy to initiate combustion.

.3 The nearly instantaneous release of this energy into the discharge gap.

Whether the last requirement can be fulfilled depends to a large extent on the conductivity of the electrodes. In order to consider this further it is necessary to classify solids and liquids into three main groups.

The first group is the conductors. In the case of solids these are the metals, and in the case of liquids the whole range of aqueous solutions including seawater. The human body, consisting of about 60% water, is effectively a liquid conductor. The important property of conductors is that not only are they incapable of holding a charge unless insulated, but also that if they are insulated and an opportunity for an electrical discharge occurs all the charge available is almost instantaneously released into the discharge.

Discharges between two conductors very frequently occur as sparks, and are much more energetic and potentially dangerous than those occurring between objects, one of which is not a conductor. In the latter case, discharges often take a more diffuse and much less dangerous form, known as corona or brush discharge, rather than a spark.

The second group is the non-conductors, which have such low conductivities that once they have received a charge they retain it for a very long period. Alternatively they can prevent the loss of charge from conductors by acting as insulators. Charged non-conductors are of primary concern because they can transfer charge to, or induce charge on, neighbouring insulated conductors which may then give rise to sparks. Very highly charged non-conductors may themselves contribute directly to incentive sparks.

The third group is a range of liquids and solids with conductivities intermediate between those of the first two groups. The liquids have conductivities exceeding 50 pS/m and are often known as static non-accumulators. Examples are black oils (containing residual materials) and crude oils, which typically have conductivities in the range of 10,000-100,000 pS/m. Some chemicals, for example alcohols, are also static non-accumulators.

The solids in this intermediate category include such materials as wood, cork, sisal and naturally occurring organic substances generally. They owe their conductivity to their ready absorption of water and they become more conductive as their surfaces are contaminated by moisture and dirt. In some cases thorough cleaning and drying may lower their conductivities sufficiently to bring them into the non-conductive range.

If materials in the intermediate conductivity group are not insulated from earth their conductivities are normally sufficiently high to prevent accumulation of an electrostatic
charge. However, their conductivities are normally low enough to inhibit production of energetic sparks.

### 2.3.17 Hazards to the marine environment

Characterization of crude oils and refined petroleum products in a release situation is one of the earliest response tasks that must be undertaken. Proper classification and an understanding of the chemical and physical properties of these substances helps determine the hazard to personnel and wildlife, the effects that may be observed on adjacent shorelines or estuaries (for spills into water), and the form a response should take. Non-petroleum-based oils also pose a potential threat to human health and the environment.

#### Chemical Composition

Crude oils and refined petroleum products consist largely of hydrocarbons, which are chemicals composed solely of hydrogen and carbon in various molecular arrangements. Crude oils contain hundreds of different hydrocarbons and other organic and inorganic substances including atoms of sulphur, nitrogen, and oxygen, as well as metals such as iron, vanadium, nickel, and chromium. Collectively, these other atoms are called heteroatoms. Certain heavy crude oils from younger geologic formations (e.g., Venezuelan crudes) contain less than 50 percent hydrocarbons and a higher proportion of organic and inorganic substances containing heteroatoms. The refining process removes many of the chemicals containing these heteroatoms. All crudes contain lighter fractions similar to gasoline as well as heavier tar or wax constituents, and may vary in consistency from a light volatile fluid to a semi-solid.

Petroleum products used for motor fuels are essentially a complex mixture of hydrocarbons. Gasolines are mixtures of hydrocarbons that contain 4 to 12 carbon atoms and have boiling points between 30 and 210 degrees Celsius. Kerosenes used for jet fuel contain hydrocarbons with 10 to 16 carbon atoms and have boiling points between 150 and 240. Diesel fuels and bunkering fuels contain hydrocarbons with higher numbers of carbon atoms and higher boiling points. In addition, diesel fuels and bunkering fuels have greater proportions of compounds containing heteroatoms.

Upon release, the hydrocarbons that are composed of fewer carbon and hydrogen atoms vaporize, leaving behind a heavier, less volatile fraction. Gasolines contain relatively high proportions of toxic and volatile hydrocarbons, such as benzene, which is known to cause cancer in humans, and hexane, which can affect the nervous system. Gasoline and kerosene releases are exceptionally hazardous due to their high flammability. Crude oils and semi-refined products, such as diesel and bunkering oils, may contain cancer-causing polycyclic aromatic hydrocarbons and other toxic substances.

#### Non-Petroleum Oils

EPA interprets the Clean Water Act definition of oil to include non-petroleum oils as well as petroleum and petroleum-refined products. Non-petroleum oils include synthetic oils, such as silicone fluids, tung oils, and wood-derivative oils, such as resin/rosin oils, animal fats and oil, and edible and inedible seed oils from plants.

Many non-petroleum oils have similar physical properties as petroleum-based oils; for example, their solubility in water is limited, they both create slicks on the surface of water, and they both form emulsions and sludges. In addition, non-petroleum oils tend to be persistent, remaining in the environment for long periods of time.

Like petroleum-based oils, non-petroleum oils can have both immediate and long-term adverse effects on the environment and can be dangerous or even deadly to wildlife. For example, non-petroleum oils can deplete available oxygen needed by aquatic organisms, foul
aquatic biota, and coat the fur and/or feathers of wildlife. For example, when a bird's plumage is coated with non-petroleum oil, their feathers lose their insulating properties, placing them at risk of freezing to death. Birds that are covered with non-petroleum oils also can smother embryos through the transfer of non-petroleum oil from the parents' plumage to the eggs. Birds and wildlife can ingest oil directly and may continue to ingest the oil as they eat if the source of their food consists of fish, shellfish, or vegetation that also are contaminated with non-petroleum oils. Other adverse effects of spilled non-petroleum oil on bird and wildlife include drowning, mortality by predation, dehydration, starvation, and/or suffocation.

2.3.18 MARPOL 73/78

All tankers, whether or not fitted with segregated or dedicated clean ballast tanks, will at some time have to perform operations for retention of oil residues on board as described in this Guide. These procedures will enable tankers to meet the relevant requirements of MARPOL 73/78.

Amended Regulation 9 of Annex I of MARPOL 73/78, which entered into force on 6th July 1993, states that any discharge into the sea of oil or oily mixtures from the cargo tank area of an oil tanker is prohibited except when all the following conditions are satisfied:

(i) "The tanker is not within a special area."

(ii) "The tanker is more than 50 nautical miles from the nearest land."

(iii) "The tanker is proceeding en route."

(iv) "The instantaneous rate of discharge of oil content does not exceed 30 litres per nautical mile."

(v) "The total quantity of oil discharged into the sea does not exceed for existing tankers 1/1 5,000 of the total quantity of the particular cargo of which the residue formed a part, and for new tankers 1/30,000 of the total quantity of the particular cargo of which the residue formed a part."

(vi) "The tanker has in operation an oil discharge monitoring and control system and a slop tank arrangement as required by Regulation 15 of this Annex."

The definitions of "new" and "existing" will be found in Regulations 1(6), 1(7), 1(26) & 1(27) of Annex I of MARPOL 73/78.

However, for ships delivered on or after 6th July 1993 and for all ships after 6th July 1998 or the date on which suitable oil filtering equipment is fitted, whichever is the earlier, oil or oily mixtures from machinery space bilges (excluding cargo pump room bilges) unless mixed with oil cargo residue may be discharged to sea when:

1. The ship is not within a special area.
2. The ship is proceeding en route.
3. The oil content of the effluent without dilution does not exceed 15 parts per million.
4. The ship has in operation:
a) for ships of 400grt and above, but less than 10,000grt, oil filtering equipment, approved by the administration, that will ensure that any oily mixture discharged into the sea after passing through the system has an oil content not exceeding 15 ppm.

b) for ships of 10,000grt and above, oil filtering equipment, and arrangements, approved by the administration, for an alarm and for automatically stopping any discharge of oily mixture when the oil content in the effluent exceeds 15 ppm.

Ships delivered before 6th July 1993 have been allowed a five year period of grace up until 6th July 1998, by which time they are required to comply with the above requirements. In the meantime, for ships delivered before 6th July 1993, oil or oily mixtures from machinery space bilges (excluding cargo pump room bilges) unless mixed with oil cargo residue may only be discharged to sea when:

1. The ship is not within a special area
2. The ship is more than 12 nautical miles from the nearest land
3. The ship is proceeding en route
4. The oil content of the effluent is less than 100 parts per million
5. The ship has in operation oily-water separating equipment approved by the administration.

Segregated ballast or clean ballast may be discharged at any time even when within 50 miles of the nearest land or within a special area.

The definitions of "segregated ballast" and "clean ballast" will be found in Regulations 1(17) & 1(16) respectively of Annex 1 of MARPOL 73/78.

Note: Irrespective of the requirements of the Convention, even stricter regulations, amounting to an absolute ban on the discharge of all oil regardless of type and quantity, exist in many territorial waters and most harbour areas.

2.3.19 Basic method assumptions

The procedures described in this section assume that the tanker is supplied with an oil/water interface detector, is using a stripping system, has at least one single slop tank or cargo tank designated as a slop tank, and is fitted with an oil content monitoring and control system. This is the basic arrangement required for retaining oil residues on board and applies to all crude oil or product tankers whether they are equipped with segregated or clean ballast tanks or not. However the appropriate steps in the basic method will only apply to vessels equipped with segregated ballast tanks on those occasions when it is necessary for them to water-wash cargo tanks, wash cargo lines or take on additional ballast in cargo tanks in accordance with MARPOL 73/78. Variations entailing more complex slop tank arrangements and the use of eductors are described in Section 3. Regulation 18 of Annex 1 of MARPOL 73/78 details pumping, piping and discharge arrangements required for oil tankers.
2.3.20 Sequence of procedures

a) On completion of discharge thoroughly drain cargo tanks and lines, including crude oil washing lines if appropriate.
b) Flush cargo lines and pumps, preferably to the slop tank, before taking on dirty ballast.
c) Wash cargo tanks and collect oily wash water in the slop tank.
d) Flush cargo lines.
e) Take on clean ballast.
f) Allow dirty ballast to settle.
g) Discharge, clean part of dirty ballast to sea beyond the 50 nautical mile limit from the nearest land whilst the ship is proceeding en route and outside special areas. (See Annex 1).
h) Strip "dirty" part of dirty ballast to slop tank.
i) Flush the stripping system to slop tank.
j) Settle and decant water from slop tank.
k) Flush lines and pumps.
l) Discharge clean ballast.
m) Dispose of residues from slop tank.

All operations involving the handling of oil or ballast should be recorded in the Oil Record Book.

2.3.21 Line draining and taking on dirty ballast

All cargo pumps and lines containing cargo should be drained and pumped ashore on completion of discharge. This includes cross connections between cargo lines, stripping lines and crude oil washing lines if applicable.

Any remaining cargo in the lines, which cannot be pumped ashore, should be drained into a separate tank or into the slop tank before ballasting begins.

Dirty ballast should then be taken on, and in the process all cargo lines should be flushed into an appropriate cargo tank or tanks. To prevent oil from leaking overboard by way of the sea suction when commencing to take ballast, pump room, line and tank valves are to be properly set and the pumps are to be running with a vacuum established on the sea line before the sea valves are opened. In order to establish this initial vacuum on the sea line, it is usually necessary to make a special effort such as bleeding gas from the pump housing and utilising stripping pumps or vacuum systems on the vapour line where such are available.

On ships, which are required to ballast, cargo tanks there may be a local requirement for dirty ballast to be loaded without hydrocarbon gas emission to atmosphere. This may entail simultaneous ballast loading and cargo discharging operations. In this case, the cargo pumps and lines to be used for loading the ballast should first be drained as described above and isolated by at least two valves. Ballast is then loaded concurrently with cargo discharge and the rest of the cargo pumps and lines drained and pumped ashore once discharge is completed. Cargo line flushing, as described above, can then be carried out once the ship has sailed and extra ballast loaded for the sea passage.
2.3.22 Tank washing

As required, cargo tanks should be water washed and washings continuously stripped to the slop tank. Care should be taken to ensure that wash water does not build up in the cargo tank.

It should be understood that the quantity of oil eventually discharged to the sea can be minimised by eliminating unnecessary washing and recirculating the wash water, thus reducing the quantity of water brought into contact with oil within the tanker. As the clean ballast will be discharged within territorial waters it is imperative that the tanks in which it is carried are sufficiently clean to ensure that the content of the effluent does not exceed 15ppm.

2.3.23 Loading clean ballast

Before starting to load clean ballast make sure that the main cargo pumps and lines to be used are clean by further flushing into a suitable dirty ballast or slop tank.

2.3.24 Settling of dirty ballast

A good oil/water separation of the dirty ballast takes time and is dependent upon the movement of the ship as well as on the type of oil cargo previously carried. Under favourable conditions it may take no more than 12 hours, but in many circumstances 24 hours or more are needed to achieve optimum results.

2.3.25 Disposal of dirty ballast

When settling is complete the ballast tanks will contain water, with an oil layer on top. The bulk of this water may be discharged to the sea, using the oil content monitor, and preferably when the ship is not rolling or pitching.

The following procedures should be adopted during the discharge of ballast water in order to ensure optimum effectiveness of the oil content monitor. Their application will also ensure that the oil content of any discharge is restricted within permitted limits in the event of failure of the oil discharge monitoring and control system.

a) If necessary flush main cargo lines and pumps into a dirty ballast tank or slop tank.
b) Start to discharge dirty ballast water.
c) Reduce discharge rates from individual tanks as the level approaches a water depth of about 20 per cent of the tank depth.
d) Thereafter reduce pumping rates to avoid drawing surface oil into the suction by vortex or weir effects.
e) Stop discharge of individual tanks when a level has been reached which, for the particular ship, is known not to give rise to any entrainment of oil. When all tanks have been discharged to this level all discharge must cease.

At this stage the officer in charge should verify that the slop tank can take the volume of dirty ballast remaining. If ullage is insufficient, the slop tank may be partially discharged, utilising the oil content monitor, to provide the necessary capacity, taking care to ensure that an adequate depth of water remains beneath the oil residue layer. The operation should then continue as follows:
a) Start transferring the remaining dirty ballast into the slop tank using the stripping system.
b) Transfer to the slop tank the contents of the pump room bilges and any other bilges connected to the cargo stripping system.
c) Flush the stripping system, which will then be dirty, into the slop tank.

2.3.26 Slop tank discharge

All decanting should be carried out utilising the oil discharge monitoring and control system, and the following procedures should be adopted in order to ensure optimum effectiveness of the oil content monitor. These procedures will also ensure that the oil content of any discharge is restricted within permitted limits in the event of failure of the oil discharge monitoring and control system.

Decanting of the contents of the slop tank is a critical step in the retention of oil on board and the timing of the various steps in the operation is important. As with dirty ballast, the time required for oil and water to separate in the slop tank depends upon the motion of the ship as well as on the type of previous cargo. Under favourable conditions a few hours may be enough, but in most circumstances 36 hours or more should be allowed.

Before starting, an accurate interface and ullage reading must be taken, using an oil/water interface detector, to determine the depth of the oil layer. (Certain products may accumulate an electrostatic charge, which must be allowed to dissipate before taking interface readings. Strict adherence to internationally accepted safety precautions in ullage reading and sampling is therefore essential.)

The interface profile may vary in depth. Hence discharge from the slop tank must cease well before the interface is reached.

Although every effort should be made to remove as much water as possible from the slop tank, the prime objective is to prevent oily water reaching the sea. Extreme care is therefore necessary, and a close check must be kept on the overboard discharge even with the automatic control system in operation.

Agitation of the contents of the slop tank must be kept to a minimum to avoid drawing oil into the suction by vortex or weir effects, particularly as the oil/water interface approaches the top of the structural members in the tank bottom. Pumping rates must be strictly controlled. The following detailed procedures should be adhered to:

a) Pump down the slop tank using one main cargo pump at slow speed until a water sounding of about 20 per cent of the tank is reached.
b) Stop the cargo pump, then take an oil/water interface and ullage reading and recalculate the remaining water depth.
c) Resume pumping of the slop tank, this time using the stripping system, until a predetermined water depth is reached which, for the particular size and construction of the slop tank, is known not to give rise to discharge of oil. Pumping, which may initially be at a moderate rate, should be slowed as this predetermined water depth is approached.
d) If oil should appear before the predetermined water depth is reached, or the oil discharge monitoring and control system automatically stops the discharge on exceeding the permitted limits, stop pumping.
e) Should pumping have to be stopped, further settling of the slop tank contents should be allowed for as long as possible before repeating steps (c) and (d).
f) No decanting must take place beyond the predetermined water depth if there is any doubt whether the oil discharge monitoring and control system, which
automatically prevents any discharge into the sea of effluent in excess of the permitted instantaneous rate of discharge of oil, is functioning correctly.
2.3.27 Discharging clean ballast

Only clean ballast or segregated ballast may be discharged within 50 miles of the nearest land or within a special area. In addition, local regulations should be checked in advance to ensure that the discharge of clean ballast is permitted in port areas.

MARPOL 73/78 provides that clean ballast discharged through an oil discharge monitoring and control system is accepted as being clean, notwithstanding the presence of visible traces of oil, as long as the oil content of the discharge is recorded by the equipment as being not more than 15 parts per million.

Even with the oil discharge monitoring and control system operating, the ballast outlet should be watched, particularly when draining a tank bottom, as this is the most likely time for oil to be picked up. If this happens discharge must be stopped immediately and the remaining contents of the tanks stripped to the slop tank. Ballast water discharged from segregated ballast tanks should be visually checked prior to and during discharge for the presence of any oil.

2.3.28 Disposal of slop residues

Before reaching the loading part the master should advise his owners or charterers of the amount of retained residues on board. These may then be handled in one of the following ways:

a) By pumping the residues ashore at the loading terminal.
b) By retaining the residues on board and loading the new cargo on top of them (but see below).
c) By retaining the residues on board, but segregated from the new cargo. If this is done, it may be possible to pump them ashore at the discharge terminal, if reception facilities are available. It may, however, be necessary to retain the residues for more than one voyage.

With cargoes other than crude oil, the need for product quality may inhibit the mixing of residues with the next cargo. The alternative in the proceeding sub-paragraph (b) is then not possible, and residues must either be discharged to reception facilities at the loading port, or retained on board for disposal ashore at a subsequent port. After carrying certain clean oil cargoes (e.g. products containing lead), it may be necessary to keep residues recovered from such cargoes segregated from residues recovered from other tanks.

The disposal of oil residues containing lead compound (present in some refined oil products) or certain other compounds (sometimes present in tank cleaning chemicals) entails a special treatment which is not always available at reception facilities. The master should then seek guidance from the owners or charterers on the disposal of residues containing these contaminants.

2.3.29 Handling sludge

Only small quantities of sludge should remain in the cargo tanks after machine washing. Should areas of heavy sludge build-up be found after initial tank washing, they are better dealt with by specially located tank washing machines and re-washing with very hot water than by resorting to hand lifting. In this manner much of the sand, scale, sediment and oil can be transferred to the slop tank, thereby minimising removal by hand.
The remaining sludge that is found after efficient cleaning is composed principally of scale, sand, water, wax and sediments of various kinds. When sludge containing oil or oil residues is recovered by hand, the material should be retained on board in suitable containers and disposed of ashore.

2.3.30 Segregated ballast tankers

Under MARPOL 73/78 all new crude oil tankers of 20,000 dwt and over and all new product tankers of 30,000 dwt and over, as defined in Regulation 1(26) of Annex 1, are required to have segregated ballast tanks with protective location (SBT/PL) of sufficient capacity to allow them to operate safely on ballast voyages without having to carry additional ballast in cargo tanks. Such tankers are commonly referred to as "MARPOL tankers".

All older, or "pre-MARPOL", product tankers of 40,000 dwt and over must operate with either SBT or dedicated clean ballast tanks (CBT).

All older, or "pre-MARPOL", crude oil tankers of 40,000 dwt and over must operate with either SBT or with a crude oil washing (COW) system.

Water ballast may be carried in cargo tanks of SBT tankers only on voyages when weather conditions are so severe that, in the opinion of the master, it is necessary to take on additional ballast water in cargo tanks for the safety of the ship. Ballast may also be carried in the cargo tanks of SBT tankers in any of the following exceptional circumstances:

a) When combination carriers are required to operate beneath loading/unloading gantries;
b) When oil tankers are required to pass under a low bridge;
c) When local port or canal regulations require specific draughts;

In the case of SBT crude oil tankers, the additional ballast permitted for any of the reasons outlined above may be carried in cargo tanks only if such tanks have been crude oil washed before departure from the unloading part or terminal.

If it does prove necessary to ballast cargo tanks on any of the above grounds, or if it is necessary to clean such tanks for inspection and/or repair, then the dirty ballast, oil residues, sludge and tank washing water must be handled in accordance with the procedures set out in the foregoing basic method or wholly retained on board for discharge to reception facilities.

2.3.31 Dedicated clean ballast tankers

Under MARPOL 73/78 "pre-MARPOL" product tankers of 40,000 dwt and over are allowed to designate certain cargo tanks for carrying ballast only (CBT). This arrangement, when operated in accordance with the ship's CBT manual, will also avoid the need to mix oil and water in ballast tanks.

If it does prove necessary to ballast cargo tanks on the grounds of safety, or if it is necessary to clean such tanks for inspection and/or repair, then the dirty ballast, oil residues, sludge and tank washing water must be handled in accordance with the procedures set out in the foregoing basic method or wholly retained on board for discharge to reception facilities.
2.3.32 New MARPOL Annex I regulations 13f and 13g prevention of oil pollution in event of collision or stranding

Under new Regulation 13F of Annex 1 of MARPOL 73/78, all new oil tankers over 5,000 dwt, as defined in regulation 13F(1), are required to be built with double hulls or other equivalent design, as approved by the IMO, for preventing oil pollution in the event of collision or grounding. All new oil tankers of between 600 and 5,000 dwt are required to be built with double bottoms.

Under new Regulation 13G of Annex 1 of MARPOL 73/78, which takes effect on 6th July 1995, all existing crude oil tankers of 20,000 dwt and above and all existing product tankers of 30,000 dwt and above have to comply with measures, which are designed to reduce oil pollution in the event of collision or stranding. The requirements regarding such measures are dependent on the ship's age. 25 years after its date of delivery, an existing oil tanker will have to have double bottom or ballast tank protection covering at least 30% of the cargo side or cargo bottom area or be withdrawn from service. Other structural or operational arrangements may be accepted provided they are approved and offer at least the same protection against oil pollution in the event of collision or stranding. Existing oil tankers, on reaching 30 years of age, must comply fully with the requirements of Regulation 13F or be withdrawn from service.

2.3.33 Crude oil washing

Under MARPOL 73/78 all "MARPOL" crude oil tankers of 20,000 dwt and over are required to be equipped with a crude oil washing (COW) system. All "pre-MARPOL" crude oil tankers of 40,000 dwt and over must operate with a COW system unless they are fitted with SBT.

The purpose of COW is to:

- a) Reduce the amounts of oil in any departure ballast loaded into cargo tanks.
- b) Reduce the amount of water washing required in those cargo tanks intended for ballast.
- c) Provide effective sludge control.

The provisions of MARPOL 73/78 require a tanker using COW to carry an approved Operations and Equipment Manual, the guidance in which should be followed at all times. In principle, however, the use of COW does not change the procedures for handling dirty ballast, oil residues, sludge and tank washing water set out under the basic method in this section.

2.3.34 Special areas

If a tanker's passage between the discharge port and the next loading port lies wholly within a special area, no discharge associated with the retention of oil residues is permitted.

If only a part of a tanker's passage between the discharge port and the next loading port lies within a special area, then any discharge associated with the retention of oil residues must be restricted to that part of the passage which lies outside the special area, and which itself is more than 50 nautical miles from the nearest land.
2.3.35 OBO and Ore/Oil carriers

For the purpose OBO and Ore/Oil carriers when engaged in the carriage of oil can be considered as tankers, and therefore in the main the basic method of retention applies to them. However, these ships are generally equipped with two interconnected slop tanks. OBO and Ore/Oil carriers transferring from oil to dry bulk trades are obliged to clean the entire cargo system. Various means for the disposal of the resulting oil residues may be considered:

a) All residues are retained on board, and discharged to reception facilities at the dry bulk loading port.
b) If reception facilities are not available at the loading port then a deviation can be made to a port where these facilities exist.
c) If (a) and (b) are not possible, all residues are retained on board in a special slop tank.
d) The ship is cleaned before departure from the oil discharge port and all washings and residues are discharged to reception facilities.

Operators of OBO and Ore/Oil carriers are particularly reminded of safety regulations in some dry bulk cargo loading and discharging ports relating to ships with oil residues on board.

2.3.36 Reception facilities

MARPOL 73/78 calls for the provision of reception facilities for oil residues in certain categories of port, including:

a) All ports and terminals in which crude oil is loaded into oil tankers where such tankers have immediately prior to arrival completed a ballast voyage of not more than 72 hours or not more than 1,200 miles;
b) All ports and terminals in which oil other than crude oil in bulk is loaded at an average quantity of more than 1,000 metric tons per day;
c) All ports having ship repair yards or tank cleaning facilities;
3 SAFETY

(STCW Code, section A-V/1 paragraph 12/13)

Learning Objectives:
On completion of this section the trainee should have a good knowledge of:
Entry into enclosed spaces
Precautions against electrostatic hazards
Gas indicators
Fire-fighting principles
Protective equipment
Tank evacuation equipment
Resuscitation equipment

3.1 GENERAL PRECAUTIONS

In order to eliminate the risk of fire and explosion on a tanker, it is necessary to avoid a source of ignition and a flammable atmosphere being present in the same place at the same time. It is not always possible to exclude both these factors and precautions are therefore directed towards excluding or controlling one of them.

In the case of cargo compartments, pump rooms, and at times the tank deck, flammable gases are to be expected and the strict elimination of all possible sources of ignition in these locations is essential.

Cabins, galleys and other areas within the accommodation block inevitably contain ignition sources such as electrical equipment, matches and cigarette lighters. While it is sound practice to minimize and control such sources of ignition, it is essential to avoid the entry of flammable gas.

In engine and boiler rooms, ignition sources such as those arising from boiler operations and electrical equipment cannot be avoided. It is therefore essential to prevent the entry of flammable gases into such compartments. The contamination of bunker fuel by volatile cargo through bulkhead leaks; pipeline mixture or any other cause will introduce an additional danger.

The routine checking of bunker spaces for flammability by tanker and terminal personnel is therefore to be encouraged.

It is possible, by good design and operational practice, for both flammable gases and ignition sources to be safely controlled in deck workshops, store rooms, forecastle, centre castle, dry cargo holds etc. The means for such control must, however, be rigorously maintained. In this connection it should be realized that an additional danger would be introduced into such areas by the contamination of bunker tanks with volatile cargo.

Although the installation and the correct operation of an inert gas system provides an added measure of safety, it does not preclude the need for close attention to the precautions set out in this chapter.

3.1.1 Smoking at Sea

While a tanker is at sea, smoking should be permitted only at times and in places specified by the master. Smoking must be prohibited on the tank deck or any other place where petroleum gas may be encountered.
3.1.2 Matches and Cigarette Lighters
The use of matches and cigarette lighters outside accommodation spaces should be prohibited, except in places where smoking is permitted. Personnel should not take matches and cigarette lighters outside these places, nor should they be carried on the tank deck or in any other place where petroleum gas may be encountered. The risk involved in carrying matches, and more particularly cigarette lighters, should be impressed on all personnel. Matches used on board should only be of the ‘safety’ type.

3.1.3 Naked Lights (Open Flame)
Naked lights must be prohibited on the tank deck and in any other place where there is a risk that petroleum gas may be present.

3.1.4 Notices
Portable and permanent notices prohibiting smoking and the use of naked lights should be conspicuously displayed at the point of access to the vessel and at the exits from the accommodation area. Within the accommodation area, instructions concerning smoking should be conspicuously displayed.

3.1.5 Galley
It is essential that galley personnel be instructed in the safe operation of galley equipment. Unauthorized and inexperienced persons should not be allowed to use such facilities. A frequent cause of fires is the accumulation of unburnt fuel or fatty deposits in galley ranges, within flue pipes and filter cowls of galley vents. Such areas require frequent inspection to ensure that they are maintained in a clean condition. Oil and deep fat fryers should be fitted with thermostats to cut off the electrical power and so prevent accidental fires. Galley staff should be trained in handling fire emergencies. The appropriate fire extinguishers and fire blankets should be provided.

3.1.6 Portable lamps and electrical equipment
All portable electrical equipment including lamps should be approved by a competent authority and must be carefully examined for possible defects before being used. Special care should be taken to ensure that the insulation is undamaged and that cables are securely attached and will remain so while the equipment is in use. Special care should also be taken to prevent mechanical damage to flexible cables (wandering leads).

3.1.7 Lamps and Other Electrical Equipment on Flexible Cables
The use of portable electrical equipment on wandering leads should be prohibited within cargo tanks and adjacent spaces, or over the tank deck, unless throughout the period the equipment is in use:

- The compartment within which or over which the equipment and the lead are to be used is safe for hot work and
• The adjacent compartments are also safe for hot work, or have been purged of hydrocarbon to less than 2% by volume and inerted, or are completely filled with ballast water, or any combination of these, and

• All tank openings to other compartments not safe for hot work or purged as previous point are closed and remain so; or

• The equipment, including all wandering leads, is intrinsically safe; or

• The equipment is contained within an approved explosion-proof housing. Any flexible cables should be of a type approved for extra hard usage, have an earth conductor, and be permanently attached to the explosion-proof housing in an approved manner.

In addition there are certain types of equipment, which are approved for use over the tank deck only.
The foregoing does not apply to the proper use of flexible cables used with signal or navigation lights or with approved types of telephones.

### 3.1.8 Hot work

Hot work is any work involving welding or burning, and other work including certain drilling and grinding operations, electrical work and the use of non-intrinsically safe electrical equipment, which might produce an incendive spark.

Hot work outside the main machinery spaces (and in the main machinery spaces when associated with fuel tanks and fuel pipelines) must take into account the possible presence of hydrocarbon vapours in the atmosphere, and the existence of potential ignition sources. Hot work should only be carried out outside the main machinery spaces if no other viable means of repair exists. Alternatives to be considered include cold work, or removal of the work piece to the main machinery spaces.

Hot work outside the main machinery spaces should only be permitted in accordance with prevailing national or international regulations and/or port/terminal requirements and should be subject to the restrictions of a shipboard hot work permit procedure.

Hot work for which a hot work permit is required should be prohibited during cargo, ballast, tank cleaning, gas freeing, purging or inerting operations.

#### Assessment of Hot Work

The master should decide whether the hot work is justifiable, and safe, and on the extent of the precautions necessary. Hot work in areas outside the main machinery spaces and other areas designated by the operator should not be proceeded with until the master has informed the operator’s shore office of details of the work proposed, and a procedure has been discussed and agreed.

Before hot work is started a safety meeting under the chairmanship of the master should be held, at which the planned work and the safety precautions should be carefully reviewed. The meeting should be attended at least by all those who will have responsibilities in connection with the work. An agreed plan for the work and the related safety precautions should be made. The plan must clearly and unambiguously designate one officer who is responsible for the supervision of the work, and another officer who is responsible for safety precautions including means of communication between all parties involved.

All personnel involved in the preparations and in the hot work operation, must be briefed and instructed in their own role. They must clearly understand which officer is responsible for work supervision and which for safety precautions. A written hot work permit should be
issued for each intended task. The permit should specify the duration of validity, which should not exceed a working day.

3.1.9 Preparations for Hot Work
All operations utilizing the cargo or ballast system, including tank cleaning, gas freeing, purging or inerting should be stopped before hot work is undertaken, and throughout the duration of the hot work. If hot work is interrupted to permit pumping of ballast or other operations using the cargo, venting or inerting system, hot work should not be re-started until all precautions have been re-checked, and a new hot work permit has been issued.
No hot work should be carried out on bulkheads of bunker tanks containing bunkers, or within 0.5 metres from such bulkheads.

3.1.10 Hot Work in Enclosed Spaces
A compartment in which hot work is to be undertaken should be cleaned and ventilated until tests of the atmosphere indicate 21% oxygen content by volume and not more than 1% LFL. It is important to continue ventilation during hot work.
Adjacent cargo tanks, including diagonally positioned cargo tanks, should either have been cleaned and gas freed to hot work standard, or cleaned and hydrocarbon vapour content reduced to not more than 1% by volume and kept inerted, or completely filled with water. Other cargo tanks, which are not gas free, should be purged of hydrocarbon vapour to less than 2% by volume and kept inerted and secured.
On a vessel without an inert gas system, all cargo tanks except tanks containing slops should be cleaned and gas freed. Slops should be placed in a tank as far as possible from the hot work area, and the tank kept closed.
Adjacent ballast tanks, and compartments other than cargo tanks, should be checked to ensure they are gas free and safe for hot work. If found to be contaminated by hydrocarbon liquid or vapours, the cause of the contamination should be determined and the tank(s) cleaned and gas freed.
All interconnecting pipelines to other compartments should be flushed through with water, drained, vented and isolated from the compartment where hot work will take place. Cargo lines may be subsequently inerted or completely filled with water if considered necessary. Vapour lines and inert gas lines to the compartment should also be ventilated and isolated. Heating coils should be flushed.
All sludge, cargo-impregnated scale, sediment or other material likely to give off vapour, which is flammable, should be removed from an area of at least 10 metres around the area of hot work.
Special attention must be given to the reverse sides of frames and bulkheads. Other areas that may be affected by the hot work, such as the area immediately below, should also be cleaned. An adjacent fuel oil bunker tank may be considered safe if tests using a combustible gas indicator give a reading of not more than 1% LFL in the ullage space of the bunker tank, and no heat transfer through the bulkhead of the bunker tank will be caused by the hot work.

3.1.11 Hot Work on the Open Deck
If hot work is to be undertaken on the open deck, cargo and slop tanks within a radius of at least 30 metres around the working area must be cleaned and hydrocarbon vapour content
reduced to less than 1% by volume and inerted. All other cargo tanks in the cargo area must be inerted with openings closed.

Adjacent ballast tanks, and compartments other than cargo tanks, should be checked to ensure they are gas-free and safe for hot work. If found to be contaminated by hydrocarbon liquid or vapours they should be cleaned and gas freed.

On a vessel without an inert gas system all cargo tanks except those containing slops, must be cleaned and freed of hydrocarbon vapour to less than 1% LFL. Tanks containing slops should be kept closed and be beyond 30 metres from the work area.

3.1.12 **Hot Work on Pipelines**

Hot work on pipelines and valves should only be permitted when the appropriate item has been detached from the system by cold work, and the remaining system blanked off. The item to be worked on should be cleaned and gas freed to a “safe for hot work” standard, regardless of whether or not it is removed from the hazardous cargo area. Heating coils should be flushed and opened to ensure that they are clean and free of hydrocarbons.

3.1.13 **Checks by Officer Responsible for Safety**

Immediately before hot work is started the officer responsible for safety precautions should examine the area where hot work is to be undertaken, and ensure that the oxygen content is 21% by volume and that tests with a combustible gas indicator show not more than 1% LFL. Adequate fire-fighting equipment must be laid out and be ready for immediate use. Fire watch procedures must be established for the area of hot work, and in adjacent, non-inerted spaces where the transfer of heat, or accidental damage, may create a hazard e.g. damage to hydraulic lines, electrical cables, thermal oil lines etc. Monitoring should be continued for sufficient time after completion of hot work. Effective means of containing and extinguishing welding sparks and molten slag must be established.

The work area must be adequately and continuously ventilated. The frequency of atmosphere monitoring must be established. Atmospheres should be re-tested after each break in work periods, and at regular intervals. Checks should be made to ensure there is no ingress of flammable vapours or liquids, toxic gases or inert gas from adjacent or connected spaces.

Welding and other equipment employed should be carefully inspected before each occasion of use to ensure it is in good condition. Where required it must be correctly earthed. Special attention must be paid when using electric-arc equipment ensuring:

- That electrical supply connections are made in a gas free space;
- That existing supply wiring is adequate to carry the electrical current demanded without overloading, causing heating;
- The insulation of flexible electric cables laid across the deck is in good condition;
- The cable route to the worksite is the safest possible, only passing over gas free or inerted spaces; and
- The earthing connection is adjacent to the work site with the earth return cable led directly back to the welding machine.
3.1.14 Permit to Work on a Tanker Berth

No construction, repair, maintenance, dismantling or modification of facilities should be carried out on a tanker berth without the permission of the terminal manager. If a tanker is moored at the berth, the agreement of the master should also be obtained by the terminal representative.

In all cases, except for routine work of a non-hazardous nature, this permission must be given in the written form of a permit to work.

3.1.15 Notices on the Tanker

On arrival at a terminal, a tanker should display notices at the gangway in appropriate languages stating:

```
WARNING
NO NAKED LIGHTS
NO SMOKING
NO UNAUTHORISED PERSONS
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Alternative wording containing the same warnings may also be used.

Photoluminescent notices stating “EMERGENCY ESCAPE ROUTES” (with directional signs) should also be displayed at appropriate locations.

In addition, notices are displayed on board tankers, which are primarily for the information of the crew. Shore personnel should also observe these requirements when on board the tanker.

3.2 Entry into Enclosed Spaces

Because of the possibility of oxygen deficiency, as well as the presence of hydrocarbon or toxic gas in a cargo tank, cofferdam, double bottom tank or any enclosed space, it is the master’s responsibility to identify such spaces and to establish procedures for safe entry.

Personnel should consult the responsible officer to determine whether entry into such enclosed spaces is permitted. It is the duty of the responsible officer to check the atmosphere in the compartment, ventilate the space, ensure the appropriate procedures are followed, ensure the safety of the personnel concerned, and issue an entry permit.

3.2.1 Pump rooms

Cargo pump rooms, by virtue of their location, design and operation, which require the space to be routinely entered by personnel, constitute a particular hazard and therefore necessitate special precautions. A pump room contains the largest concentration of cargo pipelines of any space within the ship and leakage of a volatile product from any part of this system could lead to the rapid generation of a flammable or toxic atmosphere. The pump room may also contain a number of potential ignition sources unless formal, structured maintenance, inspection and monitoring procedures are strictly adhered to.
Pump room bilges should be kept clean and dry. Particular care should be taken to prevent the escape of hydrocarbon liquids or vapour into the pump room.

It is important that the integrity of pipelines and pumps is maintained and any leaks are detected and rectified in a timely fashion. Pipelines should be visually examined and subjected to routine-pressure tests to verify their condition. Other means of non-destructive testing or examination, such as ultra-sonic wall thickness measurement, may be considered appropriate, but should always be supplemented by visual examination.

Procedures should be established to verify that mud boxes and filters are properly sealed after they have been opened up for routine cleaning or examination. Valve glands and drain cocks should be regularly inspected to ensure that they do not leak. Bulkhead penetrations should be routinely checked to ensure their effectiveness. The security of critical bolts on the cargo pumps and associated fittings, such as pedestal fixing bolts, pump casing bolts and bolts securing shaft guards, should be ensured. In addition, requirements for their examination should be included in routine maintenance procedures.

**Ventilation**

Because of the potential for the presence of hydrocarbon gas in the pump room, SOLAS (Chapter II-2, Regulation 59.3) requires the use of mechanical ventilation to maintain the atmosphere in a safe condition.

The pump room should be continuously ventilated during all cargo operations. Before anyone enters a pump room it should be thoroughly ventilated, the oxygen content of the atmosphere should be verified and the atmosphere checked for the presence of hydrocarbon and toxic gases. Ventilation should be continuous until access is no longer required or cargo operations have been completed.

**Pump room entry**

It is strongly recommended that operators develop procedures to control pump room entry, regardless of whether or not a fixed gas detection system is in use. Clear procedures should be established with regard to undertaking pre-entry checks, gas testing, and subsequent regular atmosphere monitoring.

In addition to detailing pre-entry checks, procedures should include the use of personal gas monitors for those entering the space. A communications system should provide links between the pump room, navigation bridge, engine room and cargo control room. In addition, audible and visual repeaters for essential alarm systems, such as the general alarm, should be provided within the pump room.

Arrangements should be established to enable effective communication to be maintained at all times between personnel within the pump room and those outside. Regular communication checks should be made at pre-agreed intervals and failure to respond should be cause to raise the alarm. The frequency of pump room entry for routine inspection purposes during cargo operations should be reviewed with a view to minimising personnel exposure.

Notices should be displayed at the pump room entrance prohibiting entry without permission. The pump room lifelines and harness should be rigged ready for immediate use. Where possible, an unobstructed direct lift should be provided.

**3.2.2 Cargo tanks entry**

An entry permit should be issued by a responsible officer prior to personnel entering an enclosed space. Suitable notices should be prominently displayed to inform personnel of the precautions to be taken when entering tanks or other enclosed spaces and of any restrictions placed upon the work permitted therein.
The entry permit should be rendered invalid if ventilation of the space stops or if any of the conditions noted in the checklist change.

3.2.3 Entry Procedures

No one should enter any cargo tank, cofferdam; double bottom or other enclosed space unless an entry permit has been issued by a responsible officer who has ascertained immediately before entry that the atmosphere within the space is in all respects safe for entry. Before issuing an entry permit, the responsible officer should ensure that:

- The appropriate atmosphere checks have been carried out, namely oxygen content is 21% by volume, hydrocarbon vapour concentration is not more than 1% LFL and no toxic or other contaminants are present.
- Effective ventilation will be maintained continuously while the enclosed space is occupied.
- Lifelines and harnesses are ready for immediate use at the entrance to the space.
- Approved positive pressure breathing apparatus and resuscitation equipment are ready for use at the entrance to the space.
- Where possible, a separate means of access is available for use as an alternative means of escape in an emergency.
• A responsible member of the crew is in constant attendance outside the enclosed space in the immediate vicinity of the entrance and in direct contact with a responsible officer. The lines of communications for dealing with emergencies should be clearly established and understood by all concerned.

• Know your limitations and the limitations of your equipment. Do not try to do more than you can. Don’t try to over extend the capabilities of your equipment.

• If you become drowsy or smell something or in any other way feel affected by vapours…. 

In the event of an emergency, under no circumstances should the attending crewmember enter the tank before help has arrived and the situation has been evaluated to ensure the safety of those entering the tank to undertake rescue operations.

Regular atmosphere checks should be carried out all the time personnel are within the space and a full range of tests should be undertaken prior to re-entry into the tank after any break. The use of personal detectors and carriage of emergency escape breathing apparatus are recommended.

3.3 PRECAUTIONS AGAINST ELECTROSTATIC HAZARDS

3.3.1 General precautions against electrostatic hazards

The most important countermeasure that must be taken to prevent an electrostatic hazard is to bond all metal objects together. Bonding eliminates the risk of discharges between metal objects, which can be very energetic and dangerous. To avoid discharges from conductors to earth, it is normal practice to include bonding to earth (earthing or grounding).
On ships, bonding to earth is effectively accomplished by connecting metallic objects to the metal structure of the ship, which is naturally earthed through the sea. Some examples of objects which might be electrically insulated in hazardous situations and which must therefore be bonded are:

1. Ship/shore hose couplings and flanges if more than one length of non-conducting hose or pipe is used in a string.
2. Portable tank cleaning machines.
3. Conducting manual ullaging and sampling equipment.
4. The float of a permanently fitted usage device if it lacks an earthing path through the metal tape.

The most certain method of bonding and earthing is by means of a metallic connection between the conductors. This method should be used whenever possible, although for electrostatic purposes an adequate bond can in principle be made using a material of intermediate conductivity.

Certain objects may be insulated during tanker operations, for example:
1. A metal object such as a can floating in a static accumulating liquid.
2. A loose metal object while it is failing in a tank during washing operations.

Every effort should be made to ensure that such objects are removed from the tank, since there is evidently no possibility of deliberately bonding them. This necessitates careful inspection of tanks, particularly after shipyard repairs.

3.3.2 Fixed Equipment in Cargo Tanks

Equipment permanently mounted from the top of a tank, such as fixed washing machines or high-level alarms, may act as isolated probes. A metal probe remote from any other tank structure but near a highly charged liquid surface will have a high voltage gradient at the probe tip. During the loading of static accumulator oils, this high voltage gradient may cause electrostatic discharges to the approaching liquid surface. An isolated probe configuration can be avoided by installing the device adjacent to a wall or other tank structure to reduce the voltage gradient at the probe tip. Alternatively, a support can be added running from the lower end to the tank structure so that the rising liquid meets an edge rather than the isolated tip of a probe. Another solution possible in some cases is to construct the probe-like device entirely of a non-conductive material. These measures are not necessary if the vessel is limited to crude, black oil service or the tanks are inerted.

3.3.3 Water Mists

The spraying of water into tanks, for instance during water washing, gives rise to electrostatically charged mist. This mist is uniformly spread throughout the tank being washed. The electrostatic levels vary widely from tank to tank, both in magnitude and in sign.
When washing is started in a dirty tank the charge in the mist is initially negative, reaches a maximum negative value, then goes back through zero and finally rises towards a positive equilibrium value. It has been found that, among the many variables affecting the level and polarity of charging, the characteristics of the wash water and the degree of cleanliness of the tank have the most significant influence. The electrostatic charging characteristics of the water are altered by recirculation or by the addition of tank cleaning chemicals, either of which may cause very high electrostatic potentials in the mist. Potentials are higher in large tanks than in small ones. The size and number of washing machines in a tank affect the rate of change of charge but they have little effect on the final equilibrium value.

The charged mist droplets created in the tank during washing give rise to an electrostatic field, which is characterised by a distribution of potential (voltage) throughout the tank space. The walls and structure are at earth (zero) potential; the space potential increases with distance from these surfaces and is highest at points furthest from them. The field strength, or voltage gradient in the space is greatest near the tank walls and structure, more especially where there are protrusions into the tank. If the field strength is high enough, electric breakdown occurs into the space, giving rise to a corona.

Because protrusions cause concentrations of field strength, a corona occurs preferentially from such points. A corona injects a charge of the opposite sign into the mist and is believed to be one of the main processes limiting the amount of charge in the mist to an equilibrium value. The corona discharges produced during tank washing are not strong enough to ignite the hydrocarbon gas/air mixtures that may be present.

Under certain circumstances, discharges with sufficient energy to ignite hydrocarbon gas/air mixtures can occur from unearthed conducting objects already within, or introduced into, a tank filled with charged mist. Examples of such unearthed conductors are a metal sounding rod suspended on a non-conducting rope or a piece of metal falling through the tank space. Primarily by induction, an unearthed conductor within a tank can acquire a high potential when it comes near an earthed object or structure, particularly if the latter is in the form of a protrusion. The unearthed conductor may then discharge to earth giving rise to a spark capable of igniting a flammable hydrocarbon gas/air mixture.

The processes by which unearthed conductors give rise to ignitions in a mist are fairly complex, and a number of conditions must be satisfied simultaneously before an ignition can occur. These conditions include the size of the object, its trajectory, the electrostatic level in the tank and the geometrical configuration where the discharge takes place.

As well as solid unearthed conducting objects, an isolated slug of water produced by the washing process may similarly act as a spark promoter and cause an ignition. Experiments have shown that high capacity, single nozzle fixed washing machines can produce water slugs, which, owing to their size, trajectory and duration before breaking up, may satisfy the criteria for producing incendive discharges. On the other hand, there is no evidence of such water slugs being produced.

Following extensive experimental investigations and using the results of long-term experience, the tanker industry has drawn up the tank washing guidelines. These guidelines are aimed at preventing excessive charge generation in mists and at controlling the introduction of unearthed conducting objects when there is charged mist in the tank.

Charged mists very similar to those produced during tank washing occur from time to time in partly ballasted holds of OBOs. Due to the design of these ships there may be violent mist generating impacts of the ballast against the sides of the hold when the ship rolls in even a moderate sea. The impacts also give rise to free flying slugs of water in the tank, so that if the atmosphere of the tank is flammable all the elements for an ignition are present. The most
effective counter-measure is to have tanks either empty or fully pressed up so that the violent wave motion in the tank cannot take place.

3.3.4 Steaming

Steaming can produce mist clouds, which may be electrostatically charged. The effects and possible hazards from such clouds are similar to those described for the mists created by water washing, but the introduction of steam can cause very much higher levels of charging than those produced by water washing. The time required to reach maximum charge levels is also very much less. Furthermore, although a tank may be almost free of hydrocarbon gas at the start of steaming, the heat and disturbance will often release gases and pockets of flammability may build up. For these reasons, steam should not be injected into cargo tanks where there is any risk of the presence of a flammable atmosphere.

3.3.5 Inert Gas

Small particulate matter carried in inert gas can be electrostatically charged. The charge separation originates in the combustion process and the charged particles are capable of being carried through the scrubber, fan and distribution pipes into the cargo tanks. The electrostatic charge carried by the inert gas is usually small but levels of charge have been observed well above those encountered with the water mists formed during washing. Because the tanks are normally in an inert condition, the possibility of an electrostatic ignition has to be considered only if it is necessary to inert a tank which already contains a flammable atmosphere or if a tank already inerted is likely to become flammable because the oxygen content rises as a result of ingress of air. Precautions are then required during dipping, ullaging and sampling.

3.3.6 Clothing and Footwear

A person who is highly insulated from earth by his footwear or the surface on which he is standing can become electrostatically charged. This charge can arise from physical separation of insulating materials caused, for instance, by walking on a very dry insulating surface (separation between the soles of the shoes and the surface) or by removing a garment. Experience over a very long period indicates that electrostatic discharges caused by clothing and footwear does not present a significant hazard in the oil industry. This is especially true in a marine environment where surfaces rapidly become contaminated by deposits of salt and moisture, which reduce electrical resistances, particularly at high humidities.

3.3.7 Dipping, ullaging and sampling

There is a possibility of discharges whenever equipment is lowered into cargo tanks within which there may be electrostatic charges either in the liquid contents or on water or oil mists or on inert gas particulates. If there is any possibility of the presence of a flammable hydrocarbon gas/air mixture, precautions must be taken to avoid incendive discharges throughout the system.

3.3.8 Equipment

If any form of dipping, ullaging or sampling equipment is used in a possibly flammable atmosphere where an electrostatic hazard exists or can be created, it is essential at all times to avoid the presence of an unearthed conductor. Metallic components of any equipment to be lowered into a tank should be securely bonded together and earthed to the ship before introduction and should remain earthed until after removal.
Equipment should be designed to facilitate earthing. For example, the frame holding the wheel on which a metal measuring tape is wound should be provided with a threaded stud to which a sturdy bonding cable is bolted. The stud should have electrical continuity through the frame to the metal measuring tape. The other end of the bonding cable should terminate in a spring-loaded clamp suitable for attachment to the rim of an ullage opening during use of the tape.

The suitability of equipment made wholly or partly of non-metallic components depends upon the conductivities of the materials employed and their manner of use. For example, in the case of non-conductors it is known that a significant electrostatic charge can be generated when a polypropylene rope runs rapidly through a PVC-gloved hand. For this reason only natural fibre ropes should be used for dipping, ullaging and sampling. Non-conducting materials may be acceptable in other circumstances — for example, a sample bottle holder made of a synthetic plastic — but those responsible for the provision of such equipment to ships must be satisfied that they are safe to use. It is essential in all cases that non-conducting components do not lead to the insulation of any metal components from earth.

A material of intermediate conductivity, such as wood or natural fibre, generally has sufficient conductivity intrinsically, or as a result of water absorption, to avoid the accumulation of electrostatic charge. There should be a leakage path to earth from such materials so that they are not totally insulated but this need not have the very low resistance normally provided for the bonding and earthing of metals. In practice, on ships such a path usually occurs naturally either by direct contact with the ship or by indirect contact through the operator of the equipment.

3.4 GAS INDICATORS

This part describes the principles, uses and limitations of portable instruments for measuring concentrations of hydrocarbon gas in inerted and non-inerted atmospheres, of other toxic gases and of oxygen. Certain fixed installations are also described. For all instruments reference should also be made to the manufacturer’s instructions.

3.4.1 Measurement of hydrocarbon concentration

The Catalytic Filament Combustible Gas (CFCG) Indicator is used for measuring hydrocarbon gas in air at concentrations below the lower flammable limit (LFL). The scale is graduated in % LFL. A CFCG Indicator must not be used for measuring hydrocarbon gas in inert atmospheres.

Two types of instrument are available commercially for measuring hydrocarbon gas concentrations in excess of the LFL or in oxygen deficient (inerted) atmospheres - the Non-Catalytic Heated Filament Gas Indicator and the Refractive Index Meter. The scale is graduated in % volume hydrocarbon gas.

3.4.2 Catalytic filament combustible gas indicator (CFCG)

Operating Principle

The sensing element of a CFCG indicator is usually a catalytic metal filament heated by an electric current. In some instruments the filament is replaced by a ceramic pellet with a catalyst but the mode of action is the same. When a mixture of hydrocarbon gas with air is drawn over the filament the gas oxidises on the hot filament and makes it hotter. This increases its resistance and the change of resistance provides a measure of the concentration of hydrocarbon gas in the mixture.
A simplified diagram of the electrical circuit of a CFCG indicator is shown above. It is a Wheatstone bridge with the sensor filament forming one arm of the bridge. The indicator is made ready for use by balancing the bridge with the filament at the correct operating temperature in contact with fresh air, so that the meter reading is zero. The increased resistance of the sensor filament brought about by combustion of the sample mixture throws the bridge out of balance and causes the meter to deflect by an amount proportional to the combustible gas concentration. The deflection is shown on a scale calibrated to read 0%-100% LFL. Some instruments incorporate additional circuitry to give a second, expanded, range 0%-10% LFL. To maintain consistent readings the voltage across the bridge must be kept constant and a control is provided for this purpose.

Another arm of the bridge consists of a second filament (compensator filament) identical with the sensor filament and the two are mounted close to each other in the instrument. The second filament, however, remains permanently in contact with pure air and the arrangement provides automatic compensation for the effect of ambient temperature changes on the instrument reading. The resistances in the other two arms of the bridge are made from an alloy, the electrical resistance of which is practically independent of temperature. In taking a measurement the manufacturer’s detailed instructions should be followed. After the
instrument has been initially set at zero with fresh air in contact with the sensor filament, a sample is drawn into the meter by means of a rubber aspirator bulb or a pump. The reading is taken when the pointer has ceased to rise on the scale.

The out-of-balance voltage across the meter is proportional to hydrocarbon concentration up to 2-3 times the LFL although a reading cannot go beyond 100% LFL. If the concentration is more than about twice the LFL there is insufficient oxygen in the mixture to burn the hydrocarbon gas completely. The response of the instrument to such a concentration is that the needle initially deflects to the maximum on the scale and then falls back to a reading near zero. Continuous observation of the needle is necessary to avoid overlooking this kind of response. Prolonged operation with such a gas mixture causes the deposition of carbonaceous matter on the sensor filament and may alter the response of the instrument. In such cases the response of the instrument should be checked.

For the same reason the instrument does not give a reliable reading with atmospheres deficient in oxygen, such as those in inducted tanks. The meter must not be used for measuring hydrocarbon concentrations in inducted tanks.

Non-hydrocarbon gases, such as hydrogen sulphide or carbon monoxide, or gases from lead compounds, which may be present in a tank atmosphere can affect the meter response, but only if they are present in very high concentrations.

The instrument is normally fitted with a filter to remove solid particles and liquid. It will not indicate the presence of combustible mists (such as lubricating oils) or dusts.
**Instrument Check Procedures**

The instrument is set up to read correctly in the factory using a hydrocarbon gas/air mixture, the composition of which should be indicated on the label fixed to the instrument. The response should be checked at the beginning of every day during which it is intended to use the instrument. Such a check should also be made after replacing a filament. Test kits for use in the field are available for this purpose providing a mixture of hydrocarbon gas in air (such as 50% LFL butane in air). At intervals, the instrument should be checked more thoroughly in a laboratory equipped with suitable gas blending facilities. During operation it is important to check the instrument and sample lines occasionally for leakage, since the ingress of air would dilute the sample, giving false readings. Leak testing may be achieved by pinching the sample line and squeezing the aspirator bulb; the bulb should not expand as long as the sampling line is pinched.

**Precision of Measurement**

The response of the instrument depends upon the composition of the hydrocarbon gas and in practice this composition is not known. The calibration of the instrument is such that the response is usually on the safe side for the gases encountered in tanker operations. Factors that can affect the measurements are large changes in ambient temperature and excessive pressure of the tank atmosphere being tested, leading to high flow rates which in turn affect the filament temperature. To avoid the effect of gas flow rate, it is recommended practice to take a reading when there is no flow, i.e. between two squeezes of the rubber aspirator bulb. The use of dilution tubes, which enable catalytic filament indicators to measure concentrations in over rich hydrocarbon gas/air mixtures, is not recommended.

**Operational Features**

Only instruments fitted with flashback arresters in the inlet and outlet of the detector filament chamber should be used. The arresters are essential to prevent the possibility of flame propagation from the combustible chamber; a check should therefore always be made that they are fitted properly in their place. Some authorities require, as a condition of their approval, that PVC covers be fitted around meters with aluminium cases to avoid the risk of incendive sparking if the case impacts on rusty steel. When hydrocarbons are being measured no filters should be used other than the cotton filter inserted in the gas inlet of the detector to remove solid particles or liquid from the gas sample, although a water absorbent material or water trap may be necessary in the sampling line if the gas is very wet.

**3.4.3 Non-catalytic heated filament gas indicator**

**Operating Principle**

The sensing element of this instrument is a non-catalytic hot filament. The composition of the surrounding gas determines the rate of loss of heat from the filament, and hence its temperature and resistance. The sensor filament forms one arm of a Wheatstone bridge. The initial zeroing operations balance the bridge and establish the correct voltage across the filament, thus ensuring the correct operating temperature. During zeroing the sensor filament is purged with air or inert gas free from hydrocarbons. As in the CFCG indicator, there is a second identical filament in
another arm of the bridge, which is kept permanently in contact with air and acts as a compensator filament.
The presence of hydrocarbon changes the resistance of the sensor filament and this is shown by a deflection on the bridge meter. The rate of heat loss from the filament is a non-function of hydrocarbon concentration and the meter scale reflects this non-linearity. The meter gives a direct reading of % volume hydrocarbons.
The non-catalytic filament is not affected by gas concentrations in excess of its working scale.
The instrument reading goes off the scale and remains in this position as long as the filament is exposed to the rich gas mixture. In taking a measurement, the manufacturer’s detailed instructions should be followed. After the instrument has been initially set at zero with fresh air in contact with the sensor filament, a sample is drawn into the meter by means of a rubber aspirator bulb. The bulb should be operated until the meter pointer comes to rest on the scale (usually within 15-20 squeezes) then aspiring should be stopped and the final reading taken. It is important that the reading should be taken with no flow through the instrument and with the gas at normal atmospheric pressure.

**Instrument Check Procedures**
The checking of a non-catalytic heated filament instrument requires the provision of gas mixtures of a known total hydrocarbon concentration.
The carrier gas may be air, nitrogen or carbon dioxide or a mixture of these. Since this type of instrument may be required to measure accurately either low concentrations (1%-3% by volume) or high concentrations (greater than 10% by volume) it is desirable to have either two test mixtures, say 2% and 15% by volume, or one mixture between these two numbers, say 8% by volume. Gas mixtures may be obtained in small aerosol-type dispensers or small pressurized gas cylinders, or may be prepared in a special test kit.

**Precision of Measurement**
Correct response from these instruments is achieved only when measuring gas concentrations in mixtures for which the instrument has been calibrated and which remain gaseous at the temperature of the instrument.
Relatively small deviations from normal atmospheric pressure in the instrument produce significant differences in the indicated gas concentration. If a space, which is under elevated pressure, is sampled, it may be necessary to detach the sampling line from the instrument and allow the sample pressure to equilibrate with the atmosphere pressure.

### 3.4.4 Refractive index meter

**Operating Principle**
This is an optical device depending on the difference between the refractive indices of the gas sample and air.
In this type of instrument a beam of light is divided into two, and these are then recombined at the eyepiece. The recombined beams exhibit an interference pattern, which appears to the observer as a number of dark lines in the eyepiece.
One light path is through chambers filled with air. The other path is via chambers through which the sample gas is pumped. Initially the latter chambers are filled with air and the instrument is adjusted so that one of the dark lines coincides with the zero line on the instrument scale. If a gas mixture is then pumped into the sample chambers the dark lines are displaced across the scale by an amount proportional to the change of refractive index. The displacement is measured by noting the new position on the scale of the line, which was used
initially to zero the instrument. The scale may be calibrated in concentration units or it may be an arbitrary scale whose readings are converted to the required units by a table or graph. The response of the instrument is linear and a one point test with a standard mixture at a known concentration is sufficient for checking purposes. The instrument is normally calibrated for a particular hydrocarbon gas mixture. As long as the use of the instrument is restricted to the calibration gas mixture it provides accurate measurements of gas concentrations.

The measurement of the concentration of hydrocarbon gas in an inerted atmosphere is affected by the carbon dioxide present when flue gas is used for inerting. In this case the use of soda lime as an absorbent for carbon dioxide is recommended, provided the reading is corrected appropriately. The refractive index meter is not affected by gas concentrations in excess of its scale range. The instrument reading goes off the scale and remains in this position as long as the gas chambers are filled with the gas mixture.

**Instrument Check Procedures**
A mixture of known hydrocarbon, e.g. butane in nitrogen at a known concentration, should be used to check the instrument. If the hydrocarbon test gas differs from the original calibration gas the indicated reading should be multiplied by the appropriate correction factor before judging the accuracy and stability of the instrument.
3.4.5 Measurement of low concentrations of toxic gases

Probably the most convenient and suitable equipment to use for measuring very low concentrations of toxic gases on board tankers is chemical indicator tubes. These consist of a sealed glass tube containing a proprietary filling which is designed to react with a specific gas and to give a visible indication of the concentration of that gas. To use the device the seals at each end of the glass tube are broken, the tube is inserted in a bellows-type fixed volume displacement hand pump, and a prescribed volume of gas mixture is drawn through the tube at a rate fixed by the rate of expansion of the bellows. A colour change occurs along the tube and the length of discolouration, which is a measure of the gas concentration, is read off a scale integral with the tube. In some versions of these instruments a hand operated injection syringe is used instead of a bellows pump.

It is important that all the components used for any measurement should be from the same manufacturer. It is not permissible to use a tube from one manufacturer with a hand pump from another manufacturer. It is also important that the manufacturer’s operating instructions should be carefully observed.

Since the measurement depends on passing a fixed volume of gas through the glass tube, if an extension hose is used it should be placed between the glass tube and the hand pump. The tubes are designed and intended to measure concentrations of gas in the air. Thus measurements made in a ventilated tank, in preparation for tank entry, should be reliable. Under some circumstances errors can occur if several gases are present at the same time, as one gas can interfere with the measurement of another. The manufacturer should be consulted for guidance.

For each type of tube the manufacturers must guarantee the standards of accuracy laid down in national standards. Tanker operators should consult the regulatory authority appropriate for the ship’s flag.

3.4.6 Measurement of oxygen concentrations

Oxygen analysers are normally used to determine whether an atmosphere, for example inside a cargo tank, may be considered fully inerted or safe for entry. The fixed types of analysers are used for monitoring the oxygen content of the boiler uptakes and the inert gas main.

The following are the most common types of oxygen analysers in use:

- Paramagnetic sensors.
- Electrolytic sensors.
- Selective chemical absorption liquids.

All analysers regardless of type should be used strictly in accordance with the manufacturer’s instructions. If so used, and subject to the limitations listed below, the analysers may be regarded as reliable.
3.4.7 Use of oxygen analysers

Paramagnetic Sensors
Oxygen is strongly paramagnetic whereas most other common gases are not. This property therefore enables oxygen to be determined in a wide variety of gas mixtures.

One commonly used oxygen analyser of the paramagnetic type has a sample cell in which a lightweight body is suspended in a magnetic field. When sample gas is drawn through the cell the suspended body experiences a torque proportional to the magnetic susceptibility of the gas. An equal and opposing torque is produced by an electric current passing through a coil wound round the suspended body. The equalizing current is a measure of the magnetic force and is thus a measure of the magnetic susceptibility of the sample, i.e. related to its oxygen content. Before use the analyser should be calibrated, using nitrogen or carbon dioxide to purge the sample cell for a zero check and with air at 21% oxygen for span.

The analyser readings are directly proportional to the pressure in the measuring cell. The unit is calibrated to a specific atmospheric pressure and the small error due to atmospheric pressure variations can be corrected if required. Reading errors can be more significant during pressure variations using some gas sampling arrangements, but can be avoided by reducing the sampling pressure to atmospheric during readings. Continuous samples should be supplied to the instrument by positive pressure. They should not be drawn through the analyser by negative pressure as the measuring pressure then becomes uncertain.

The filter should be cleared or replaced when an increase in sample pressure is required to maintain a reasonable gas flow through the analyser. The same effect is produced if the filter becomes wet due to insufficient gas drying. The need for filter cleaning or replacement should be checked regularly.
Electrolytic Sensors
Analysers of this type determine the oxygen content of a gas mixture by measuring the output of an electrolytic cell. In one common analyser, oxygen diffuses through a membrane into the cell causing current to flow between two special electrodes separated by a liquid or gel electrolyte. The current flow is related to the oxygen concentration in the sample, and the scale is arranged to give a direct indication of oxygen content. The cell may be housed in a separate sensor head connected by cable to the read-out unit. The analyser readings are directly proportional to the pressure in the measuring cell but only small errors are caused by normal variations in atmospheric pressure. Certain gases may affect the sensor and give rise to false readings. Sulphur dioxide and oxides of nitrogen interfere if they are present in concentrations of more than 0.25% by volume. Mercaptans and hydrogen sulphide can poison the sensor if their levels are greater than 1% by volume. This poisoning does not occur immediately but over a period of time; a poisoned sensor drifts and cannot be calibrated in air. In such cases reference should be made to the manufacturer’s instructions.

Selective Chemical Absorption Liquids
In this type of analyser, a known volume of sample gas in brought into contact with a liquid, which absorbs oxygen, causing a volume change in the liquid. The relationship of this volume change to the original volume is a measure of the oxygen content of the sample. The use of this type of analyser for checking the condition of the ullage space in a loaded compartment is not recommended, because of the effect of high concentrations of hydrocarbon gases on the reagents.

Maintenance, Calibration and Test Procedures
As these analysers are of vital importance, they should be carefully maintained and tested strictly in accordance with the manufacturer’s instructions. It is essential that each time an instrument is to be used, a check is made of batteries (if fitted), zero setting and calibration. During use frequent checks should be made to ensure accurate readings are obtained at all times. Calibration is simple on all analysers, using atmospheric air as standard. Zero calibration can be checked with nitrogen or carbon dioxide.

3.4.8 Personal Oxygen Monitors
Personal oxygen monitors who are capable of continuously measuring the oxygen content of the atmosphere are available. These monitors employ an electrolytic sensor. They should automatically provide an audible and visual alarm when the atmosphere becomes deficient in oxygen so as to give the wearer adequate warning of unsafe conditions. The monitors should be tested at regular intervals.

3.4.9 Gas Sample Lines
The material and condition of sample lines can affect the accuracy of gas measurements. Metal tubes are unsuited to most cargo tank gas measurements and flexible lines must be used. The gases from crude oils and many petroleum products are composed essentially of paraffinic hydrocarbons and there are a number of suitable materials available for flexible sample tubing. The problem of material selection is more difficult for those gases containing substantial proportions of aromatic hydrocarbons, in particular xylene. It is recommended that
in such cases suppliers of sample tubing should be asked to provide test data showing the suitability of their product for the purposes for which it will be employed. Sample tubing must be resistant to water. Sample tubing which is cracked or blocked, or which has become contaminated with cargo residues, greatly affects instrument readings. Users should check the condition of the tubing regularly and replace defective tubing.

3.4.10 Sampling Procedures

Every tank has ‘dead spots’ where the rate of change of gas concentration during ventilation or purging is less than the average in the bulk of the tank. The location of these dead spots depends on the positions of the inlet and outlet through which ventilating air or inert gas is admitted and expelled and also on the disposition of the structural members in the tank. Generally, but not invariably, the dead spots are to be found within the tank bottom structure. The sample line must be long enough to permit sampling in the bottom structure. The differences in gas concentration between the bulk volume of the tank and the dead spots vary depending on the operating procedures in use. For example, the powerful water jets produced by fixed washing machines are excellent mixing devices, which tend to eliminate major differences in gas concentration between one location in the tank and another. Similarly, the introduction of ventilating air or inert gas as powerful jets directed downwards from the deck-head produces good mixing and minimises variations in concentration.

3.5 FIRE-FIGHTING PRINCIPLES – REVISION

Theory of fire fighting
Fire requires a combination of fuel, oxygen and a source of ignition. Most combustible or flammable substances, some only when heated, give off gas, which burns if ignited when mixed with an appropriate quantity of oxygen, as in air. Fires can be controlled and extinguished by the removal of heat, fuel or air. The main aim when fighting fires must therefore be to reduce the temperature or to remove the fuel or to exclude the supply of air with the greatest possible speed.

3.5.1 Types of fire

Combustible Material Fires
Examples of such fires are bedding, clothing, cleaning rags, wood, canvas, rope and paper fires. Cooling by large quantities of water, or the use of extinguishing agents containing a large proportion of water, is of primary importance when fighting fires of such ordinary combustible material. Cooling the source and surrounding area should continue long enough to prevent any possibility of re-ignition.

Liquid Petroleum Fires
Foam is an efficient agent for extinguishing most liquid petroleum fires. It should be applied so as to flow evenly and progressively over the burning surface, avoiding undue agitation. This can best be achieved by directing the foam jet against any vertical surface adjacent to the fire, both in order to break the force of the jet and to build up an unbroken smothering blanket. If there is no vertical surface the jet should be advanced in oscillating sweeps with the wind, taking care to avoid plunging it into the liquid. Foam spray streams, while limited in range, are also effective. Volatile oil fires of limited size can be extinguished by water fog or water spray. Dry chemical powder or vaporising halon liquids are also effective in dealing with such fires.
Non-volatile oil fires, which have not been burning for too long, can be extinguished by water fog or water spray if the whole of the burning surface is accessible. The surface of the liquid transfers its heat rapidly to the water droplets, which present a very large cooling surface, and the flame can be extinguished with advancing and oscillating sweeps of fog or spray across the whole width of the fire. Any oil fire, which has been burning for some time, is more difficult to extinguish with water, since the oil will have been heated to a progressively greater depth and cannot readily be cooled to a point where it ceases to give off gas. Furthermore, the use of a water jet may spread the burning oil by splashing or overflow. Spreading can also occur through agitation of the oil caused by violent boiling of water. Water should only be applied to oil fires as a spray or fog, although jets of water can play a valuable role in cooling hot bulkheads and tank walls. The best way of dealing with such fires in tanks is by means of a smothering agent, such as foam, carbon dioxide, or in some cases dry chemical, coupled if possible with sealing off the tank and cooling adjacent areas or spaces. The risk of re-ignition of a liquid petroleum fire must be borne constantly in mind. Having extinguished such a fire, a watch should be maintained and fire-fighting equipment and personnel kept in a state of immediate readiness.

Liquefied Petroleum Gas Fires
Fires involving escaping liquefied petroleum gas should, where possible, be extinguished by stopping the gas flow. If the flow of gas cannot be stopped it may be safer to allow the fire to continue to burn, at the same time using water spray to cool and control the effect of radiant heat. Extinguishing the flame may result in a wide spread of un-ignited gas and subsequent wider spread of flame if it is re-ignited. In order to reach and close the valve controlling the flow of gas, it may be necessary to extinguish flames from small leaks in its vicinity. In this case dry powder extinguishers should be used. Water jets should never be used directly into a liquefied petroleum gas fire. Foam will not extinguish such fires.

Electrical Equipment Fires
These may be caused by short circuit, overheating or the spreading of a fire from elsewhere. The immediate action should be to de-energize the equipment, and a non-conductive agent, such as carbon dioxide or dry chemical, should then be used to extinguish the fire.
3.5.2 Extinguishing agents – cooling

Water
Water is the most common cooling agent. This is largely because water possesses very good heat absorbing qualities and is available in ample quantities at terminals and on ships. A water jet, although excellent for fighting fires involving combustible materials, should not be used on burning oil, or on burning cooking oil or fat in galleys, because of the danger of spreading the fire.

Water spray and water fog may be used effectively against oil fires and for making a screen between the fire-fighter and the fire. Owing to the danger of electrical shock, water should not be directed towards any electrical equipment.

A wetting agent may be added to water when it is to be used on tightly packed combustible materials. This has the effect of lowering its surface tension and thus increasing its effective penetration.

Foam
Foam has a limited heat absorbing effect and should not normally be used for cooling.

3.5.3 Extinguishing agents – smothering

Foam
Foam is an aggregation of small bubbles, of lower specific gravity than oil or water, which flows across the surface of a burning liquid and forms a coherent smothering blanket. It will also reduce the surface temperature of the liquid by the absorption of some heat.

There are a number of different types of foam concentrates available. These include standard protein foam, fluoro-protein foams and synthetic concentrates. The synthetics are divided into aqueous film forming foam (AFFF) and hydrocarbon surfactant type foam concentrates.

Normally the protein, fluoro-protein and AFFF concentrates are used at 3% to 6% by volume concentration in water. Hydrocarbon surfactant concentrates are available for use at 1% to 6% by volume concentration.

High expansion foam has an expansion ratio from about 150:1 to 1500:1. It is made from hydrocarbon surfactant concentrates and is used to extinguish a fire in an enclosed space by filling the compartment rapidly with foam, thus preventing the movement of free air. The foam generator, which may be fixed or mobile, sprays the foam solution on to a fine mesh net through which air is driven by a fan. High expansion foam is unsuitable for use in outside locations as it cannot readily be directed on to a hot fire and is quickly dispersed in light winds.

Medium expansion foam has an expansion ratio from about 15:1 up to 150:1. It is made from the same concentrates as high expansion foam, but its aeration does not require a fan. Portable applicators can be used to deliver considerable quantities of foam on to spill fires, but their throw is limited and the foam is liable to be dispersed in moderate winds.

Low expansion foam has an expansion ratio from about 3:1 up to about 15:1. It is made from protein based or synthetic concentrates and can be applied to spill or tank fires from fixed monitors or portable applicators. Good throw is possible and the foam is resistant to wind.

Foam applicators should be directed away from liquid petroleum fires until any water in the system has been flushed clear.

Foam should not come into contact with any electrical equipment.

The various foam concentrates are basically incompatible with each other and should not be mixed in storage. However, some foams separately generated with these concentrates are
compatible when applied to a fire in sequence or simultaneously. The majority of foam concentrates can be used in conventional foam making devices suitable for producing protein foams. The systems should be thoroughly flushed out and cleaned before changing agents, as the synthetic concentrates may dislodge sediment and block the proportioning equipment. Some of the foams produced from the various concentrates are compatible with dry chemical powder and are suitable for combined use. The degree of compatibility between the various foams and between the foams and dry chemical agents varies and should be established by suitable tests.

The compatibility of foam compounds is a factor to be borne in mind when considering joint operations with other services. Foam concentrates may deteriorate with time depending on the storage conditions. Storage at high temperatures and in contact with air will cause sludge and sediment to form. This may affect the extinguishing ability of the expanded foam. Samples of the foam concentrate should therefore be returned periodically to the manufacturer for testing and evaluation.

**Carbon Dioxide**

Carbon dioxide is an excellent smothering agent for extinguishing fires, when used in conditions where it will not be widely diffused. Carbon dioxide is therefore effective in enclosed areas such as machinery spaces, pump rooms and electrical switch rooms where it can penetrate into places that cannot be reached by other means. On an open deck or jetty area, carbon dioxide is comparatively ineffective.

Carbon dioxide does not damage delicate machinery or instruments and, being a non-conductor, can be used safely on or around electrical equipment. Due to the possibility of static electricity generation, carbon dioxide should not be injected into any space containing a flammable atmosphere, which is not on fire. Carbon dioxide is asphyxiating and cannot be detected by sight or smell. No one should enter confined or partially confined spaces when carbon dioxide extinguishers have been used unless supervised and protected by suitable breathing apparatus and lifeline. Canister type respirators should not be used. Any compartment, which has been flooded with carbon dioxide, must be fully ventilated before entry without breathing apparatus.

**Steam**

Steam is inefficient as a smothering agent because of the substantial delay that may occur before sufficient air is displaced to render the atmosphere incapable of supporting combustion. Steam should not be injected into any space containing an unignited flammable atmosphere due to the possibility of static electricity generation.

**Sand**

Sand is relatively ineffective as an extinguishing agent and is only useful on small fires on hard surfaces. Its basic use is to dry up small spills.
3.5.4 Flame inhibitors

General
Flame inhibitors are materials, which interfere chemically with the combustion process, and thereby extinguish the flames. However cooling or removal of fuel is necessary if re-ignition is to be prevented.

Dry Chemical Powder
Dry chemical powder is discharged from an extinguisher as a free flowing cloud. It is most effective in dealing initially with a fire resulting from an oil spill on a jetty or on the deck of a tanker but can also be used in confined spaces. It is especially useful on burning liquids escaping from leaking pipelines and joints. It is a non-conductor and therefore suitable for dealing with electrical fires. It must be directed into the flames.
Dry chemical powder has a negligible cooling effect and affords no protection against re-ignition, arising, for example, from the presence of hot metal surfaces.
Certain types of dry chemical powder can cause a breakdown of a foam blanket and only those labelled ‘foam compatible’ should be used in conjunction with foam. Dry chemical powder clogs and becomes useless if it is allowed to become damp when stored or when extinguishers are being filled.

Vaporising Liquids (Halons)
Vaporising liquids, in the same way as dry chemical powder, have a flame inhibiting effect and also have a slight smothering effect. There are a number of different liquids available, all halogenated hydrocarbons, often identified by a system of halon numbers. The halons are most effective in enclosed spaces such as computer centres, storage rooms, tanker engine or pump rooms, generator enclosures and similar locations.
All halons are considered to be toxic to some degree because contact with hot surfaces and flames causes them to break down, yielding toxic substances. All personnel should therefore evacuate the area where halons are to be used, although it is possible to start the discharge of halons before the evacuation is complete as the normal concentrations encountered in extinguishing fires are acceptable for brief periods. After the fire has been extinguished the area should be thoroughly ventilated. If it is necessary to enter the area before ventilating, suitable breathing apparatus should be used.
Halon gases are known to have significant ozone depleting properties and, under the terms of the Montreal Protocol, production of Halon is to be phased out by the year 2000. New shipboard installations have been prohibited since July 1992. Carbon tetrachloride should not be used as it is highly toxic.

3.5.5 Tanker fire-fighting equipment

The requirements for ships’ fire-fighting equipment are laid down by the regulations of the particular country in which the tanker is registered. These regulations are generally based on the principles of the International Convention for the Safety of Life at Sea (SOLAS), 1974, as amended.

Tanker fixed fire-fighting installations – cooling
All tankers are provided with a water fire-fighting system consisting of pumps, a fire main with hydrant points, fire hoses complete with couplings, and jet nozzles or, preferably, jet/spray nozzles. A sufficient number of hydrants are provided and located so as to ensure
that two jets of water can reach any part of the ship. Certain bulkheads are sometimes fitted with permanent water spray lines.

An International Shore Fire Connection should be provided on tankers so that an external water supply can be coupled to any hydrant in the ship’s fire main. These connections should be available for immediate use.

**Tanker fixed fire-fighting installations – smothering**

One or more, or a combination of, the different smothering systems listed below may be installed on board tankers.

**Carbon Dioxide Flooding System**

This system is designed to fight fires in the engine room, boiler room and pump room. The system normally consists of a battery of large carbon dioxide cylinders. The carbon dioxide is piped from the cylinder manifold to suitable points having diffusing nozzles. An alarm should be activated in the compartment before the carbon dioxide is released to give personnel time to evacuate the compartment.

**Foam Systems**

These are used for fighting fire in the cargo spaces, on the cargo deck, in the pump room or in the engine spaces. A foam system has storage tanks containing foam concentrate. Water from the fire pumps picks up the correct proportion of foam concentrate from the tank through a proportioner and the foam solution is then conveyed through permanent supply lines to offtake points.

**Water Fog**

Water fog is supplied through a system of high-pressure water lines and fog nozzles. A ring of nozzles around the inside of the tank opening effectively blankets a cargo tank hatch fire. Some ships are also fitted with fixed pressurised water fog protection for boiler rooms, machinery spaces, and pump rooms.

**Water Curtain**

Some ships have a fixed system to give a protective water curtain between the cargo deck and the superstructure.

**Inert Gas System**

The purpose of an inert gas system is to prevent cargo tank fires or explosions. It is not a fixed fire-fighting installation, but in the event of a fire, the system may be of assistance in extinguishing it.

**3.6 PROTECTIVE EQUIPMENT**

**General**

Breathing apparatus, of the positive pressure type, should always be used whenever it is necessary to make an emergency entry into a space which is known to contain toxic vapours or gas or to be deficient in oxygen, and/or is known to contain contaminants which cannot be effectively dealt with by air purifying equipment. Entry should only be permitted in exceptional circumstances when no other practicable, safe alternative exists.
3.6.1 Self Contained Breathing Apparatus

This consists of a portable supply of compressed air contained in a cylinder or cylinders attached to a carrying frame and harness worn by the user. Air is provided to the user through a facemask, which can be adjusted to give an airtight fit. A pressure gauge indicates the pressure in the cylinder and an audible alarm sounds when the supply is running low. Only positive pressure type sets are recommended for use in enclosed spaces as these, as their name implies, maintain a positive pressure within the face mask at all times.

When using the equipment, the following should be noted:

- The pressure gauge must be checked before use.
- The operation of the audible low-pressure alarm should be tested before use.
- The facemask must be checked and adjusted to ensure that it is airtight. In this regard, the presence of any facial hair may adversely effect the mask’s seal and, should this be the case, another person should be selected to wear the apparatus.
- The pressure gauge should be monitored frequently during use to check on remaining air supply.
- Ample time should be allowed for getting out of the hazardous atmosphere. In any event, the user must leave immediately if the low pressure alarms sounds. It should be remembered that the duration of the air supply depends on the weight and fitness of the user and the extent of his exertion.

If the user suspects at any time that the equipment may not be operating satisfactorily or be concerned that the integrity of the face mask seal may be damaged, he should vacate the space immediately.

3.6.2 Air Line Breathing Apparatus

Air line breathing apparatus enables compressed air equipment to be used for longer periods than would be possible using self-contained equipment.

This equipment consists of a face mask which is supplied by air through a small diameter hose leading outside the space where it is connected to either compressed air cylinders or an air line served by a compressor. If the ships air supply is used, it is essential that it is properly filtered and adequately monitored for toxic or hazardous constituents. The hose is attached to the user by means of a belt or other arrangement, which enables rapid disconnection in an emergency. Air supply to the facemask is regulated by a flow control valve or orifice. If the air supply is from a compressor, the arrangement will include an emergency supply of air in cylinders for use in the event of the compressor failing. In such an emergency, the user should be signalled to vacate the space immediately.

A trained and competent person must be in control of the airline pressure and be alert to the need to change over to the alternative supply should normal working pressure not be maintained.

When using air line breathing apparatus:

- Check and ensure that the facemask is adjusted to be airtight.
• Check the working pressure before each use.
• Check the audible low-pressure alarm before each use.
• To avoid damage, keep the airlines clear of sharp projections.
• Ensure that the air hose does not exceed 90 metres in length.
• Allow ample time to vacate the space when the low pressure alarm sounds. The duration of the emergency air carried by the user will depend on an individual’s weight and fitness and each user should be aware of his particular limitations.

Should there be any doubt about the efficiency of the equipment, the user should vacate the space immediately.

The user should carry a completely separate supply of clean air for use in emergency evacuation from the space in the event of the air line failing.

3.6.3 Cartridge or Canister Face Masks
These units, which consist of a cartridge or canister attached to a facemask, are designed to purify the air of specific contaminants. It is important that they are only used for their designed purpose and within the limits prescribed by manufacturers.

Such units will not protect the user against concentrations of hydrocarbon or toxic vapours in excess of their design parameters, or against oxygen deficiency, and they should never be used in place of breathing apparatus.

3.6.4 Hose Mask (Fresh Air Breathing Apparatus)
This equipment consists of a mask supplied by air from a large diameter hose connected to a rotary pump or bellows. It is cumbersome and provides no seal against the entry of gases.

Although this equipment may be found on some vessels, it is recommended that it is NOT used for enclosed space entry.
4 POLLUTION PREVENTION

Learning objectives:
- that an oil tanker must comply with constructional requirements
- that different requirements may apply to certain oil tankers
- that LOT procedures are normally allowed on crude oil tankers
- that the sea surface and discharge outlets must be observed when discharging ballast or decanting slop tanks
- that pumps must be running before opening sea inlets to prevent pipeline contents polluting the sea
- that the ship is provided with an Oil Record Book
- that coded entries and the use of English or French in the Oil Record Book are to facilitate inspectors by foreign authorities

General

The MARPOL Convention is the main international convention covering prevention of pollution of the marine environment by ships from operational or accidental causes. It is a combination of two treaties adopted in 1973 and 1978 respectively and updated by amendments through the years.


As the 1973 MARPOL Convention had not yet entered into force, the 1978 MARPOL Protocol absorbed the parent Convention. The combined instrument is referred to as the International Convention for the Prevention of Marine Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78), and it entered into force on 2 October 1983 (Annexes I and II).
The Convention includes regulations aimed at preventing and minimizing pollution from ships - both accidental pollution and that from routine operations - and currently includes six technical Annexes:

**Annex I - Regulations for the Prevention of Pollution by Oil**

**Annex II - Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk**

**Annex III - Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form**

**Annex IV - Prevention of Pollution by Sewage from Ships** (not yet in force)

**Annex V - Prevention of Pollution by Garbage from Ships**

**Annex VI - Prevention of Air Pollution from Ships** (adopted September 1997 - not yet in force)

*States Parties must accept Annexes I and II, but the other Annexes are voluntary.*

### 4.1 Ship and Equipment

**General**

During the past twenty-five years the pollution of the world's oceans has become a matter of increasing international concern. Most of it comes from land-based sources and includes the by-products of industry, runoff from agricultural pesticides and herbicides and effluents discharged from urban areas. Nevertheless, a very significant amount of pollution is caused by shipping and maritime activities generally. The substances involved vary enormously in quantities transported and their potential harm to the marine environment. The following paragraphs summarize the pollution control situation insofar as the main types of shipping activity are concerned.

#### 4.1.1 Oil & oil spills

In tonnage terms, the most important pollutant resulting from shipping operations is oil. The National Academy of Sciences of the United States estimated in 1980 that as much as 3.54 million tons of oil enter the sea every year, some 1.5 million tons of which resulted from the transport of oil by sea (the remainder comes from land-based activities and includes industrial wastes, urban runoff and natural seepage).

Tankers at sea do not cause most oil pollution. Five times as much oil pollution at sea comes from sources on land as from tankers.

*Information from NAS source, 1992:*

*In fact every year 1.4 billion tons of oil moves by sea, in 6,000 tankers, and already 99.98% of that cargo is delivered safely.*

Traffic/Pilots, regulation:
The brightest, shiniest, safest oil tanker can still cause a wreck if traffic conditions are uncontrolled, charts are inaccurate and pilot guidance is substandard.

The best-known cause of oil pollution is tanker accidents. Although this may contribute a comparatively small percentage of the total oil entering the sea in a year, the consequences of an accident can be disastrous to the immediate area, particularly if the ship involved is a large one and the accident occurs close to the coast. The wrecks of the Torrey Canyon (1967) and the Amoco Cadiz (1978) are examples.

Oil affects the marine environment in different ways. It blankets the surface, interfering with the exchange of oxygen between the sea and the atmosphere; its heavier constituents blanket the seafloor, interfering with the growth of marine life; many constituent elements are toxic and get into the food chain; and oil on the beach interferes with recreational uses of that beach.

Furthermore, oil may enter seawater-distilling inlets and it may be deposited on tidal mudflats, again with detrimental results. In the face of growing oil pollution, international action was taken in the shape of the adoption of the International Convention for the Prevention of Pollution from Ships, 1973. In 1978 a Protocol tightening the provisions of the Convention, especially in respect of oil tankers, was adopted. The combined instrument is now known as MARPOL 73178. Marine pollution is more than oil pollution, and MARPOL 73/78 deals with these different pollution categories. Annex I of the Convention deals with oil pollution.

Annex I of MARPOL 73/78
As said before, Annex I deals with pollution caused by accidents occurring to oil tankers and by tanker operations. The prevention of accidents is primarily a safety matter, and is dealt with through safety conventions. Annex I does, however, serve to mitigate the effects of accidents.

With respect to oil tankers, the protection of the marine environment is approached through:

1) CONSTRUCTION REQUIREMENTS
2) EQUIPMENT REQUIREMENTS
3) OPERATIONAL REQUIREMENTS
4) SURVEY AND CERTIFICATE REQUIREMENTS
5) CONTROL PROCEDURES
6) PENALTIES
7) TRAINING REQUIREMENTS
The construction requirements reflect the desire to avoid ballast water coming into contact with cargo oil, thereby restricting the generation of oily water mixtures, and preventing the discharge of oil into the sea. They also reflect the desire to give ships carrying oil a greater survival capability, to protect the oil tanks by means of void spaces, and to limit tank size so that, if an accident does occur, the outflow of oil will also be limited.

The equipment requirements reflect the desire to enable a ship to comply with operational requirements. An earlier pollution convention (OILPOL 54/69) had also stipulated operational procedures, but without specifying the means of compliance; this was thought to be unsatisfactory. MARPOL 73/78 therefore not only lays down operational requirements but also provides for the means to operate in accordance with those requirements.

4.1.2 Segregated ballast tanks (SBT)

New crude oil tankers of more than 20,000 tonnes deadweight and new product tankers of more than 30,000 tonnes deadweight must be provided with segregated ballast tanks of sufficient capacity, so that only in extraordinary circumstances will there be a need to take ballast water in cargo tanks. SBT reduce the need for tank washing and therefore reduce oily water mixtures, but only if they are of adequate capacity.

Segregated ballast tanks are defined as tanks which are completely separated from the cargo oil and fuel oil systems and which are permanently allocated to the carriage of ballast. They are served by their own pumps and piping adequate for their purpose.

The capacity should be such that, at any time of the voyage,

1) THE AMIDSHIPS DRAUGHT IS NOT LESS THAN $2.0 + 0.02 \text{ L METRES (L = LENGTH BETWEEN PERPENDICULARS)}$;

2) THE TRIM BY THE STERN IS NOT MORE THAN 0.015 L;

3) THE PROPELLER IS FULLY IMMERSED.

This is enough for all, but hurricane or typhoon conditions if course and speed are properly, adjusted in heavy weather.

Additional ballast can be taken in the ship's cargo tanks if the master thinks it necessary. This is done by means of a special pump room cross-over connection (removable spool piece or blind), between the ballast and cargo systems. Heavy weather ballast carried in cargo tanks, which have been crude oil, washed but not water washed must be handled as dirty ballast.

4.1.3 SBT pollution

SBT is not a fail-safe means of preventing pollution. Petroleum cargo can enter the SBT tanks through bulkhead leaks. SBT tanks can also be contaminated by cargo leaking into ballast piping which passes through cargo tanks, or by cargo leaking out of cargo piping which passes through ballast tanks. To maintain the maximum pollution safeguards while using SBT, routine operational checks and piping integrity tests must be carefully, followed.

Case study;
In June 1987 and March 1989, two different vessels commenced taking on ballast water into segregated tanks by gravity, (without use of the ballast pumps), soon after commencement of
discharge of cargoes of crude oil. Unknown to the vessel's crews, the ballast lines had fractured within the cargo tanks through which they passed. Instead of ballast water flowing into the ship, the greater head pressure of oil in the cargo tanks caused about 25 barrels and 35 barrels, respectively, of oil to escape via the segregated ballast sea valves into the harbour.

Case analysis;
If the vessel had maintained a program of ballast line integrity checks on each ballast voyage, the defects should have been discovered and the pollution incident avoided. If there is any doubt about the integrity of ballast lines on a ship, then ballast should only be loaded by pumping. In this case, the ballast tanks would have later been found contaminated by cargo, but that would have been an easier problem to fix than a pollution incident.

New tankers, in this context, are those built after the 1st of January 1980. Ships built before that date are subject to less stringent requirements, in recognition of the fact that retrofitting segregated ballast systems may be costly and impracticable. Such ships need only be fitted with SBT if they exceed 40,000 tonnes deadweight, but may instead choose to:

1) Operate with dedicated clean ballast tanks (CBT), if product tankers.

2) be equipped and operate with a crude oil washing (COW) system, if crude oil tankers.

4.1.4 Protective location of ballast tanks
In addition to providing sufficient ballast capacity, which results in stipulated mean draught and trim SBT should also be located so as to offer some degree of protection against stranding and collision. Ideally, this would be a double skin and double bottom of specified width and depth. This is not necessary in practice; instead, the total area of the protected side and bottom should comply with certain parameters. In addition, the regulations stipulate a minimum width for the wing ballast tanks of 2 meters and a minimum height for the double-bottom ballast tanks of 2 meters or B/15, whichever is the lesser (B = maximum breadth of the ship). There is no requirement for the ratio of side and bottom protection, as long as the total area complies with Annex 1;

In practice, this means that in oil tankers the SBT are wing tanks, adjacent to the ship's shell plating.

4.1.5 Preparing for heavy weather ballast - taking dirty ballast
Ballast quantities as low as 25% of the ship's deadweight may be sufficient for unDocking operations in most ports. Ballasting will continue as the ship departs the unloading port until all the ballast required by the departure ballast plan is on board. In most cases, the draft and trim produced by the SBT or CBT capacity of the ship is sufficient to manoeuvre in port and proceed en route to the next loading port without undue fuel consumption or damage to the vessel.
Additional ballast may be taken into the ship's cargo tanks if the master thinks it is necessary for the safety of the ship. This does not mean that the master can ballast dirty cargo tanks to maintain desired speed in adverse weather. The most effective ways to reduce damage in heavy weather are to reduce speed or alter course. Only when these measures have been taken, may additional ballast be loaded in the cargo tanks to ensure the safety of the ship.
When it is probable that additional ballast will be needed during the voyage, the appropriate tanks will be required to have been crude oil washed. Ballast water that has been put into a tank that has been crude oil washed, but not water rinsed, shall be regarded as 'dirty ballast'
and handled accordingly. This may mean discharging ballast ashore at the end of voyages made entirely within a prohibited zone.
**Ballast water shall not be put into tanks that have not been crude oil washed.**

When preparing additional tanks for heavy weather ballast, the following is typical things to be done wish reference to IMO.

1) While filling the CBT tanks, flush the selected tanks, suction and piping with clean ballast water.

2) Flood the tank bottoms until covered fully.

3) Check the water, do the same procedure until satisfied.

### 4.1.6 Crude oil tankers without CBT or SBT

Crude oil tankers without CBT or SBT must ballast cargo tanks before departure from the discharge port. Ballast should not be put in cargo tanks unless they have been crude oil washed. The selected cargo tanks are discharged early in the discharge program. A complete COW cycle is performed in the selected tanks, with particular attention to the thoroughness of the bottom wash. The tank fill and suction lines should be stripped, and then isolated with two valve-separation from any continuing cargo operations. The tank fill lines should be flushed to a slop tank (if available) before filling the selected tanks with ballast.

### 4.1.7 Slop tanks

Slop tanks must be of adequate capacity to ensure that tank washings and other oily mixtures can be retained on board for separation of the oil and water and subsequent discharge of the water as part of the LOT procedures; Annex I requires at least one slop tank for ships of less than 70,000 tonnes deadweight and at least two slop tanks for larger ships. The capacity of the slop tank is expressed as a percentage of the cargo-carrying capacity (and are most likely to be 3 % as minimum) but, depends on the tank-washing method used;

1) A larger capacity, and therefore larger tanks, is required for open-cycle washing than for washing in the recirculation mode.

2) SBT and COW tankers and combination carriers may also have smaller slop tanks.

Slop-tank arrangements must be such as to facilitate the separation of oil and water.
Minimum slop-tank arrangement
4.1.8 Slop tank heating

Tank washing after a cargo of high pour point or high viscosity oil may encounter difficulty maintaining the recovered oil in a liquid state. The slop tank must be continuously heated to permit gravity separation and decanting and to keep the recovered oil liquid. It will usually be necessary to maintain maximum heat on the slop tank(s) while tank washing and decanting to keep the water and oil sufficiently hot. However as decanting proceeds the heat must be reduced to avoid overheating the oil. Recovered fuel oil should be heated to not more then 60°C and recovered crude oil (except some heavy crude oils), to not more than 43°C after removal of free water.

4.1.9 Load-on-top operations

By a process of heating and careful decanting, the water content of the slop tank can be slowly reduced until only the top oil layer, the oil/water interface layer and a shallow bottom water layer are left. If the characteristics of the slop oil and the nature of the next cargo permit, the slops may be retained on board and the next cargo loaded on top of them. This is normally done with crude oil cargoes when the same or a similar crude will be carried on the next voyage. It may also be done with some products provided the cargo shipper is advised and approves of the procedure.

If there is any doubt about retaining the slops, the master must communicate this question to the owners and cargo owner or charterer and request their advice. When requesting advice, the master must advise the quantity of slops and the nature of their contents (Including tetra-ethyl lead or detergents).

Charterer may wish to LOT, in which case full freight will be normally paid. If charterer does not wish to LOT, the slops must be segregated and freight will not be paid on the space/deadweight used. Most charter parties provide for the charterer to make the decision regarding the disposition of slops.

Charterers may require the slops to be discharged. The time required to do this normally constitutes laytime used.

4.1.10 Overboard piping

All discharging from cargo and ballast tanks must, in principle, be made above the waterline to ensure that both discharging and water surface may be observed. Since discharging above
the waterline may pose hazards in port for persons working on lighters, jetties, passing small craft, etc. etc. - the discharging of clean and segregated ballast may be permitted under the waterline when in port. Pipelines on board reflect these requirements. On oil tanker of, 20 000 tonnes deadweight or more, it should be possible to drain pumps and lines, if necessary by connecting them to a stripping device. A special **Small-diameter** line should be provided to discharge these drainings to the shore outboard of the ships manifold valves.

![Diagram](image)

**Pumps and line drainage arrangement and small-diameter discharge line**

### 4.1.11 Dedicated dean ballast tanks (CBTS)

Like COW, the use of CBT is aimed at reducing the generation of oil/water mixtures. CBT must be used on oil tankers, which are not provided with SBT, which carry oils other than crude oil, and which, as a consequence, cannot practice COW.

In principle, an oil tanker with CBT is the same as an SBT tanker. Since ballast water is carried in tanks designated for that purpose, there is no need to change ballast whilst under way to the loading port, because of the pollution caused by a phénomena known as “non indigenous pathogens”. Capacity and distribution should ensure that no additional ballast is needed on most occasions, and the location of CBT in the ship's sides, where possible, offers some degree of protection against pollution arising from collision. The measure is a temporary one, only to be used on product tankers of, 40,000 tonnes dead weight and above, built before 1980.

In practice it has been difficult to allocate cargo tanks in an existing configuration which would result in compliance with trim and draught requirements. It has often been necessary to utilize peak tanks and cofferdams for ballast to meet the requirements.

In one important respect CBT differs from SBT, and that is in the use of pumps and piping. CBT tankers may have to make use of cargo pumps and piping for ballasting during and after cargo operations, and considerable flushing of pumps and lines may have to take place to avoid contaminating the ballast water. These flushing may not be discharged into the sea and, contrary to practice on non-CBT ships, cannot be transferred to the ballast tanks, since
these have been thoroughly cleaned at an earlier stage and must remain clean. Pump and line flushing must therefore be transferred to the slop tanks and, for that reason, space may have to be left in the slop tanks even on a loaded voyage. Oil tankers certified as CBT tankers must be provided with a CBT Operation Manual setting out the correct line-flushing procedures for the particular ship.

A number of oil tankers operating with CBT have a dedicated ballast system serving those tanks; for these, operations are very similar to those on SBT tankers. Care must be taken to prevent oil entering the ballast tanks through the cargo piping, and there should be a two-valve separation between cargo and ballast.

4.1.12 Equipment Requirements

Oil Discharge Monitoring and Control Equipment (ODM)
The discharge provisions limit both the total quantity of oil that may be discharged into the sea from the cargo-tank area and the instantaneous rate of discharge of oil. Monitoring equipment must be provided to enable oil tankers to comply. The discharge provisions also stipulate that the equipment should be in operation when oil and water mixtures are being discharged into the sea. International specifications for the equipment have been established, and only approved types may be used on board. The equipment must come into operation whenever a discharge takes place.
The discharge of segregated and clean ballast (except from CBT tankers) need not be monitored. The equipment must halt the discharge automatically when the permitted quantity of oil or the permitted number of litres of oil per mile has been reached.

The task to be performed requires complicated equipment. Not only must the oil content of the effluent be measured, a difficult enough task, but the discharge rate of the pumps over a wide range of output and the speed of the ship must also be recorded. A computer is needed to transfer input into output, i.e. total quantity of oil and instantaneous rate of discharge (litres
of oil per mile). Output must be recorded and the time of discharge must be identified. The principles involved are described briefly below.

An oil discharge monitoring and control system consists essentially of four systems:

1) An oil content meter that is able to analyse the relative content of oil in the water stream, expressed in parts per million (ppm)

2) A flow meter that is able to measure the flow rate of oily water through the discharge pipe

3) A computing unit that is able to calculate the oil discharge rate in litres per nautical mile and total quantity, together with date and time identification

4) An overboard valve control system that is able to stop the discharge when the permissible limit has been reached.

It is difficult to monitor oil content of water, considering the small concentrations of oil involved and the many disturbing factors (such as widely varying properties of oil, other contaminants in the water and a hostile environment for the equipment).

The most accurate technique for determining the oil content of water is based on analysis of the absorption of infrared light. The absorption of infrared light of an oil/water mixture is fairly dependent of the type of the oil, but the method cannot be used accurately whilst the oil droplets are suspended in water since water also absorbs infra-red radiation. The oil is therefore normally extracted in a suitable solvent that is non-soluble in water, such as carbon tetrachloride.

This method of oil content measurement cannot easily be adapted to shipboard use because of the need for continuous analysis with a short time delay.

4.2 OPERATIONAL POLLUTION

History of MARPOL 73/78

Oil pollution of the seas was recognized as a problem in the first half of the 20th century and various countries introduced national regulations to control discharges of oil within their territorial waters. In 1954, the United Kingdom organized a conference on oil pollution which resulted in the adoption of the International Convention for the Prevention of Pollution of the Sea by Oil (OILPOL), 1954. Following entry into force of the IMO Convention in 1958, the depository and Secretariat functions in relation to the Convention were transferred from the United Kingdom Government to IMO.

4.2.1 OILPOL Convention

The 1954 Convention, which was amended in 1962, 1969 and 1971, primarily addressed pollution resulting from routine tanker operations and from the discharge of oily wastes from machinery spaces - regarded as the major causes of oil pollution from ships.
The 1954 OILPOL Convention, which entered into force on 26 July 1958, attempted to tackle the problem of pollution of the seas by oil - defined as crude oil, fuel oil, heavy diesel oil and lubricating oil - in two main ways:

- it established "prohibited zones" extending at least 50 miles from the nearest land in which the discharge of oil or of mixtures containing more than 100 parts of oil per million was forbidden;

- it required Contracting Parties to take all appropriate steps to promote the provision of facilities for the reception of oily water and residues.

In 1962, IMO adopted amendments to the Convention which extended its application to ships of a lower tonnage and also extended the "prohibited zones". Amendments adopted in 1969 contained regulations to further restrict operational discharge of oil from oil tankers and from machinery spaces of all ships.

Although the 1954 OILPOL Convention went some way in dealing with oil pollution, growth in oil trade and developments in industrial practices were beginning to make it clear that further action was required. Nonetheless, pollution control was at the time still a minor concern for IMO, and indeed the world was only beginning to wake up to the environmental consequences of an increasingly industrialised society.

**Torrey Canyon**

In 1967, the tanker *Torrey Canyon* ran aground while entering the English Channel and spilled her entire cargo of 120,000 tons of crude oil into the sea. This resulted in the biggest oil pollution incident ever recorded up to that time. The incident raised questions about measures then in place to prevent oil pollution from ships and also exposed deficiencies in the existing system for providing compensation following accidents at sea.

First, IMO called an Extraordinary session of its Council, which drew up a plan of action on technical and legal aspects of the *Torrey Canyon* incident. Then, the IMO Assembly decided in 1969 to convene an international conference in 1973 to prepare a suitable international agreement for placing restraints on the contamination of the sea, land and air by ships.

In the meantime, in 1971, IMO adopted further amendments to OILPOL 1954 to afford additional protection to the Great Barrier Reef of Australia and also to limit the size of tanks on oil tankers, thereby minimizing the amount of oil which could escape in the event of a collision or stranding.

**1978 Conference**

More importantly in terms of achieving the entry into force of MARPOL, the 1978 MARPOL Protocol allowed States to become Party to the Convention by first implementing Annex I (oil), as it was decided that Annex II (chemicals) would not become binding until three years after the Protocol entered into force.

4.2.2 Annex I: Prevention of pollution by oil

Entry into force: 2 October 1983

The 1973 Convention maintained the oil discharge criteria prescribed in the 1969 amendments to the 1954 Oil Pollution Convention, without substantial changes, namely:

Operational discharges of oil from tankers are allowed only when all of the following conditions are met:

1. the total quantity of oil which a tanker may discharge in any ballast voyage whilst under way must not exceed 1/15,000 of the total cargo carrying capacity of the vessel;
2. the rate at which oil may be discharged must not exceed 30 litres per mile travelled by the ship; and
3. no discharge of any oil whatsoever must be made from the cargo spaces of a tanker within 50 miles of the nearest land.

An oil record book is required, in which is recorded the movement of cargo oil and its residues from loading to discharging on a tank-to-tank basis.

In addition, in the 1973 Convention, the maximum quantity of oil permitted to be discharged on a ballast voyage of new oil tankers was reduced from 1/15,000 of the cargo capacity to 1/30,000 of the amount of cargo carried. These criteria applied equally both to persistent (black) and non-persistent (white) oils.

As with the 1969 OILPOL amendments, the 1973 Convention recognized the "load on top" (LOT) system which had been developed by the oil industry in the 1960s. On a ballast voyage the tanker takes on ballast water (departure ballast) in dirty cargo tanks. Other tanks are washed to take on clean ballast. The tank washings are pumped into a special slop tank. After a few days, the departure ballast settles and oil flows to the top. Clean water beneath is then decanted while new arrival ballast water is taken on. The upper layer of the departure ballast is transferred to the slop tanks. After further settling and decanting, the next cargo is loaded on top of the remaining oil in the slop tank, hence the term load on top.

A new and important feature of the 1973 Convention was the concept of "special areas" which are considered to be so vulnerable to pollution by oil that oil discharges within them have been completely prohibited, with minor and well-defined exceptions. The 1973 Convention identified the Mediterranean Sea, the Black Sea, and the Baltic Sea, the Red Sea and the Arabian Gulf area as special areas. All oil-carrying ships are required to be capable of operating the method of retaining oily wastes on board through the "load on top" system or for discharge to shore reception facilities.

This involves the fitting of appropriate equipment, including an oil-discharge monitoring and control system, oily-water separating equipment and a filtering system, slop tanks, sludge tanks, piping and pumping arrangements.
New oil tankers (i.e. those for which the building contract was placed after 31 December 1975) of 70,000 tons deadweight and above, must be fitted with segregated ballast tanks large enough to provide adequate operating draught without the need to carry ballast water in cargo oil tanks.

Secondly, new oil tankers are required to meet certain subdivision and damage stability requirements so that, in any loading conditions, they can survive after damage by collision or stranding.

**The Protocol of 1978** made a number of changes to Annex I of the parent convention. Segregated ballast tanks (SBT) are required on all new tankers of 20,000 dwt and above (in the parent convention SBTs were only required on new tankers of 70,000 dwt and above). The Protocol also required SBTs to be protectively located - that is, they must be positioned in such a way that they will help protect the cargo tanks in the event of a collision or grounding.

Another important innovation concerned crude oil washing (COW), which had been developed by the oil industry in the 1970s and offered major benefits. Under COW, tanks are washed not with water but with crude oil - the cargo itself. COW was accepted as an alternative to SBTs on existing tankers and is an additional requirement on new tankers.

For existing crude oil tankers (built before entry into force of the Protocol) a third alternative was permissible for a period of two to four years after entry into force of MARPOL 73/78. The dedicated clean ballast tanks (CBT) system meant that certain tanks are dedicated solely to the carriage of ballast water. This was cheaper than a full SBT system since it utilized existing pumping and piping, but when the period of grace has expired other systems must be used.

Drainage and discharge arrangements were also altered in the Protocol, regulations for improved stripping systems were introduced.

Some oil tankers operate solely in specific trades between ports which are provided with adequate reception facilities. Some others do not use water as ballast. The TSPP Conference recognized that such ships should not be subject to all MARPOL requirements and they were consequently exempted from the SBT, COW and CBT requirements. It is generally recognized that the effectiveness of international conventions depends upon the degree to which they are obeyed and this in turn depends largely upon the extent to which they are enforced. The 1978 Protocol to MARPOL therefore introduced stricter regulations for the survey and certification of ships.

The 1992 amendments to Annex I made it mandatory for new oil tankers to have double hulls – and it brought in a phase-in schedule for existing tankers to fit double hulls.

### 4.2.3 The 1999 amendments

**Adoption:** 1 July 1999 **Entry into force:** 1 January 2001 (under tacit acceptance)

Amendments to Regulation 13G of Annex I (Regulations for the Prevention of Pollution by Oil) make existing oil tankers between 20,000 and 30,000 tons deadweight carrying persistent product oil, including heavy diesel oil and fuel oil, subject to the same construction requirements as crude oil tankers.
Regulation 13G requires, in principle, existing tankers to comply with requirements for new tankers in Regulation 13F, including double hull requirements for new tankers or alternative arrangements, not later than 25 years after date of delivery.

The amendments extend the application from applying to crude oil tankers of 20,000 tons deadweight and above and product carriers of 30,000 tons deadweight and above, to also apply to tankers between 20,000 and 30,000 tons deadweight which carry heavy diesel oil or fuel oil.

The aim of the amendments is to address concerns that oil pollution incidents involving persistent oils are as severe as those involving crude oil, so regulations applicable to crude oil tankers should also apply to tankers carrying persistent oils.

Related amendments to the Supplement of the IOPP (International Oil Pollution Prevention) Certificate, covering in particular oil separating/filtering equipment and retention and disposal of oil residues were also adopted.
4.2.4 The 2001 amendments

Adoption: 27 April 2001

Entry into force: 1 September 2002

The amendment to Annex I brings in a new global timetable for accelerating the phase-out of single-hull oil tankers. The timetable will see most single-hull oil tankers eliminated by 2015 or earlier. Double-hull tankers offer greater protection of the environment from pollution in certain types of accident. All new oil tankers built since 1996 are required to have double hulls.

The revised regulation identifies three categories of tankers, as follows:

1. "Category 1 oil tanker" means oil tankers of 20,000 tons deadweight and above carrying crude oil, fuel oil, heavy diesel oil or lubricating oil as cargo, and of 30,000 tons deadweight and above carrying other oils, which do not comply with the requirements for protectively located segregated ballast tanks (commonly known as Pre-MARPOL tankers).

2. "Category 2 oil tanker" means oil tankers of 20,000 tons deadweight and above carrying crude oil, fuel oil, heavy diesel oil or lubricating oil as cargo, and of 30,000 tons deadweight and above carrying other oils, which do comply with the protectively located segregated ballast tank requirements (MARPOL tankers), while

3. "Category 3 oil tanker" means an oil tanker of 5,000 tons deadweight and above but less than the tonnage specified for Category 1 and 2 tankers.

Although the new phase-out timetable sets 2015 as the principal cut-off date for all single-hull tankers, the flag state administration may allow for some newer single hull ships registered in its country that conform to certain technical specifications to continue trading until the 25th anniversary of their delivery.

However, under the provisions of paragraph 8(b), any Port State can deny entry of those single hull tankers which are allowed to operate until their 25th anniversary to ports or offshore terminals. They must communicate their intention to do this to IMO.

As an additional precautionary measure, a Condition Assessment Scheme (CAS) will have to be applied to all Category 1 vessels continuing to trade after 2005 and all Category 2 vessels after 2010. A resolution adopting the CAS was passed at the meeting.

Although the CAS does not specify structural standards in excess of the provisions of other IMO conventions, codes and recommendations, its requirements stipulate more stringent and transparent verification of the reported structural condition of the ship and that documentary and survey procedures have been properly carried out and completed.

The requirements of the CAS include enhanced and transparent verification of the reported structural condition and of the ship and verification that the documentary and survey procedures have been properly carried out and completed. The Scheme requires that compliance with the CAS is assessed during the Enhanced Survey Programme of Inspections concurrent with intermediate or renewal surveys currently required by resolution A.744(18), as amended.
4.3 Oil Record Book

Every ship to which these Regulations apply of 400 GRT and above, other than an oil tanker, and every oil tanker of 150 GRT and above shall be provided with an Oil Record Book Part I (Machinery Space Operations). Every oil tanker of 150 GRT and above shall also be provided with an oil Record Book Part II (Cargo/Ballast Operations).

The oil Record Book, whether it forms Part of the ship's official log book or engine room log book or otherwise, shall be in the form set out in Schedule 2, hereto.

When making entries in the Oil Record Book, the date, operational code and item number shall be inserted in the appropriate columns and the required particulars shall be recorded chronologically in the blank spaces.

The Oil Record Book shall be completed on each occasion, on a tank-to-tank basis if appropriate, whenever any of the following operations take place in the ship:

(a) for machinery space operations (all ships)
   (i) ballasting or cleaning of oil fuel tanks;
   (ii) discharge of ballast or cleaning water from oil fuel tanks which have been ballasted or cleaned;
   (iii) disposal of oily residues (sludge);
   (iv) discharge overboard of bilge water which has accumulated in machinery spaces;

(b) for cargo/ballast operation (oil tankers)
   (i) loading of oil cargo;
   (ii) internal transfer of oil cargo during voyage;
   (iii) unloading of oil cargo;
   (iv) ballasting of cargo tanks and dedicated clean ballast tanks;
   (v) cleaning of cargo tanks including crude oil washing;
   (vi) discharge of ballast except from segregated ballast tanks;
   (vii) discharge of water from slop tanks;
   (viii) closing of all applicable valves or similar devices after slop tank discharge operations;
   (ix) closing of valves necessary for the isolation of dedicated clean ballast tanks from cargo and stripping lines after slop tank discharge operations;
   (x) disposal of residues.

(3) In the event of such discharge of oil or oily mixture as is referred to in regulation 11 or in the event of an accidental or other exceptional discharge of oil not excepted by that regulation, a statement shall be made in the Oil Record Book of the circumstances of, and the reasons for, the discharge.

(4) Each operation described in paragraph (2) of this regulation shall be fully recorded without delay in the Oil Record Book so that all entries in the book appropriate to that operation are completed. Each completed operation shall be signed by the officer or officers in charge of the operations concerned and each completed page shall be signed by the master.

(5) The Oil Record Book shall be kept in such a place as to be readily available for inspection at all reasonable times and, except in the case of unmanned ships under tow, shall be kept on board. It shall be preserved for a period of three years after the last entry.
has been made.

(6) A person authorized by the Certifying Authority may inspect the Oil Record Book on board any ship whilst the ship is in a port or off shore terminal and may make a copy of any entry in that book and may require the master of the ship to certify that the copy is a true copy of such entry. Any copy so made which has been certified by the master of the ship as a true copy of an entry in the ship's Oil Record Book shall be admissible in any judicial proceedings as evidence of the facts stated in the entry. The inspection of an Oil Record Book and the taking of a certified copy by the competent authority, or an authorized person, under this paragraph shall be performed as expeditiously as possible without causing the ship to be unduly delayed.

4.4 Action in Case of Oil Spills

INTERNATIONAL CONVENTION ON OIL POLLUTION PREPAREDNESS, RESPONSE AND COOPERATION

Conscious of the need to preserve the human environment in general and the marine environment in particular, recognizing the serious threat posed to the marine environment by oil pollution incidents involving ships, offshore units, sea ports and oil handling facilities. Mindful of the importance of precautionary measures and prevention in avoiding oil pollution in the first instance, and the need for strict application of existing international instruments dealing with maritime safety and marine pollution prevention, particularly the International Convention for the Safety of Life at Sea, 1974, as amended, and the International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto, as amended, and also the speedy development of enhanced standards for the design, operation and maintenance of ships carrying oil, and of offshore units. Mindful also that, in the event of an oil pollution incident, prompt and effective action is essential in order to minimize the damage, which may result from such an incident. Emphasizing the importance of effective preparation for combating oil pollution incidents and the important role, which the oil and shipping industries have in this regard.

4.4.1 General provisions

(1) Parties undertake, individually or jointly, to take all appropriate measures in accordance with the provisions of this Convention and the Annex thereto to prepare for and respond to an oil pollution incident.

(2) The Annex to this Convention shall constitute an integral part of the Convention and a reference to this Convention constitutes at the same time a reference to the Annex.

(3) This Convention shall not apply to any warship, naval auxiliary or other ship owned or operated by a State and used, for the time being, only on government non-commercial service. However, each Party shall ensure by the adoption of appropriate measures not impairing the operations or operational capabilities of such ships owned or operated by it, that such ships act in a manner consistent, so far as is reasonable and practicable, with this Convention.
4.4.2 Definitions

For the purposes of this Convention:

(1) Oil means petroleum in any form including crude oil, fuel oil, sludge, oil refuse and refined products.

(2) Oil pollution incident means an occurrence or series of occurrences having the same origin, which results or may result in a discharge of oil and which poses or may pose a threat to the marine environment, or to the coastline or related interests of one or more States, and which requires emergency action or other immediate response.

(3) Ship means a vessel of any type whatsoever operating in the marine environment and includes hydrofoil boats, air-cushion vehicles, submersibles, and floating craft of any type.

(4) Offshore unit means any fixed or floating offshore installation or structure engaged in gas or oil exploration, exploitation or production activities, or loading or unloading of oil.

(5) Sea ports and oil handling facilities means those facilities which present a risk of an oil pollution incident and includes, inter alia, sea ports oil terminals, pipelines and other oil handling facilities.

(6) Organization means the International Maritime Organization.

(7) Secretary-General means the Secretary-General of the Organization.

4.4.3 Oil pollution emergency plans

(1) (a) Each Party shall require that ships entitled to fly its flag have on board a shipboard oil pollution emergency plan as required by and in accordance with the provisions adopted by the Organization for this purpose.

(b) A ship required to have on board an oil pollution emergency plan in accordance with subparagraph (a) is subject, while in a port or at an offshore terminal under the jurisdiction of a Party to inspection by officers duly authorized by that Party, in accordance with the practices provided for in existing international agreements or its national legislation.

(2) Each Party shall require that operators of offshore units under its jurisdiction have oil pollution emergency plans, which are coordinated with the national system established in accordance with article 6 and approved in accordance with procedures established by the competent national authority.

(3) Each Party shall require that authorities or operators in charge of such sea ports and oil handling facilities under its jurisdiction as it deems appropriate have oil pollution emergency plans or similar arrangements which are coordinated with the national system established in accordance with article 6 and approved in accordance with procedures established by the competent national authority.
4.4.4 Oil pollution reporting procedures

(1) Each Party shall:

(a) require masters or other persons having charge of ships flying its flag and persons having charge of offshore units under its jurisdiction to report without delay any event on their ship or offshore unit involving a discharge or probable discharge of oil:

(i) in the case of a ship, to the nearest coastal State;

(ii) in the case of an offshore unit, to the coastal State to whose jurisdiction the unit is subject;

(b) require masters or other persons having charge of ships flying its flag and persons having charge of offshore units under its jurisdiction to report without delay any observed event at sea involving a discharge of oil or the presence of oil:

(i) in the case of a ship, to the nearest coastal State;

(ii) in the case of an offshore unit, to the coastal State to whose jurisdiction the unit is subject;

(c) require persons having charge of sea ports and oil handling facilities under its jurisdiction to report without delay any event involving a discharge or probable discharge of oil or the presence of oil to the competent national authority;

(d) instruct its maritime inspection vessels or aircraft and other appropriate services or officials to report without delay any observed event at sea or at a sea port or oil handling facility involving a discharge of oil or the presence of oil to the competent national authority or, as the case may be, to the nearest coastal State;

(e) request the pilots of civil aircraft to report without delay any observed event at sea involving a discharge of oil or the presence of oil to the nearest coastal State.

(2) Reports under paragraph (1)(a)(i) shall be made in accordance with the requirements developed by the Organization and based on the guidelines and general principles adopted by the Organization. Reports under paragraph (1)(a)(ii), (b), (c) and (d) shall be made in accordance with the guidelines and general principles adopted by the Organization to the extent applicable.

4.4.5 Action on receiving an oil pollution report

(1) Whenever a Party receives a report referred to in article 4 or pollution information provided by other sources, it shall:

(a) assess the event to determine whether it is an oil pollution incident;

(b) assess the nature, extent and possible consequences of the oil pollution incident; and

(c) then, without delay, inform all States whose interests are affected or likely to be affected by such oil pollution incident, together with
(i) details of its assessments and any action it has taken, or intends to take, to deal with the incident, and

(ii) further information as appropriate, until the action taken to respond to the incident has been concluded or until joint action has been decided by such States.

(2) When the severity of such oil pollution incident so justifies, the Party should provide the Organization directly or, as appropriate, through the relevant regional organization or arrangements with the information referred to in paragraph (1)(b) and (c).

(3) When the severity of such oil pollution incident so justifies, other States affected by it are urged to inform the Organization directly or, as appropriate, through the relevant regional organizations or arrangements of their assessment of the extent of the threat to their interests and any action taken or intended.

(4) Parties should use, in so far as practicable, the oil pollution reporting system developed by the Organization when exchanging information and communicating with other States and with the Organization.

4.4.6 National and regional systems for preparedness and response

(1) Each Party shall establish a national system for responding promptly and effectively to oil pollution incidents. This system shall include as a minimum:

(a) the designation of:
   (i) the competent national authority or authorities with responsibility for oil pollution preparedness and response;

   (ii) the national operational contact point or points, which shall be responsible for the receipt and transmission of oil pollution reports as referred to in article 4; and

   (iii) an authority which is entitled to act on behalf of the State to request assistance or to decide to render the assistance requested;

(b) a national contingency plan for preparedness and response, which includes the organizational relationship of the various bodies, involved, whether public or private, taking into account guidelines developed by the Organization.

(2) In addition, each Party, within its capabilities either individually or through bilateral or multilateral cooperation and, as appropriate, in cooperation with the oil and shipping industries, port authorities and other relevant entities, shall establish:

(a) a minimum level of pre-positioned oil spill combating equipment, commensurate with the risk involved, and programmes for its use;

(b) a programme of exercises for oil pollution response organizations and training of relevant personnel;
4.4.7 Technical co-operation

(1) Parties undertake directly or through the Organization and other international bodies, as appropriate, in respect of oil pollution preparedness and response, to provide support for those Parties which request technical assistance:

(a) to train personnel;

(b) to ensure the availability of relevant technology, equipment and facilities;

(c) to facilitate other measures and arrangements to prepare for and respond to oil pollution incidents; and

(d) to initiate joint research and development programmes.

(2) Parties undertake to co-operate actively, subject to their national laws, regulations and policies, in the transfer of technology in respect of oil pollution preparedness and response.
4.5 Air Pollution

The Protocol of 1997 (Annex VI - Regulations for the Prevention of Air Pollution from Ships)
Adoption: 26 September 1997
Entry into force: 12 months after being accepted by at least 15 states with not less than 50% of world merchant shipping tonnage (The Conference also adopted a Resolution which invites IMO's Marine Environment Protection Committee (MEPC) to identify any impediments to entry into force of the Protocol, if the conditions for entry into force have not been met by 31 December 2002).

The rules, when they come into force, will set limits on sulphur oxide (SOx) and nitrogen oxide (NOx) emissions from ship exhausts and prohibit deliberate emissions of ozone depleting substances.

The new Annex VI includes a global cap of 4.5% m/m on the sulphur content of fuel oil and calls on IMO to monitor the worldwide average sulphur content of fuel once the Protocol comes into force.

Annex VI contains provisions allowing for special "SOx Emission Control Areas" to be established with more stringent control on sulphur emissions. In these areas, the sulphur content of fuel oil used on board ships must not exceed 1.5% m/m. Alternatively, ships must fit an exhaust gas cleaning system or use any other technological method to limit SOx emissions.

The Baltic Sea is designated as a SOx Emission Control area in the Protocol.

Annex VI prohibits deliberate emissions of ozone depleting substances, which include halons and chlorofluorocarbons (CFCs). New installations containing ozone-depleting substances are prohibited on all ships. But new installations containing hydro-chlorofluorocarbons (HCFCs) are permitted until 1 January 2020.

The requirements of the IMO Protocol are in accordance with the Montreal Protocol of 1987, as amended in London in 1990. The Montreal Protocol is an international environmental treaty, drawn up under the auspices of the United Nations, under which nations agreed to cut CFC consumption and production in order to protect the ozone layer.

Annex VI sets limits on emissions of nitrogen oxides (NOx) from diesel engines. A mandatory NOx Technical Code, developed by IMO, defines how this is to be done.

The Annex also prohibits the incineration on board ship of certain products, such as contaminated packaging materials and polychlorinated biphenyls (PCBs).

Format of Annex VI
Annex VI consists of three Chapters and a number of Appendices:
- Chapter 1 - General
- Chapter II - Survey, Certification and Means of Control
- Chapter III - Requirements for Control of Emissions from Ships
- Appendices including the form of the International Air Pollution Prevention Certificate; criteria and procedures for designation of SOx emission control areas; information for inclusion in the bunker delivery note; approval and operating limits for shipboard incinerators; test cycles and weighting factors for verification of compliance of marine diesel engines with the NOx limits; and details of surveys and inspections to be carried out.
A rapid increase in the number of ships operating on low-sulphur oil, spurred to some extent by the demands for environmentally friendly transport from some of the big shippers, has come about since 1998.

The response has not been so marked in regard to NOx emissions. As of October 1999, applications for reduction of the fairway dues had only been made for eleven ships. The number is however expected to increase before long. The difference can be explained as follows: Whereas the cost of switching to low-sulphur fuel is regarded as moderate and its implementation easy, reducing NOx emissions requires a larger investment and so the question of profitability enters. The incentive should however be greater if more countries were to introduce a system of environmentally differentiated dues.

4.5.1 The means are available

The technology already exists for cost-effective reduction of the emissions of sulphur and nitrogen oxides from ships.

4.5.2 Sulphur

Emissions are directly proportional to the sulphur content of the fuel. The simplest and least expensive way of reducing them is to go over to using bunker oil with a low sulphur content. The average sulphur content is now around 3 per cent, but low-sulphur oils can also be had. They require no engine modification, and the additional cost is no more than marginal. For oils with a sulphur content of 1 and 0.5 per cent it is around $10 and $30 per ton (at present high-sulphur oil costs around $130 per ton). Because of its higher quality, low-sulphur oil also has the advantage of making for smoother engine running, with less risk of operating problems.

4.5.3 Nitrogen oxides

There are various methods for reducing NOx emissions, differing somewhat in cost and effectiveness.

4.5.4 Water injection and water emulsion.

Water is injected into the combustion chamber or mixed with the fuel in order to lower the temperature of combustion and hence reduce NOx formation. The potential for emission reduction is at most around 50 per cent, but at the cost of increased fuel consumption. The installation cost is however lower than for either of the following methods.

**HAM, Humid Air Motor**, is a technique for preventing the formation of NOx during combustion by adding water vapour to the combustion air. Performance is unaffected either by the quality of the bunker oil or by engine workload. HAM has the advantage over SCR of somewhat lowering operating costs instead of increasing them. The method is able to reduce NOx by 70-80 per cent at a cost apparently similar to that of SCR.

**Selective Catalytic Reduction, SCR**, is a system for after-treatment of the exhaust gases. It can reduce the emissions of nitrogen oxides by up to 90 per cent, but requires low-sulphur
bunker oil and extra engine space for retro-fitting. Nitrogen oxides are reduced to nitrogen gas by spraying urea or ammonia into the gases before they pass through a catalytic converter. Reduction costs are generally below 0.6 euro per kg NOx, lower if the equipment can be installed while the ship is being built. There are now some forty ships fitted for SCR. About half of them are Swedish, and most of the others are frequent callers at Swedish ports.
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 suctions are placed approximately in the middle, and two stripping suctions 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 crosswise, 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.

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.

![Inertgas-lines](image-url)
### 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 hauls routes, the 45,000 dwt product tanker is still the workhorse of the regional balance and distribution refined product trades. Principal cargoes include gasoline, kerosene, diesel and lpg. Oil. The bigger product tankers comprise range 1 (R1) ships (55-60,000 dwt) and range 2 (R2) ships (60,000+ dwt). They carry large volume cargoes such as condensates, naphtha and residual fuel oil, with naphtha, a light product used as a petrochemical feedstock, amongst others. Featuring prominently R1/T product tankers are able to transport 25-30,000 tonnes per month of products, while R2 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 caustic chemicals such as benzene, ethylene, toluene and caustic soda solution, in addition to the full range of petroleum products.

#### PROPULSION SYSTEM

Driven by a fixed-pitch propeller, the slow-speed diesel engine develops 13,000 shp at 40 rpm to provide a ship speed of 11.5 knots. Two 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. An electrically driven bow thruster is fitted for increased maneuverability.

#### 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.
- Two automatic vapour emission control systems feature an independent high-level alarm for the cargo and ship 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 computer in the bridge cargo control room.
- The ship is fitted with an inert gas generator and emergency towing equipment. Ballast tanks are inerted and used in oil washing can be carried out.

#### PIPING AND CARGO SEGREGATION

Cargo piping systems are designed with optimal loading, discharge, cleaning and cleaning characteristics in mind. Dedicated storage and loading systems are usually provided for segregated cargoes, with two or more segregated cargo pumps connected to each cargo line and crossover. Combined crude/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 to the left of each tank in accordance with the pump to shipboard to allow 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 cargo residue. A typical discharge rate for a cargo pump on a ship of this size is 4500m3/hour, and the hydraulic power pack enables the use of up to six pumps simultaneously.

#### TANK COATINGS AND CLEANING

The use of corrosion-resistant ballast and the positioning of stilleners outside the cargo tank, in the double hull spaces and on deck, enables cargo tanks to be designed with flitch walls to facilitate cleaning. The arrangement is also conducive to the application of cargo tank linings. Typical product tankers have three- to four-layer tank lining systems, although if it is a product or chemical tanker which will be engaged in the mechanical 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 lined with high-quality, anti-freeze, epoxy coatings to minimise the impact of corrosion and to facilitate inspection and maintenance. Most tankers are provided with two sets of ballasting pumps, located in the aft and forward or pump room, for ballasting and bilging. 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° – 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.

Unquote

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).
Cargo Tank vent system (2).

1 high-velocity relief valve
2 pressure/vacuum relief valve
3 drain cock
4 hatch
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.
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 falls, in order to compensate for the additional weight of tape used.

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.

![Diagram of pneumatic or hydraulic level gauge](image-url)

Pneumatic or hydraulic gauges using closed cell
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.

Differential-pressure gauge
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 diagram]

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.
6 OIL TANKER OPERATIONS

Learning objectives:
- to prevent flammable gas entering the ventilation system
- that number of craft coming alongside should be kept to a minimum
- that tanks or lines containing petroleum should not be drained into the pump-room bilges
- define specific gravity
- define the API scale
- the danger of line blowing and precautions to be taken
- that special procedures apply for ship-to-ship transfers
- define clean ballast
- COW operations
- tank cleaning operation
- tank cleaning with open-cycle and closed-cycle
- that slop tanks can be heated for better separation of oil and water
- that gas-freeing may take place through displacement or mixing
- the subjects to be covered by the discharge plan

6.1 General Precautions

6.1.1 Openings in superstructures

A tanker’s accommodation normally contains equipment, which is not suitable for use in flammable atmospheres. It is therefore imperative that petroleum gas is kept out of the accommodation.

All external openings should be closed when the tanker, or a ship at an adjacent berth, is conducting any of the following operations:

- Handling volatile petroleum or non-volatile petroleum near to or above its flashpoint.
- Loading non-volatile petroleum into tanks containing hydrocarbon vapours.
- Crude oil washing.
- Ballasting, purging, gas freeing or tank washing after discharge of volatile petroleum.

Although discomfort may be caused to personnel in accommodation that is completely closed during conditions of high temperatures and humidity, this discomfort should be accepted in the interests of safety.

6.1.2 Doors, Ports and Windows

In the accommodation, all external doors, ports and similar openings which lead directly from the tank deck to the accommodation or machinery spaces (other than the pump room), or which overlook the tank deck at any level, or which overlook the poop deck forward of the funnel should be kept closed. A screen door cannot be considered a safe substitute for an external door. Additional doors and ports may have to be closed in special circumstances, such as during stern loading, or due to structural peculiarities of the tanker. If doors have to be opened for access they should be closed immediately after use. Doors that must be kept closed should be clearly marked, but in no case should doors be locked.
6.1.3 Ventilators

Ventilators should be kept trimmed to prevent the entry of petroleum gas, particularly on tankers, which depend on natural ventilation. If ventilators are located so that petroleum gas can enter regardless of the direction in which they are trimmed, they should be covered, plugged or closed.

6.1.4 Central Air Conditioning and Mechanical Ventilating Systems

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 enclosed spaces.

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 closed and/or covered.

6.1.5 Window Type Air Conditioning Units

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 covered or closed.

6.1.6 Cargo Tank Lids

During the handling of volatile petroleum and loading of non-volatile petroleum into tanks containing hydrocarbon vapour, and while ballasting after the discharge of volatile cargo, all cargo tank lids should be closed and secured.

Cargo tank lids or coamings should be clearly marked with the number and location (port, centre or starboard) of the tank they serve.

Tank openings of cargo tanks, which are not gas free, should be kept closed unless gas freeing alongside by agreement.

6.1.7 Sighting and Ullage Ports

During any of the cargo and ballast handling operations referred to in 6.1.1, sighting and ullage ports should be kept closed. If for design reasons they are required to be open for venting purposes, the openings should be protected by a flame screen which may be removed for a short period during ullaging, sighting, sounding and sampling. These screens should be a good fit and be kept clean and in good condition. Closed loading of cargoes having toxic effects should be adopted.

6.1.8 Cargo Tank Vent Outlets

The cargo tank venting system should be set for the operation concerned and, if required, the outlets should be protected by a device to prevent the passage of flame. High velocity vents should be set in the operational position to ensure the high exit velocity of vented gas.

When volatile cargo is being loaded into tanks connected to a venting system which also serves tanks into which non-volatile cargo is to be loaded, particular attention should be paid to the setting of p/v valves and the associated venting system, including any inert gas system, in order to prevent flammable gas entering the tanks to be loaded with non-volatile cargo.
6.1.9 Tank Washing Openings
During tank cleaning or gas freeing operations tank-washing covers should only be removed from the tanks in which these operations are taking place and should be replaced as soon as these operations are completed. Other tank washing covers may be loosened in preparation but they should be left in their fully closed position.

6.1.10 Segregated Ballast Tank Lids
Segregated ballast tank lids should be kept closed when cargo or ballast is being handled as petroleum gas could be drawn into these tanks. Segregated ballast tank lids must be clearly marked as such.

6.1.11 Pump room precautions
The pump room precautions should be observed before and during all cargo handling operations. Tanks or pipelines should not be drained into the pump room bilges but if, on completion of deballastng this has to be done, care must be taken to ensure that such drainings do not contain petroleum. Tanks or lines containing petroleum must not be drained into the pump room bilges. Loading through or pressurization of pump room pipelines should be avoided if possible. No repairs are to be undertaken on cargo pumps, their associated relief valves or control systems, while the pumps are running. Throughout cargo handling operations, the pump room ventilation system must be in continuous operation.

6.1.12 Inspection of glands, bearings, etc.
Before starting any cargo operation, an inspection should be made to ensure that strainer covers, inspection plates and drain plugs are in position and secure. Drain valves in the pump room cargo system, especially those on cargo oil pumps, should be firmly shut. Any bulkhead glands should be checked and adjusted or lubricated as necessary to ensure an efficient gas tight seal between the pump room and the machinery space. During all cargo operations, including loading, the pump room should be inspected at regular intervals to check for leakages from glands, drain plugs and drain valves, especially those fitted to the cargo oil pumps. If the pumps are in use, pump glands, bearings and the bulkhead glands (if fitted) should be checked for overheating. In the event of leakage or overheating the pump should be stopped. No attempt should be made to adjust the pump glands on rotating shafts while the pump is in service.

6.1.13 Flange connections
Flanges for ship to shore cargo connections, at the end of the terminal pipelines and on the ship’s manifold, should be in accordance with the OCIMF publication “Recommendations for Oil Tanker Manifolds and Associated Equipment”. Flange faces, gaskets and seals should be clean and in good condition. Where bolted connections are made, all bolt holes should be used and care taken in tightening bolts as uneven or over tightening of bolts could result in leakage or fracture. Improvised arrangements using ‘G’ clamps or similar devices must not be used for flange connections.
6.1.14 Removal of blank flanges

Each tanker and terminal manifold flange should have a removable blank flange, made of steel or other approved material such as phenol resin, and preferably fitted with handles. Precautions should be taken to ensure that, prior to the removal of blanks from tanker and terminal pipelines, the section between the last valve and blank does not contain oil under pressure. Precautions must also be taken to prevent any spillage.
6.1.15 Reducers and Spools

Reducers and spools should be made of steel and fitted with flanges conforming with BS 1560, ANSI B16.5 or equivalent. Ordinary cast iron should not be used. (See OCIMF ‘Recommendations for Oil Tanker Manifolds and Associated Equipment’.) There should be an exchange of information between the ship and terminal when manifold reducers or spools are made of any material other than steel since particular attention is necessary in their manufacture to achieve the equivalent strength of steel and to avoid the possibility of fracture.

6.1.16 Examination of cargo hoses before use

It is the responsibility of the terminal to provide hoses, which are in good condition, but the master of a tanker may reject any which appear to be defective.
Before being connected, hose strings should be examined for any possible defect, which may be visible in the bore or outer covers such as blistering, abrasion, flattening of the hose or evidence of leaks. Hoses for which the rated pressure has been exceeded must be removed and re-tested before further use. Hoses to be used should have been pressure tested to manufacturer’s specifications at intervals, which are in accordance with the manufacturer’s recommendations or as recommended in the OCIMF publication “Guidelines for the Handling, Storage, Inspection and Testing of Hoses in the Field”. Intervals between tests should not in any case exceed one year. The date of such pressure testing should be indicated on the hose.

6.1.17 Handling, lifting and suspending

Hoses should always be handled with care and should not be dragged over a surface or rolled in a manner, which twists the body of the hose. Hoses should not be allowed to come into contact with a hot surface such as a steam pipe. Protection should be provided at any point where chafing or rubbing can occur. Lifting bridles and saddles should be provided. The use of steel wires in direct contact with the hose cover should not be permitted. Hoses should not be lifted at a single point with ends hanging down but should be supported at a number of places so that they are not bent to a radius less than that recommended by the manufacturer. Excessive weight on the ship’s manifold should be avoided. If there is an excessive overhang, or the ship’s valve is outside the stool support, additional support should be given to the manifold. A horizontal curved plate or pipe section should be fitted at the ship’s side to protect the hose from sharp edges and obstructions. Adequate support for the hose when connected to the manifold should be provided. Where this is a single lifting point, such as a derrick, the hose string should be supported by bridles or saddles.

6.1.18 Submarine and floating hose strings

Divers should inspect hoses in service at offshore mooring installations periodically. Particular attention should be paid to kinked or damaged sections, oil seepage from the hose flange areas, heavy marine growth and scuffing on the seabed. Where hose strings are lowered and raised repeatedly from the seabed, care should be taken to avoid damage caused by chains and lifting plates.
Particular attention should be paid when lowering hose strings to avoid coiling down. Dragging of hoses over the seabed should be minimised.

Before attempting to lift a hose string on board the responsible officer should check that the total weight involved does not exceed the safe working load of the ship’s derrick or crane, which it is proposed to use. The terminal should advise the total weight of the hose string to be lifted in relation to the height of the lift, which could be as much as 8 metres above deck level for a tanker’s manifold connection situated 4.6 metres inboard. In wave and/or swell conditions greater than 1 metre significant height, the movement of the hose may impose dynamic loads. In these circumstances the load to be lifted may be as much as 1.5 times the static weight of the hose and its contents.

During the lifting of hose strings, contact with the ship’s side and any sharp edges should be avoided.

When the hose string has been lifted to the required height for connecting to the manifold, and while it remains connected, the vertical section of the hose string should be supported by hang off chains or wires made fast to a strong point on the ship’s deck. In order to prevent spillage, precautions must be taken to ensure that, prior to the removal of blanks from submarine or floating pipelines, the pipeline does not contain petroleum under pressure. A visual inspection of each floating hose string should be made before connecting it to the tanker manifold to determine if damage has been caused by contact with other vessels, crossed lines, possible kinking, oil seepage etc. If any damage to the hose is found which is considered to be critical to the intended operation, the hose should be withdrawn from use to allow further inspection and repair.

6.1.19 Metal cargo arms

Each installation of metal arms has a designed operating envelope which takes into account the elevation changes resulting from the tide, the freeboard of the largest and smallest tankers for which the berth was intended, minimum and maximum manifold setbacks, limited changes in horizontal position due to drift off and ranging, and maximum and minimum spacing when operating with other arms in the bank.
The limits of this envelope should be thoroughly understood by operators because operating outside it can cause undue stress. Metal arm installations should have alarms for excessive range and drift. The person in charge of operations on a berth should ensure that the tanker’s manifolds are kept within the operating envelope during all stages of loading and discharging operations.

6.1.20 Forces on Manifolds

Most arms are counterbalanced so that no weight other than that of the liquid content of the arm is placed on the manifold. As the weight of oil in the arms, particularly the larger diameter arms, can be considerable it may be advisable for this weight to be relieved by a support or jack. Some arms have integral jacks, which are also used to avoid overstressing of the tanker’s manifold by the weight of the arm or other external forces such as the wind. Some counterbalanced arms are made slightly ‘tail heavy’ to compensate for clinging of oil and so that arms will normally return to the parked position if released, not under power, from the ship’s manifold. Additionally, in some aspects of the operating envelope there can be uplift on the manifold. For both these reasons manifolds should also be secured against upward forces.

6.1.21 Precautions while arms are connected

The following precautions should be taken during the period that arms are connected:

- The ship’s moorings should be monitored frequently by ship and shore personnel and tended as necessary so that any movement of the ship is restricted to within the limits of the metal arm-operating envelope.
- If drift or range alarms are activated all transfer operations should be stopped and remedial measures taken.
- The arms should be free to move with the motion of the ship. Care should be taken to
ensure that hydraulic or mechanical locks cannot be inadvertently engaged.

- The arms should not foul each other.
- Excessive vibration should be avoided.

## 6.2 Loading and Discharging Operations

### 6.2.1 Liquid Level Data-Gathering Systems.
To ascertain the liquid level in a tanker's cargo oil tanks, it is necessary to measure manually, mechanically or electronically:

- The amount of liquid in the tank, measuring from the bottom of the tank to the surface of the liquid. The resulting measurement is known as "The Sounding".

- The amount of space between the top of the tank (ullage plug) and the surface of the liquid. This measurement was known as "The Ullage".

### 6.2.2 Cargo calculations

Ullage, in combination with the calibration tables, enables us to determine the volume of cargo on board. Important though this information may be, it is only one step towards calculating the mass of cargo, a factor usually of more importance to the ship. Calculations of dead weight, freeboard, trim, stability and stress need information on mass rather than volume. It is therefore essential that volume be converted to mass.

The relationship between the volume and mass of a liquid can be expressed by its specific gravity (S.G.) also known as relative density (R.D.), which is the ratio between the mass of a given volume of liquid and the mass of the same volume of pure water. An easy way to determine the R.D. of a liquid is to weigh 1 litre of this liquid and express its weigh in kilograms. Since the mass of 1 litre of water equals 1 kg, the mass of the liquid in kilograms equals its R.D. For example, if 1 litre of oil were found to weigh 0.951 kg, its R.D. would be 0.951. This is the problem expressed in its simplest terms, for no mention has been made of temperature or of the fact that the industry usually works with different units.

Relative density is only correct at one particular temperature, known as the standard temperature. In the case illustrated above, the standard temperature is 4° C. For the oil industry, the standard temperature has been fixed at 60° F, and the R.D. that is advised by loading installation must be converted when cargo temperature differs from that temperature.

Conversely, if the R.D of the oil is checked on board by means of a hydrometer, the value measured must be converted to standard temperature in order to compare it with the figure provided by the installation.

The American Petroleum Institute uses another scale of mass/volume ratio. This is known as API scale, which is an arbitrary scale derived from the formula:

\[
API = \frac{141.5}{R.D. at 60°F} - 131.5
\]

Note that API goes up as the R.D. goes down.
6.2.3 M.T. "Seagull"

Vessel M.T. "Seagull" on her way from US Gulf to West Africa.
Built 1982
Speed 13 knots fully loaded
Slop 70 MT.
Stores 150 MT.
Fresh water 250 MT.
H.F.O. 1,900 MT.
M.D.O. 150 MT.
Lub. oil 1.00 MT.
D.W. D.W. summer = 131,489 MT.
D.W. winter = 128,090 MT. (126,080 LT.)

Tanks
4 centre tanks (CT)
4 wing tanks (WT)
2 slop tanks (WT # 5 P+S)

On February 2nd. the vessel received following loading orders:

Proceed to Bonny and load 460,000 bbls. Bonny Medium API 26.8 temp. 85° F. Thereafter proceed to Forcados and load 410,000 bbls. Forcados Blend API 30.4 temp. 85° F

6.2.4 Preliminary cargo calculation

As soon as the loading order received, you can start to do a preliminary calculation on how much cargo it's possible to load on this journey. First of all, you should check if it is possible to load the quantities asked for.

Using the ASTM tables, you can calculate the weight of a volume of oil at a certain temperature, or vice versa.
In the loading orders, the volumes given in barrels are volumes at a standard temperature of 60° F. This is the volume the cargo should occupy if it was loaded at a temperature of 60° F. The actual loading temperature is believed to be 85° F. This means that the cargo will take even more space as the oil expands with higher temperature.

In the loading order the weight is given in Long Tons (LT) at a standard temperature of 60° F. In the oil industry, it is still common to give the values in US Bbls and API and Long tons. But if the loading orders are given in Metric Tons (MT) and in cubic meters (M³), a standard temperature of 15° C is used.

Calculating with m³ and MT, you should use Density instead of API when you calculate the cargo. The industry is slowly moving towards the metric system. Today "World Scale", the system on which the freight of petroleum cargoes is calculated, is based on MT and the ship owners are paid after MT.

Use the same standards of weights, volumes, and temperatures, as indicated by the loading order, when you are preparing your calculations. This will reduce the possibility of misunderstandings.
In this ship we use the metric system and remember that all weights of slop, bunker, diesel, stores, etc. are given in MT.

First you have to calculate how much cargo the charterer want to load in the ship. Use ASTM table 11, Vol. XI/XII, where against given API, you can find the factors to calculate "Long Ton per barrel at 60° F".

The factor given for API = 26.8 = 0.13956 and for API= 30.4 =0.13645 Using that factor you get:

\[
\begin{align*}
460,000 \text{ bbls} & \times 0.13956 = 64,198 \text{ LT} \\
410,000 \text{ bbls} & \times 0.13645 = 55,945 \text{ LT}
\end{align*}
\]

In Volume XI/XII, using Table 1, you find that the factor for converting LT to MT is 1.01605.

\[
\begin{align*}
64,198 \text{ LT} & \times 1.01605 = 65,228 \text{ MT} \\
55,945 \text{ LT} & \times 1.01605 = 56,843 \text{ MT}
\end{align*}
\]

Total 122,071 MT

The charterer wants you to load 122,071 MT. and the question is: Can you do it?

In order to find the ship's total dw. in loaded condition you should take the following into consideration:

1. Estimated quantity of fuel on departure last loading port.
2. Quantity of diesel and lubricating oil on departure last loading port.
3. Quantity of fresh water on departure last loading port.
4. Quantity of slop on board on departure last loading port.
5. Quantity of stores on departure last loading port.

Based on above figures you can set up the following simple calculation:

\[
\begin{align*}
\text{Cargo} & = 122,071 \text{ MT} \\
\text{Slop} & = 70 \text{ MT} \\
\text{Fuel} & = 1,900 \text{ MT} \\
\text{Diesel} & = 150 \text{ MT} \\
\text{Lub. oil} & = 100 \text{ MT} \\
\text{FW.} & = 250 \text{ MT} \\
\text{Stores} & = 150 \text{ MT}
\end{align*}
\]

\[
\text{Tot. DW.} = 124,691 \text{ MT}
\]

Consulting the Load Line Chart, you can see that this time of the year the ship will pass into the winter zone when she passes Cape Finisterre. This means that the ship should be at her "winter mark" passing Finisterre. Consulting the distance tables you will find the distance from Forcados, the last loading port, to Finisterre is 3.430 miles.
Based on the ship's normal speed, fully loaded, 13 knots it will take 11 days to reach the winter zone. The ship is normally burning 50 tons bunker per day, which gives you a total of 550 MT.

This is what you can load on top of the ship's dead weight at her "winter mark".

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>DW. winter:</td>
<td>124,740 MT.</td>
</tr>
<tr>
<td>11 days consumption:</td>
<td>550 MT.</td>
</tr>
<tr>
<td>DW. for cargo:</td>
<td>125,290 MT.</td>
</tr>
</tbody>
</table>

As you can see it's possible to load the requested 122,071 tons of crude. You even have an allowance of 600 MT.

Now you can check available volume for the cargo. Use Table 6A. "Correction of Volume to 60°F Against API Gravity at 60°F".

First calculate the Bonny Medium, API 26.8. Use API 27.0 and 85°F as arguments and you will get the factor = 0.9892. The volume of the cargo must be bigger at loading temperature than at standard temperature 60°F. Divide 460,000 bbls with the factor and you will get 465,022 gross bbls.

Note that we are talking about net. bbls when measuring at standard temperature and gross bbls when the cargo is measured at actual temperature.

Forcados Blend, API 30.4, is calculated the same way but with API 30.5 and temperature 85°F as arguments. Divide 410,000 bbls with the factor found, 0.9888, and you will get 414,644 gross bbls.

Now you can make a rough estimation of where to place the cargo. Allowing 2% for expansion, 98% of the total cubic of the centre tanks (CT) is 383,628 bbls. And 98% of the wing tank (WT) capacity is 587,696 bbls.

First cargo to be loaded is Bonny Medium, 465,022 bbls.

It should be possible to load that cargo in the all centre tanks and WT 2. which will give you a total of 468,802 bbls available space.

That leaves you with the rest of the wing tanks and the slop tanks for the parcel of Forcados Blend of 414,644 bbls.

As available space in remaining WT. is 502,522 bbls. there is sufficient space for the Forcados cargo.

If the charterer doesn't state something else, the ship has an allowance of 5%, more or less, cargo. This gives you a certain freedom to complete the cargo, and to place different parcels of cargo in the most favourable position depending on trim, stress, and bending moments of the ship.

The following abbreviation are frequently used in loading orders:

MOLOO = "More or less, owners option". This means that you have the right to load 5% more or less, if your operation department doesn't state something else.
MOLCO = "More or less, charterers option". The charter is giving you the limits. This is not common with cargoes of crude.

MIN/MAX = This is an order to load exactly the quantities stated in the message.
6.2.5 Ullage Tables

Every time you calculate the volume of cargo or ballast water in a tank, you need the ship's ullage tables or calibration scales.

6.2.6 The accuracy of the ullage tables

The quality of the ullage tables can differ from shipyard to shipyard. As a matter of fact, the ullage tables seldom give you the exact volumes. After loading the ship a couple of times, you will find that your own figures will differ from the cargo figures given by the installation. Shore figures nearly always differ from ship's figures.

6.2.7 “Vessels Experience Factor” (VEF).

Most of the time, VEF is used in loading ports. The factor is used when you and the personnel from the installation are comparing your figures to decide if cargo differences are reasonable. If they are, the ship is released; if they are not, there is a time-consuming job to check the measurements and your calculations one more time. Today nearly all charterers demand that VEF should be used. They also state exactly how this ratio should be computed. There are many ways to calculate VEF. We will here show you one simple way of doing it, but don't be surprised if in a port, the surveyors and their company urge you to do it in another way.

You should compare the results of loadings done under the same, or nearly the same, conditions.

That's why you should not use the results obtained in connection with the following operations:
- Loadings right after dry-docking.
- Lighterings.
- Loadings where Bill of Lading is based solely on the ship's figures.
- Loadings after structural changes of the ship resulting in changed cargo capacity.

Even if VEF can be derived from a minimum of three (3) loading operations, the accuracy will, of course, be better if you use more operations.

1. Prepare a list of suitable loading operations. Find the ratio between ship's and shore figures.
   Example: Shore figures = 2,345m$^3$
   Ship's figures = 2,348m$^3$
   The ratio is found by dividing 2,348 with 2,345.
   Result = 0.9987.

2. Calculate the average between all used ratios.

3. Calculate 0.3% of the found average ratio.

4. Go back to step 2 and cut out all ratios that differ more than the figure you got under step 3.
5. Calculate a new average ratio from the figures left.

6. Finally, calculate how much 0.3% is of the average ratio.

7. a/ VEF is the figure calculated under 5.
   b/ Consider the accuracy of your VEF to be plus/minus the figure you got under 6.

Checking the cargo documents you find the following ratio between ship's and shore figures and based on this ratio you can calculate the VEF.

1. Note the following useable ratios:

<table>
<thead>
<tr>
<th>Voyage</th>
<th>Ratio ship's fig./shore fig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.9998</td>
</tr>
<tr>
<td>2</td>
<td>1.0120</td>
</tr>
<tr>
<td>3</td>
<td>1.0010</td>
</tr>
<tr>
<td>4</td>
<td>1.0027</td>
</tr>
<tr>
<td>5</td>
<td>1.0022</td>
</tr>
<tr>
<td>6</td>
<td>1.0054</td>
</tr>
<tr>
<td>7</td>
<td>1.0008</td>
</tr>
<tr>
<td>8</td>
<td>0.9990</td>
</tr>
<tr>
<td>9</td>
<td>0.9975</td>
</tr>
<tr>
<td>10</td>
<td>0.9985</td>
</tr>
</tbody>
</table>

2. The average of these figures 1.0019.

3. 0.3% of 1.0019 = 0.003

4. Cut out all ratios out of 1.0019 plus/minus 0.003, i.e. 0.9989 and 1.0049. The ratios given from journey 2, 6, 9 and 10 are not to be used.

5. New average ratio = 1.0009.

6. 0.3% of 1.0009 = 0.003.

7. a/ VEF = 1.0009 - b/ The accuracy of VEF = 0.003.

6.2.8 The ASTM tables

The volume of oil will change depending on its temperature. You must use the ASTM tables to calculate the volume of a cargo at a certain temperature. And you must use the tables when you are calculating the weight of a certain volume of cargo. Probably, there are quite a few volumes on board your ship. Their full name is the API/ASTM/IP Tables and the American Petroleum Institute, the American Society for Testing Materials, and the Institute of Petroleum in London publish them.

The tables are published in 12 (1 - XII) different volumes to be used for calculations concerning crude oils. Volumes XIII-XIV should be used when calculating lubricating oils. These tables replace the former American and metric editions. The latest edition is from 1980 and is considered to be more accurate than the earlier edition, but still some operators use the old edition.
Normally, you only need three (3) volumes to do the cargo calculation on board.

1. Volume I containing:
   - Table 5A, giving “Correction of Observed API Gravity to API Gravity at 60° F”.
   - Table 6A, giving “Correction of Volume to 60° F against API Gravity at 60° F”.

2. Volume VII containing:
   - Table 53A, giving “Correction of Observed Density to Density at 15° C”.
   - Table 54A, giving “Correction of Volume to 15° C Against Density at 15° C”.

3. Volume XI/XII, containing:
   - Tables 1, 2, 3, 4, 8, 9, 10, 11, 12, 13 and 14.
   - Tables 21, 22, 26, 27, 28, 29, 30, 31, 33, 34, 51, 52, 56, 57 and 58

Volume X could also be interesting to have on board as it gives explanations to tables and methods used in deriving the different tables.

Use Table 6A when you calculating volumes at temperatures other than the standard temperature of 60° F.

Use Table 54A. when you calculating volumes at other temperatures than the standard temperature of 15° C.

Use Table 11 when calculating weights in Long Tons against US Barrels at 60° F.

Use Table 56 when you calculating weights in Metric Tons at the standard temperature 15° C.

6.2.9 Calculating the cargo

When you calculate a cargo of oil you should always find its volume at a standard temperature. If you are going to use the metric system, use 15° C, and if you want to use barrels you should use 60° F.

The telex with the loading orders expressed volumes in Bbls and the API was also given. That means that the given volume is a net volume at a standard temperature of 60° F.

It is important not to mix these two systems.
You should never shift between the two standards, translating bbls into $M^3$ and API into Density.

You should always use the given standard as you are widening the area of uncertainty if you start to pump between different tables.

But, of course, you can convert the final results to whatever result you wish in the end. The oil industry uses a confusing number of different standards when calculating oil.

Volumes are given in barrels, $M^3$, cubic feet, or even in gallons. Weights are given in Long tons, Metric tons, Short tons, or even in Pounds. This lack of conformity forces you into a "grey zone" of uncertainty when you calculate the cargo of the ship.
6.2.10 Measurements and weights

The oil-industry uses a confusing number of measurements and weights. You have already used some of them, but before you go on with your cargo calculations let's look a bit closer at the measurements and weights used.

Both API and Density are used. But you can say that there is a shift towards using Density. In the American sector of the industry, API is still widely used. When you are using the metric system calculating with MT and m³, density is more suitable to work with.

6.2.11 Density

Density is described as “mass per unit of volume”. On board we are talking about the “weight in vacuum per unit of volume”. The density varies with the temperature of the oil. That is why it is absolutely necessary to note the temperature of the oil.

Using density means also using a standard temperature of 15°C. On board the ship you often have to determine the density of the slop oil. Using a suitable aerometer, you can test the sample taken.

The temperature of the sample is often not 15°C. To be able to calculate the weight of the slop, you have to find the standard volume, or the net volume, using the factor at 15°C. This factor is found in Table 53A.

When you calculate a cargo of oil, you are not interested in “weight in vacuum”. You are, of course, only interested in the “weight in air”. If you use Table 56, you should know that the table is corrected for it and you will get the “weight in air” as a result.

6.2.12 Volumes

Cubic meters - m³.

As you can see in the ullage tables, the volumes are given in m³ as well as US. Barrels, cubic feet and Tons F.W.

If you use density with your calculation it's easier to use m³. Density multiplied with the volume of the oil at 15°C gives you the weight of the cargo in metric tons.

US Barrels - bbls.

This is still the most common unit used by the oil industry. 1 US barrel = 0.158984 m³.

Cubic feet.

This unit is not very common today. 1 cubic foot = 0.0283169 m³.

Tons F.W.

In some ullage tables you find Tons F.W. Regardless of the name, this is not a weight. This is a volume containing the weight of one English ton, which is the same as 1016 kg of fresh water.

Depending on the uncertainty of the meaning of Tons F.W., this measurement is very seldom used on board.
6.2.13 Weights

There are two weights to count with in the oil industry. Either you use Metric tons (Tonnes or MT) or English ton (Long Tons or LT).
1 LT = 1.01605 MT.

6.2.14 Temperatures

Temperatures are given in either Centigrades (°C) or in Grades Fahrenheit (°F). If you need to convert between these temperatures, use Table 2.

6.2.15 Measuring of petroleum cargo.

A correct measurement of the level of the cargo in the cargo tanks is the base for cargo calculations, stability, and stress calculation.

To measure the cargo, you have to have knowledge and experience. You have to do your work meticulously and use your common sense.

You can either measure the level of the liquid in cargo or ballast tanks by hand, or use some permanent level-indicating system.

While the ship is discharging or loading, it is sufficient to rely on readings from a functioning automatic tank-level-measuring system.

For reasons of safety, it is very important that the responsible officer on board continuously follows the change of levels and weights in the tanks. The ever-changing weights must be calculated at suitable intervals, and the new data used to adjust the distribution of weights on the Loadicator or a similar cargo distribution instrument.

When the ship is loaded, or before the discharge commences, it's necessary to measure the ullages as accurate as possible. The ullages will be the base for cargo calculation.

The measurements should be taken with utmost care; the accuracy should be within 5 mm.

6.2.16 Ullage tape

An ullage tape is a gauge tape of stainless steel. It is graduated either meter/centimetre or feet/ inch. Which one of these measurements are used depends on what measure is used in the ullage tables.

The steel tape is coiled up on a drum with the help of a crank. The whole thing is mounted on a handle to enable the user to use the crank freely. To the free end of the steel tape is attached a graduated weight or a measuring rod. The graduation of the rod is the same as the tape.

You should be a bit careful reading an ullage tape. There are still two types used in ships.

The older type is the one where the 0-point is where the rod is fastened to the tape. The graduation of the rod is then done the opposite way. You add the measurement read on the rod to the actual reading of the tape.

There is another, and more modern, type of ullage tape, which is more frequently used on board ships today.

On this ullage tape the 0-point is in the end of the rod. That means that you should deduct the reading of the rod from the reading of the tape. Take a good look at the ullage tape you are going to use. Costly mistakes are frequently done.

To use the ullage tape you have to open an “ullage plug”, i.e. the point of measurement of every tank. The ullage plug is located as much as possible in the middle of the tank, thus minimizing errors from trim or list.
In some ships the ullage plugs are not placed even close to the centre of the tanks. When this is the case you have to be especially cautious when the ship has trim or list. If you don’t compensate for this, the errors may be big.

When you have opened the ullage plug, the tape is cranked out and lowered down into the tank until the rod is in contact with the surface of the liquid. The tape is then lowered that much that you have an “even reading” on your ullage tape at the rim of the ullage plug. Then it is wound up again. This is practical when you try to find the measurement. You only have to deduct, or add, the reading of the rod from the reading of the tape.

You should always keep the ship's ullage tapes in perfect condition. They should be kept clean from oil and dirt. The tapes should be treated with the utmost care to prevent wrinkling and crumpling of the tape. There are officially measured ullage tapes with certificates.

6.2.17 Sounding tape

In some tanks you take soundings instead of ullages. Taking a sounding means that you measure the distance from the bottom of the tank up to the level of the liquid.

You often use an ullage tape with a heavier weight in the end. The weight is there to enable you to feel when the tape hits the bottom of the tank.

Usually there is a graduated “dipping rod” on the end of a line long enough to reach the bottom of the tank. Dipping is often done before loading or after discharge to find out if there is some quantity of water or cargo residues left in the tank. Chalking the rod helps to find the sounding moves easily when measuring water on light oils.

All modern tankers are equipped with a special valve in the aft end of the tanks, especially arranged to make it possible to “dip” the aft end of the tanks without opening the tanks to the atmosphere (closed measuring) and losing all the I.G. pressure.

6.2.18 Safety restrictions when taking ullages

Taking ullages is risky and you have to take all precautions against explosions. You should study the special part of ISGOTT, describing these risks.

You have to be especially cautious when handling products prone to build high levels of static electricity.

Apart from the risk of explosion and fire, there is always a risk to work on a deck inhaling noxious and dangerous gasses fuming out of the tanks while taking ullage. You must take precautions to protect the health of your crew and yourself. Always stay to the windward of the open ullage plug and don't stay on deck more than you need. Use breathing apparatuses as protection when topping tanks. Special light breathing masks are today available on the market.
6.2.19 Automatic tank level gauging systems

Today most tanker ships have fixed automatic ullage meters installed in all cargo tanks. Ullages are taken in closed tanks and the ship's personnel are not exposed to hazardous gases. There are several different systems on the market. Here we will just take a look at two of them - one mechanical system with floats and one of the latest radar based system.

The first fixed ullage meters were just simple ullage tapes with floats mounted permanently in the tanks. Even today the principle is pretty much like that, but of course, the technique and the mechanics of the meters is better and more refined. The counting mechanisms and remote control transmitters make it possible to supervise and read the usages in the ship's cargo control room. The most modern systems use microprocessors to work on the signals transmitted by the unit.

Of course, the permanently installed ullage meters also will be affected by trim and list. Don’t forget to apply corrections, if necessary. The automatic ullage meter always consists of a housing mounted in a special trunk on deck, close to the centre of the tank. Between the housing and the tank bottom there are a couple of thin steering-wires. They are connected to the housing by springs, which keep them tight and protect them from breaking when the ship moves. Between these steering-wires runs the float, hung up by an ullage tape of stainless steel. The ullage tape is tightened by a special feather motor with enough power to take home the “slack” of the tape. But the mechanism is not strong enough to lift the float from the surface of the liquid. The ullage tape runs over a wheel whose shaft is connected to a counting mechanism showing how much tape is used, i.e. the ullage.

The same shaft is often connected to a transmitter unit converting the turning of the shaft to electrical signals. These signals are transmitted to the control room where the result can be read from meters. The mechanical parts of the meters are sensitive to wear and tear. It's important to remember to “dock” and secure the floats in their upper docking position when they are not used. There is a special crank to be used docking the floats.

If you forget to secure the ullage meters, the life of the feather motor will be dramatically reduced during a voyage. The swell and the constant movement is rapidly going to destroy the feather mechanism.

Do not use this type of meter during tank washing. The powerful jets of liquid will rapidly destroy ullage tapes and floats.
If these kinds of systems are well looked after and their functions checked regularly, they can very well be used to measure the ullage in a completely closed system.

Mechanically operated float gauge
6.2.20 Tank level gauging systems based on radar technique.

We will probably see a lot more of radar-based tank gauging systems in the future. Up till now, most of the existing systems have been installed in chemical and product tankers, but today even crude carriers are equipped with these advanced and accurate systems. Basically, it is a simple radar unit with an antenna directed down in the tank. The antenna is protected and mounted into a trunk on deck. Radar pulses are sent down in the tank where they are reflected back from the surface of the liquid. The pulses are received by the unit’s receiver.

![Tank radar]

This radar gives a very accurate measurement from the point of measurement to liquids surface. This type of equipment is well fit to work in this tough environment. The radar pulses are not affected at all by the temperature, pressure or mix of gases in the tank. Data of measurements, that is the time elapsed from when the signal is sent until it's received on its way back, are processed by micro processor in the central unit. The signals are converted and transmitted to instruments showing the ullage of the tanks. The system needs a minimum of maintenance. But the initial price is high, and these units contain highly sophisticated electronics difficult to service and repair on board.

6.2.21 Portable tank level gauges

Permanently installed tank level gauges are relatively expensive and difficult to install and service. To be able to discharge a tanker ship with its tanks closed, there is a need for a special system enabling the operator to check the levels in the aft part of the tanks. With the ship trimming by the stern, the fixed system just shows an empty tank when there is still a lot of liquid left in the aft end of the tank. Some manufacturers have designed portable gauging systems to take care of this problem. These systems are cheap, accurate, and most of the time, very simple. In the aft end of the tanks are special valves installed at the tanklids. The valves are built to let a portable unit and its rod pass through. The portable gauging instruments consist mainly of a wheel with a gauging tape plus a special coupling to be attached to the special valves in the deck.
With this, come also different types of sondes for measuring usage and control of interface between oil and water. The interface is usually indicated by a special sound signal. There is also a temperature sonde, enabling the operator to read the temperature digitally at any level. Manufacturers also supply different types of devices for taking samples from the oil in the tanks or from the bottoms of the tanks.

6.2.22 Cargo measurements in practice.

Of course, it should be possible to find out how much cargo a tanker had loaded by carrying out a “draught survey”, but the weight of the cargo is usually found by calculations based on loaded volume.
The ship's calculations are the “ship's figures”. The calculations done by the terminal are the “shore figures”. These two “figures” are always compared with each other and the “vessel’s experience factor” (VEF).
Most of the time, the measured quantities differ, but using the VEF when the differences are compared, will give a fair idea if the difference is inside the allowed limits. If it is, the ship is “released” and allowed to sail.
Should there be too big a difference, the ship is not allowed to sail. Measurements and calculations are done all over again to find, where and how big the eventual difference is.
In case of a difference, it is most important that the captain notes protest to be appended to the Bill of Lading.
The master should be careful to follow the instructions, given to him by the company's operational department, concerning protests.
Finding the volumes by taking ullages in the tanks during loading or discharge is also necessary to give the officers information about draught, trim, bending moments and shear forces on the hull.
When we are talking about measurements, we are mainly talking about finding the level of liquid in the tanks.

1. Finding final ullages or the sounded depths in cargo and ballast tanks.
2. Controlling ullages and “dippings” in cargo and ballast tanks during and after loading or discharge.
3. Finding the interface between oil and water in slop tanks.

6.2.23 Equipment for taking temperatures

To find the temperature of the cargo, three different types of equipment are used on board.

1. The mercury thermometer, the "cup thermometer"
2. Portable electronic thermometer units
3. Permanently installed temperature sondes transmitting the temperature to gauges

All this equipment must be continually and carefully checked. Temperature is the most important economical factor to consider. It is far more important than the API or the Density.

The cup thermometers

Still this old type of thermometer seems to be the most common thermometer on board in tankers. The thermometer is capsuled in a brass casing and fastened to a line of suitable length. Its bottom end is shaped in the form of a cup around the mercury bowl. It is capable of holding a certain volume of liquid when the thermometer is taken out of the tank. This is
to protect the thermometer from being chilled by the air. The temperature should be read before the cup is emptied of the oil. With a thermometer of this type you can only take the temperature at one level at a time in the tank. Usually the thermometers are placed in the centre of the volumes to be measured. The thermometers are graduated either in Centigrade (°C) or in Fahrenheit (°F). Before a mercury thermometer, or any thermometer, is sent on board it should be tested against a laboratory-controlled thermometer. The tests are done at three (3) or more temperatures within the normal working-range of the thermometer. This laboratory control should be done regularly once every year. This is a neglected routine in many ships. Before the thermometers are used on board, they should also be checked against an accurate certified thermometer kept on board. Before you use thermometers, put them all in the same bucket of water and check temperatures and eventual divergences. This control should be done at temperatures close to the cargo temperature. It is a good routine to have all thermometers numbered and to keep a special thermometer journal up to date. Note when the thermometers were tested and the divergences from the correct temperature. Another good routine is to use the same thermometers in the same tanks all the time.
**Electronic thermometers**
To get better and more accurate results, many operators use electronic thermometers where they can read the temperature momentarily and digitally at any level of the tank. Usually such a device consists of a thermo-sonde fastened to an ullage band. The temperature can be read on a digital display on deck.
This kind of thermometer should, of course, be tested once a year in a laboratory over their normal working range. The test is done in a temperature-stabilized bath and the results are documented.
Before a portable electronic thermometer is used on board, it should always be tested against a controlled mercury thermometer.
The thermometer should also be tested after it has been used. The results should be noted in the ship's thermometer journal. Controlling the instruments is company policy.

**Permanent thermometer systems**
Quite a few ships have permanent systems with thermo-sondes mounted in the tanks. The temperatures can be controlled from a display in the cargo control room.
These systems should be as carefully controlled and tested as any other system. Check against certified or especially controlled thermometers and follow the manufacturers manual.
You must realise that in port the personnel from the terminal will not rely on these permanent systems. They will use their portable equipment, or better, you will use the ship's portable thermometer to determine the temperature of the cargo.

**The temperature of the cargo**
It is very important to use the correct temperature when calculating cargo. Seen from an economical point of view, the temperature is the most important factor to be controlled by the chief officer.
The temperature of the cargo must be determined in a professional way. An average error of 1° C results in our ship in an error of 0,05% of the total cargo volume.

During loading, temperatures are not a very big problem. Due to the fast action and the turbulence in the tanks, the temperature is normally quite the same all over the tank. It is enough to take the temperatures at one level - in the centre of the volume.
By experience we know that the temperatures, after a voyage, or after a prolonged loading operation, will be found to be different in different layers in the tanks.
There are good reasons for taking the temperatures at different depths in the tanks and calculate an average temperature for each tank.
Not very long ago, the temperature of the cargo was found by placing a thermometer in every second tank. Today the temperature must be taken in every tank and each tank should be calculated separately.
The temperature should be recorded at nearest 0.1°C. The difference between a good job and a careless one could amount to 1,000 bbls in an ULCC.

6.2.24 Measuring the slop.

During the voyage there can be a problem in finding out just how much slop there is. Even with the electronic interface instrument, it is difficult to find where the interface between oil and water.

When you are going to measure the slop, you take the ullage and the temperature of the slop. Then you try to find the interface between oil and water. It is important that there is water left in the tank after the slop has been drained of water because in some ports there are severe fines if there is no water left in the bottom. The assumption is of course, that if there is no water, the ship must have pumped out too much oil while draining the tank.

To find the interface, two methods are used.

1. Using a water sensitive paste, which is coloured at contact with water.
2. Using an electronic interface instrument.

Water finding paste
The paste is smeared out thin at the last part of the ullage tape. If you do not like to try your luck at different depth, you can smear a large part of the tape and let it go all the way to the bottom of the tank.

When the tape is wound up again, you have to remove the oil to be able to see the discoloration of the paste, which has been in contact with water. The only way to do this is to use a spray bottle with grease remover or white spirit, spraying away the thick oil from the tape as it comes up on deck.

Theoretically, the paste has changed its colour where it came in contact with water. There should be a sharp borderline to where it is not coloured. Very often this is not the case. Working with these kinds of tests, you have to base your judgement on tests where the discoloring of the paste could be described as doubtful or uncertain.

This depends on the fact that there is seldom any sharp interface found. Between the clean water in the bottom of the tank, and the oil on top of it is an area mainly consisting of a mixture of oil and water, an emulsion.

To determine just what this emulsion looks like is impossible. You can only try to make a qualified guess about its consistency.

You should know that different pastes are more or less sensitive to water. Some pastes react with as little as 20% water in an emulsion, other pastes do not react until the content of water comes close to 80%.

Often you will find no change of colour at all at the tape. Don’t believe there is no water in the slop tank. There is always water in this tank - if it has not been discharged over board or to a shore installation.

The work of testing the slop could be very difficult if it is raining, or if there is a sea spraying the deck.
Electronic interface instruments.
There are various types of instruments on the market. The modern instruments often work with sound signals of different frequencies marking the presence of water or oil. The sound of the signal is supposed to tell you if there is oil emulsion or water.

The older instruments often have a meter from which you can read whether the sonde is in water or in oil by the deflection of the pointer. The principle is the same and builds on the fact that oil and water conduct electricity differently.

Also these kinds of instruments take a lot of experience to handle. You must be able to estimate the consistence of the emulsion - a stable emulsion can hold as much as 60% water.

After tank cleaning you should let the slop settle for a few days, before you try to estimate and find the interface between oil and water. You use both paste on the usage tape and the electronic instrument.

It is not easy to get a reliable result. As you suspected, you have two different measurements on where the interface is.

The discolouring of the paste is very vague. In the end you decide to trust the electronic instrument, which shows more water than the test done with the paste. This result is very common; you often measure more water using the electronic instrument compared to measurements using paste.

The ullage in the slop tank       7.54 m = 1,095
The ullage of the interface      8.41 m = 1,005

You estimate the layer of slop to be about 90 m³. Now it is time to start pumping the water over board through the Oil Discharge Monitor (ODM). But before you do that, ensure that the overboard line has been properly flushed with water. If the line is not clean, the overboard valve will not open.
After starting the ODM you can start to pump clean water from the bottom of the slop tank with the stripping pump. You can only pump as long as the ODM approves on the quality of the water.

The ODM gives alarm and the over board valve closes. That is the way it goes with these automatic monitors. They are very sensitive and you cannot do much more than accept its verdict. Now you doubt that your early estimation of the quantity of slop will be true.

There are still a few days left to the loading port and after flushing the overboard line with water, you will probably discharge more water from the tank. Exactly how much is impossible to say; you can only do your very best. But let us hope for something like 100 MT. Doing your best may include heating the slop a bit to speed up the settling process. The slop tank is fitted with a heating system to heat the contents and encourage separation. The slop is left until the day before arrival. The stripping pump, and its over board line, is carefully flushed with water.

The stripping pump is run very slowly and you manage to get out quite a lot of water until the ODM alarms and the pumping is stopped.

Down in the bottom of the tank, you have a mixture of water and oil, which could not be discharged.

When the ship is in port, every tank will be searched for “free water”. This “free water” is deducted from the cargo and no freight is paid for it.

The mixture of water and oil left in the slop tank will be considered as “free water” and added to what is found in the other tanks.

In the deck office you have a set of hydrometers to help you find the density of the cargo sample. Before you start, you had better check what kind of result these hydrometers give you; some may be graduated for specific gravity, others for density or API. Built into the hydrometer is a thermometer; check if it give you °C or °F.

In our ship all the hydrometers give density and temperature in °C. The sample is poured into a test glass and the hydrometer is carefully submerged into the oil.

Observed density is 852.5 and the temperature is 27.0 °C.

Now you should first find the corresponding density at 15 °C. Temperatures should not be interpolated. If you are going to use the result using Table 53A, you don't have to interpolate between density either.

The result is: density at 15 °C is 860.3. The weight of the oil is 0.8603 MT/m³ in a volume of oil at 15 °C.

Next thing is to find this volume at 15 °C.

The volume at 27 °C is 117m³.

Use Table 54A. and you will get the volume factor = 0.9900.

The volume at 15 °C is: 117 x 0.9900 = 115.8 m³.

The weight of the oil must be: 115.8 x 0.8603 = 99.6 MT.

6.2.25 Vocabulary

On Board Quantity (O.B.Q.)
This refers to all materials measured or estimated remaining in the ship's cargo tanks and pipelines prior to loading. This includes water, oil, slops, oily residues, oil/water emission, sludge, and sediment. The slop may be included if it should be a part of the cargo.

Liquid and Solids Remaining on Board (R.O.B)
This refers to the measurable material remaining on board a vessel after discharge. This includes measurable sludge, sediment, oil, water or oily residues lying on the bottom of the cargo tanks, pipelines, and pumps.
Estimated ROB
This refers to the estimated materials remaining on board a vessel after discharge. This includes sediment or sediment clingage on interior surfaces of the cargo tanks.

Sediment and Water (S&W)
This refers to materials coexisting with, but foreign to, the petroleum liquid. It is measured for commercial reasons. S&W is found by testing the oil in a laboratory using different methods. S&W is expressed in percent of the volume loaded.

Free Water (F.W.)
This is the total measured volume of water in the tanks. The water is not suspended in the liquid at observed temperature (See Sediment and Water, S&W). Water found in the bottom of the slop tank may be included if the slop tank isn't segregated from the rest of the tanks.

Total Observed Volume (T.O.V.)
This is the total measured volume of liquid in the cargo tanks, at the observed temperature and pressure, including F.W. and sediment, etc. The slop will be included if not segregated from the rest of the cargo.

Gross Observed Volume (G.O.V.)
This is the total measured volume of all petroleum liquids in the cargo tanks at observed temperature and pressure. Free water (F.W.) and O.B.Q is deducted. Also the slop is deducted if it isn't segregated.

Net Observed Volume (N.O.V.-)
This is the total volume of all petroleum liquids in the cargo tanks at observed temperature and pressure. S&W is deducted as well as F.W., O.B.Q and slop, if not segregated, is deducted from the volume.

Gross Standard Volume (G.S.V.)
This is the total volume of all petroleum liquids and S&W, minus F.W. and O.B.Q and slop if it isn’t segregated. This volume is corrected by using the temperature factor for API gravity, Density, etc. to a standard temperature of 60 °F or 15 °C.

Total Calculated Volume (T.C.V.)
This is the volume of all petroleum liquid and S&W and F.W., O.B.Q and slop if not segregated, corrected to standard temperature at 60 °F or 15 °C.

Net Standard Volume (N.S.V.)
This is the total volume of all petroleum liquids in the cargo tanks, minus S.W., F.W., O.B.Q. and slop not segregated, corrected to a standard temperature of 60 °F or 15 °C.
When the ship arrives at the loading port, you can expect the following to happen:

1. The tanks will be inspected to find how much sediment and liquid is left in them.
2. O.B.Q is established.
3. The slop will be measured and controlled to find Free Water.
4. The volume of oil and its weight will be measured after loading.

Usually the establishing of density and the water content of the crude is done by using standard laboratory tests.

6.2.26 Sampling

Samples are taken from the cargo to establish quality and samples are taken from the bottom of the tanks to find the amount of sediment and free water under the oil. The problem is to get a real representative sample of this huge volume of crude oil. The analyses of the sample can never be better than the sample itself. When we talk about testing and sampling of petroleum products, we mean such activities as:

1. Taking the temperature of the cargo.
2. Taking samples of the crude oil to find the density and the quality of the crude.
3. Taking samples to estimate the water content of the crude.
4. Taking samples from the bottom of the tanks to estimate the amount of sediment and residue from earlier cargoes.

The testing and sampling is done by surveyors representing the installation, the charterer or independent surveyors, often representing the ship owner.

On board the ship, the chief officer should always carry out this work and he must carefully observe and note all facts connected with the measuring or sampling of cargo.

He should make sure that measurements are correct and that there are no differences between the figures obtained by ship and shore personnel.

If there should be different opinions about measurements and samples, the chief officer must note the facts. These notations and a protest based on facts may be very important when claims are settled between the charterer and the ship owner.

The presence of a surveyor from shore does not mean that he, in any sense, has taken over the responsibility from the ship's officers.
6.2.27 Equipment used for sampling and testing quality and density of the cargo.

The hydrometer
To control the density, specific gravity or the AP, a hydrometer is used. The hydrometer consists of a cylindrical floating body of glass, weighted down with lead-shots. The floating body ends with a thin graduated pipe. If the hydrometer is submerged in a liquid, it will sink to a certain level, which could be read, from the scale on the pipe. In a lighter product the hydrometer sinks a little deeper, and the reverse if floating in a heavier product.

Before you test the density of the product you should check the scales. Sometimes hydrometers with different scales are kept on board. They could be graduated for Density, Apparent Density, Specific Gravity or API. Most hydrometers have a thin line engraved at the pipe. Check that the line corresponds with the one on the scale.

 Normally, you can count on an accuracy of three figures. The fourth figure will be a bit uncertain and the accuracy can be estimated to about ± 0,2 to 0,4 %.

Some hydrometers have a built-in thermometer. If not, you should use a calibrated laboratory thermometer to check the temperature of the sample. Together with the hydrometer, you can use a graduated glass to contain the sampled volume.

How to determine the density of a liquid
Normally, you don’t take samples in order to establish the density of the cargo on board. The density is given from the installation and you have to trust their information.

Determining the density of the slop oil is one of the few occasions when you have to find the density yourself in a crude carrier.

A sample of the slop oil is poured into a graduated glass. Finding a sheltered place, you put the glass on a plane surface. A checked hydrometer suitable for the range of density you believe the slop to be is carefully floated in the oil. After a short while, the hydrometer is floating free in the glass and has found its position of buoyancy. Try to read the scale as accurately as possible. In heavy products with high viscosity it will take some time for the hydrometer to find its position of buoyancy. When you let the hydrometer float free, it dips into the oil before finding its position of repose. The scale is smeared a bit with the oil and it is not easy to read the scale.

Be careful to read the right level of the oil. Because of the surface tension, the correct level is always a trifle lower than the actual level.

The temperature of the sample should be determined at the same time as the density is tested. This hydrometer has a built-in thermometer, which you find almost impossible to read because of the smearing of the hydrometer.

You have to get it out of the sample of oil to clean it with a rag. This manoeuvre doesn't take long, but if there is a big difference between the temperature of the sample and the temperature on deck, you may get an inaccurate reading from the thermometer.
Samples taken from the cargo
The general idea of obtaining samples from the ship's cargo tanks is, of course, to get a representative sample of the cargo. The buyer of the oil loaded in the ship, wants to ensure the quality of the product is the one he paid for.
The samples are sent to a laboratory to be analysed. But to determine the quality of a crude oil cargo out of analysing a few samples is not an easy task.
After being stored in the ship's tanks during a voyage, crude oil is not, compared to other liquids, a homogeneous liquid anymore.
Crude oil has a complex chemical structure and parts of it are extremely volatile at normal temperatures.
Most of the time, all the samples are poured into the same can. This can then faithfully be sent to the laboratory in the hope of acquiring a reliable result. Time is always short in ships. Routines are formed to handle sampling with speed and pure negligence is common.
The storage of samples
Samples stored on board should be marked with:

- the name of the ship
- the port of origin
- the date
- the type of product
- the tank from which the sample was taken
- the level at which the sample was taken.

When storing bottles of petroleum samples on board, it is wise to store these bottles in an upside-down position. If the cork or cap should leak, the content of the bottle will be less, but the quality will not be changed due to evaporation. The samples should be stored in a fire-safe, reasonably cool and dark place. To cover the time limits for eventual cargo claims the samples should, if nothing else is said, be stored on board for a time of at least one year.

Dead bottom sampling
There are two reasons for taking samples from the bottom of the tanks:

1. To find free water (F.W.) under the volume of oil prior to the discharge.
2. To find out how much liquid, residues or sediments is left in the tanks before loading and after discharge.

When the ship arrives at the port of discharge, the cargo is measured tank by tank. Ullages are taken but there is also a search for free water under the crude oil. Today it's common to use some sort of electronic device to detect free water.

O.B.Q. and R.O.B. survey
O.B.Q. (On board Quantity) surveys are carried out before the ship is allowed to load. R.O.B. (Remaining On Board) surveys are done after the ship is discharged. The purpose of these surveys is, of course, to find remaining cargo in the ship. These surveys are not very reliable, but they can give a hint of what's left in the tanks.

In a ship like this, with a single bottom and the cargo pumps installed in a pump room back aft, the tanks can not be completely dry. In the aft end of the tank there is always a small, wedge-formed amount of cargo left. It is impossible to drain this liquid aft of the suction bells.

When you stop draining the tanks, there must always be small amounts of cargo slowly floating aft from bulkheads and tank bottoms.

This amount of residue is not possible to measure with the ship's automatic ullage gauges. But these amounts of cargo are really discussed at length.

Often the discussion is whether there is 1 cm. or 2 cm. of cargo left in the tank. Usually, it ends with the measurement and calculation of the discussed “wedge”
To be able to calculate and estimate the wedge, the tank in question is dipped in its aft end. The tank is also dipped in the ullage plug, where it is, of course, empty. Everyone who knows the looks of a tank's bottom understands how uncertain this method must be. The amount of sediment and residues varies a lot over the surface of the tank's bottom. It's extremely difficult to make correct measurements of small volumes in the bottom of the tanks. If you analyse this kind of calculation for a moment, it's easy to understand its weakness. When you take ullage, the result is more correct when you measure a small ullage compared to a bigger ullage. Small amounts of cargo should be measured by dipping the tank. If you have managed to empty the tanks, you should forcefully state that the ship is “well drained” and that you have done everything as stated in the charter party. The ship's pumps are in good working order and the unpumpable residue the surveyors are talking about, is negligible and not in reach of the ships pumps.

To defend your position and the ship owner’s interests, you should carefully document everything that happened during the discharge in your pump log. You should also be careful to note what kind of routines the surveyors used and in what positions the tanks were dipped. In most ships documentation is not done properly. The routines differ from one ship to another even in the same company.

Sometimes, the ship owners use what is called “independent surveyors” to protect their interest. Normally, it does not take more than half an hour to inspect all the tanks. In case of a dispute, such a quick survey cannot be considered as properly done.

Actually, there is no other way to find the amount of residues than to use the sounding rod. There are no instruments for accurate sampling and measurement of sludge and unpumpable residues. In an argument over whether the residues are pumpable or not, you may ask the surveyor to bring up a sample of the unpumpable liquid. If it's pumpable, it should possible to take a sample.

You should also offer to start the pumps to show that the residues are not reachable or pumpable. Never hesitate to return to a tank to drain it once more with eductors. Be careful to follow the instructions given by the company's operational department covering this kind of situations.
6.2.28 Cargo calculation in practice.

After loading and before discharging you have to fill in all relevant information regarding cargo calculation in the ullage sheet. Most of the major companies have their own layout and the ullage sheet is more or less tailor made for each company. Below you will find an example on how to correct the ullage, calculate the cargo and fill in the relevant figures in the sheet.

Vessel: MT "Seagull"
Loading port: Ras Tanura
Cargo: Arabian Medium API. 34.5 Loading temp. 87.5°F
Voyage: 02/98
Date and Time: 26-Jan-98 1230

Cargo tank: CT. # 4
Measured ullage: 126.1 cm (measured in cargo hatch)
Draft after loading: F: 8.30 m - A: 8.90 m
List: 1 foot to port
Free water before loading: 23 cm = 48 bbls.

Fill in ullage sheet and calculate!

Calculation:
Draft A: 08.90 m.
Draft F: 08.30 m.
Trim: 0.60 m. = 2 feet by stern

Measured ullage: 126.1 cm
Trim corr.: 5.6 cm (+)
List cc rr.: 1.7 cm (-)
Corr. tillage: 130.0 cm

From ullage tab.: ullage 130 cm. in CT.4 gives 102,519 bbls.
From Tab. 6A: 0.9870 v. cf. = (102,519 x 0.9870) = 101,138.88 bbls GSV
From Tab. 11: 0.1330 wcf = (101,138.88 x 0.13308) = 13,459.56 LT
From Tab. 1: 1.01605 x 13,459.56 LT = 13,675.59 MT
**VESSEL ULLAGE AND CAPACITY REPORT**

<table>
<thead>
<tr>
<th>Before</th>
<th>After</th>
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**Vessel**: M.T. “Seagull”  
**Port**: Ras Tannura  
**Cargo**: Free Arabian Medium  
**Voyage No.**: 02/98  
**Date/Time**: 26-Jan-98

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<th>Tank No.</th>
<th>Ullages cm.</th>
<th>Trim/list corrected ullage cm.</th>
<th>Total Obs. Volume US BBLS</th>
<th>Gauge cm.</th>
<th>Water Volume US BBLS</th>
<th>Gross Obs. Volume US BBLS</th>
<th>Temp. F.</th>
<th>API @ 60° F</th>
<th>V.C.F. Table</th>
<th>Gross Std. Volume US BBLS @60° F</th>
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<table>
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<tr>
<th>Gross Standard Volume (bbl)</th>
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<tbody>
<tr>
<td>Fwd. Draft (m)</td>
<td>8.30</td>
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<tr>
<td>Aft Draft (m)</td>
<td>8.91</td>
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<tr>
<td>List (ft)</td>
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<td>W.C.F. Table 11</td>
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<tr>
<td>W.C.F. Table 1</td>
<td>1.01605</td>
</tr>
<tr>
<td>API @ 60°</td>
<td>34.5</td>
</tr>
</tbody>
</table>

**Chiefs Officer**:  
**Signatures**:  

---

**Gross Free Water (bbl)**: 48.00  
**Total calculated Volume (bbl)**: 101,186.88  
**Long Tons**: 13,459.56  
**Metric Tonnes**: 13,675.59  
**Capacity of Vessels lines**: API @ 60°
6.2.29 Cargo losses during transit

Evaporation
During loading and under the voyage, the lightest and the most volatile parts of the cargo evaporate. The evaporation and loss of cargo to the atmosphere can be considerable when transporting lighter qualities of crude oil.

All liquids evaporate.
Boiling water rapidly evaporates to gas. The “boiling point” of a liquid is the temperature at which the vapour pressure of the liquid is equal or higher than the pressure of the atmosphere. A liquid molecule changes into a gas molecule.
But you also know that water doesn't have to be boiled to evaporate and become gas. Water in an open jar will disappear at normal temperatures. This depends on the movements of the molecules in the water. They are constantly moving and when they move they collide. The collisions give some of them enough energy to enable them to break loose from the surface of the water and become gas molecules.
The same thing happens in crude oil but the process is, of course, more complicated. In the crude gases are dissolved which at normal temperatures exist in the form of gas.
The proportion of such gases gives the crude its characteristics. If you shake a bottle of crude oil you can see that the surface foams like a soft drink. Shaking the bottle you give energy to the sample of crude and the lighter parts will evaporate. Crude oil has no exact boiling point; it “boils” at a certain range of temperatures.
Handling petroleum, and other cargoes, the vapour pressure is of utmost interest. The vapour pressure governs the way a crude oil will behave during the voyage.
You may say that the vapour pressure is the pressure exerted on the enclosed space by the evaporated gases at a certain temperature.
When a tank is filled with oil, a small space remains at the top of the tank. As the oil evaporates and the temperature heightens, the pressure rises in this closed space.
The relation between pressure and temperature governs if a gas should remain in form of gas or become liquefied.
When the gas is saturated enough it reaches the dew point and the gas is changed into liquid.
In a closed space there will be a form of balance where evaporated gas again will become liquid. Before loading, the tank is filled with inert gas. When you fill the tank with crude oil evaporation takes place from the surface of the liquid. The inert gas is forced away by petroleum gases. After awhile a layer of hydrocarbons, 1-2 meter thick, will be formed above the surface. If the situation should be static in the tank during the voyage, a state of equilibrium should be established where gas evaporates and becomes liquid again.
But the situation in a ship is not static. During the voyage the temperature will vary and the ship moves all the time. Energy is given to the cargo in the tanks and the tanks start to breathe. Sometimes the pressure becomes higher than the allowed pressure for the tanks; a safety valve opens and hydrocarbons escape to the atmosphere.
When the temperature on the other hand is lowered, an underpressure is formed in the tank. If the pressure becomes too low, the valve opens to let inert gas into the tank.
Hydrocarbons will evaporate and cargo is lost. The presence of inert gas does not prevent evaporation and loss of cargo.
Another way to give energy to the cargo is to wash down the tanks with crude oil (COW) during discharge.

It's impossible to estimate how much cargo is lost during such an operation, but it's reasonable to believe that considerable amounts of cargo evaporate when COW is carried out using lighter qualities of crude oil.
This loss of cargo must be considered when light grades of crude oil are transported. Some of these crudes, the so-called spiked crudes, have been mixed with gas before the transport. To minimize the loss of cargo during the voyage, you have to study the conditions for the transport.

It's impossible to keep the ship's tanks completely closed. There are valves to regulate the connection between the tanks and the inert gas plant of the ship. The pressure of the tank varies with the temperature. The pressure of the inert gas line is controlled automatically.

Every cargo tank is equipped with a pressure/vacuum valve, a P/V valve. When the pressure rises, the P/V valve will open to air. The reverse happens when the pressure is too low. At a preset value the P/V valve will open and let air into the tank.

This function is also built into the inert gas system of the ship. Normally, the cargo tanks are all connected through the inert gas line, which has one, or several built in P/V functions. There is always one mechanical P/V valve at the inert gas line.

There is also a “Water lock” preventing the pressure from rising above what is allowed for the construction. The water level in the lock varies with the pressure at the inert gas line. When the pressure gets too high the water lock will “blow”. Remember that water evaporates; don't forget to check the lock’s water level.

All tanks are connected over the inert gas line, which helps to take care of variations of pressure, but impose the risk of contamination between different products and grades through this line.
Sediment
Another type of cargo losses depends on solid particles settling as sediment in the cargo tanks during the transport.
You will always find sediment in the bottom of the tanks. The quantity of this sediment depends on what type of crude oil the ship has been carrying in her tanks. It also depends on the temperature of the cargo during the voyage. During recent years more consideration has been given to what is called the “cloud-point” of the crude oil. This is the temperature at which the wax dissolved in the oil starts to crystallise and become solid.
Depending on this new knowledge more crude oil cargoes are heated during the voyage. Crude oils never known to present any problem to transport, and pump, are disposing great amounts of wax even at normal temperatures during the voyage.
Sediment is not found only in the bottoms of the tanks. A great deal of wax deposits on the bulkheads. This is called clingage. The amount of clingage grows if the temperature of sea and air is low.

Conclusion
If you consider all the aspects of measuring crude oil cargoes, you will understand to handle the measurements acquired in loading ports and ports of discharge with a caution.
Before discussing the weight of the cargo, you should think of the possibilities making wrong decisions.
From what we have said you may draw the conclusion that it's impossible to determine a correct density, temperature or volume of a cargo of crude oil. But that is of course not correct either.
One thing is true. If there is a dispute over volumes and weights, the ship will be in a much better position in this dispute if you use professional routines and document all actions taken during loading and discharge.

6.3 Ballasting and Deballasting

6.3.1 The ballast voyage
The basis for safe and efficient cargo handling operations begins during the ballast voyage. For each cargo voyage, the vessel must be able to demonstrate that it has been maintained in a “seaworthy” condition throughout and has done everything necessary for the proper care of the cargo.
Ballast water is used in tankers to increase seaworthiness and stability, equalise stress on the hull and improve manoeuvrability and fuel economy. Some ballast plans have the additional objective of reducing vibration underway. To minimize hull stresses, ballast tanks should be filled in the order indicated by the ship's ballast plan, and in proper co-ordination with the discharge plan.
Normal ballast plans produce a trim of between one and three meters by the stern. Careful attention to the trim of the ship can add as much as 0.5 knots to the voyage speed. A larger trim is essential for good draining while tank washing. The master is responsible for selecting a ballast plan for a safe and economic passage.
An approximate guide for the amount of ballast suitable for different weather conditions is:

<table>
<thead>
<tr>
<th>Wind force</th>
<th>Recommended ballast tonnage</th>
</tr>
</thead>
<tbody>
<tr>
<td>up to 4</td>
<td>30% of DWT</td>
</tr>
<tr>
<td>4 to 6</td>
<td>37% of DWT</td>
</tr>
<tr>
<td>above 6</td>
<td>42% of DWT</td>
</tr>
</tbody>
</table>

Ducted propellers require deeper stem drafts to reduce vibration. The ballast quantity must take account of the draft limitations of the fairway or channel and the height limitations of overhead bridges and power cables. Required air draft may be achieved by trimming the ship by the stem rather than by adding ballast.

If no CBT/ SBT capacity has been provided, ballast must be taken into dirty (or crude oil washed), cargo tanks. Such ballast becomes “dirty ballast” and must be disposed of according to MARPOL regulations. Any oil floating on top of the ballast water may be measured and declared as pumpable cargo by surveyors.

### 6.3.2 SBT Systems

Before 1978, one of the tanker procedures that have most frequently resulted in operational pollution of harbours was taking ballast following the discharge of cargo. In 1978, the International Maritime Organization adopted the MARPOL 1978 Protocol. This comprehensive anti-pollution agreement includes requirements for certain ships to be provided with ballast tanks, pumps and pipelines, which are completely “segregated” from the ship's cargo systems. Ships whose ballast systems meet the applicable requirements are certified as Segregated Ballast Tank (SBT), tankers.

The SBT tanks are required to be protectively located on all “new” crude carriers over 20,000 DWT and all “new” product carriers over 30,000 DWT. The protective location is intended to reduce accidental pollution due to collision or stranding. The SBT tanks can contain sufficient ballast to achieve an amidships draft in meters of $2 + 0.02 \times LBP$, with the propeller immersed. This is enough for all but hurricane or typhoon conditions if course and speed are properly adjusted in heavy weather.

Additional ballast can be taken in the ship's cargo tanks if the master thinks it necessary. This is done by means of a special pump room crossover connection (removable spool piece or blind), between the ballast and cargo systems. Heavy weather ballast carried in cargo tanks, which have been crude oil washed but not water washed must be handled as dirty ballast.

### 6.3.3 SBT pollution

SBT is not a fail-safe means of preventing pollution. Petroleum cargo can enter the SBT tanks through bulkhead leaks. SBT tanks can also be contaminated by cargo leaking into ballast piping which passes through cargo tanks, or by cargo leaking out of cargo piping which passes through ballast tanks. To maintain the maximum pollution safeguards while using SBT, routine operational checks and piping integrity tests must be carefully followed. Bulkhead leaks or ballast piping leaks can be sources of SBT contamination producing pollution and explosion hazards.
6.3.4 SBT operations in the discharge port

Before taking on ballast at the discharge port, it is advisable to vapour test the atmospheres of the ballast tanks. Before taking on SBT, open the tank-filling valve a few minutes prior to opening any other valves. Then inspect the ballast tank for any oil ingress as stated. Presence of hydrocarbon vapours in a ballast tank will indicate either a bulkhead or pipeline leak. Whatever the cause, the ballast piping to the affected tank will have to be flushed, and the tank washed before it can be used for clean ballast. The tank may be ballasted without washing, but the ballast will have to be handled as “dirty ballast” when it is discharged. The required entry must be made in the oil record book.

6.3.5 SBT contamination procedures

Once any contaminated ballast tanks have been suitably cleaned and ballasted, the vessel may depart for sea.

After the vessel is at sea, the cargo tank(s) adjacent to the contaminated ballast tank can be washed, ventilated and entered to examine the adjacent ballast tank bulkhead for leaks. (Keep in mind that some cracks will leak with pressure on one side, but will be forced closed by pressure on the other side “one-way leaks”. If the leak is located, the ballast tank can be emptied and the leak cold-patched with composition adhesive.

The location of the leak must be reported to owners/managers for permanent repair at the earliest opportunity. After the ballast is discharged at the loading port, the ballast tank can be ventilated and entered and the other side of the leak temporarily repaired, if necessary, before cargo is loaded.

If no bulkhead leak can be found, and particularly if the contamination appears in more than one ballast tank, a pipeline leak should be suspected. Test for a pipeline leak by leaving the ballast suction/fill valve to an affected ballast tank open during the ballast voyage and look for an accumulation of water in the empty cargo tanks. The water will indicate the location of the leaking pipe section. When the leak is located the cargo tank must be washed and ventilated and the affected section of pipe clamped to restore ballast system integrity until a permanent repair can be made. The installation of the pipe clamp, the type of clamp used, exact location of the leak, and the names of personnel who made the temporary repair must all be recorded in the preventive maintenance program record. The leaking pipe section must be scheduled for a permanent repair at the earliest opportunity, not later than the next shipyard period.

6.3.6 SBT precautions

Normally SBT tanks are filled while the cargo is being discharged, and emptied while cargo is being loaded. SBT provides an economic saving by permitting the vessel, to be able to sail immediately after completing discharge of cargo. Without SBT, when the cargo has been discharged, the ship would be in a “hogged” condition, with the amidships empty and the heavier bow and stem structures tending to arch the keel of the ship. To prevent these stresses, ballast will normally be taken in the amidships segregated ballast tanks first. The forepeak and afterpeak ballast tanks are filled last.

SBT hatches must be kept closed when handling cargo or ballast to avoid drawing hydrocarbon vapours into the tanks. (SBT tanks are not normally connected to the IGS system)

Do not overflow the ballast tanks in port: it may wash oily residues from the deck overboard, causing pollution.

Vessels, which ballast in rivers or shallow harbours, tend to accumulate sediment in their ballast tanks. Tanks with sediment accumulation should be washed and if necessary entered
and descaled on the loaded passage. All confined space entry procedures must be followed while cleaning ballast tanks.
6.3.7 **Written ballast plan**

The chief officer must prepare a ballasting plan for each loading and discharge port. The plan may be part of the general loading or discharge plan, in which case it should be set out in a separate section. The plan is prepared by considering the berth draft and freeboard restrictions and stresses on the hull resulting from the off-loading plan. The plan should be issued to the watch officers before arrival at the port so that it can be reviewed by them and discussed as necessary.

6.3.8 **Clean ballast tank systems and procedures**

Tank ships that are not equipped with segregated ballast tanks (SBT) may use their cargo system piping to take ballast into tanks reserved from carrying cargo. These reserved, clean, ballast tanks (CBT), are either original cargo tanks set aside for this purpose, or specially constructed tanks. The original purpose of the CBT concept was to provide an interim step between the earlier system of placing ballast in cargo tanks, and the ultimate goal of requiring SBT for all tankers. CBT was intended to reduce creation of oil and water mixtures on ships which:

- Are not provided with SBT, or
- Cannot COW because they do not carry crude oil,

Some CBT tankers have a pump and line sections reserved for ballast. The ballast operations for these ships are a combination of CBT and SBT procedures. The CBT filling and discharge procedures involve several opportunities for a pollution incident if they are not conducted exactly according to approved procedures. (See Annex I of MARPOL 73/78)

6.3.9 **Clean ballast systems**

The requirements for CBT systems and CBT operations are detailed and specific. They are set forth in IMO Resolution A.495 (XII) of 1981. Unlike segregated ballast tank (SBT) systems, clean ballast tank ships do not have complete separation of the ballast and cargo systems. A CBT ship uses some of its cargo piping, pumps, and valves to load and discharge ballast from the clean ballast tanks. However, it has become an apparently permanent fixture of older tankers, giving them an extended economic life and continued opportunities to cause operational pollution. The CBT system has added complexity to existing tanker operations. Using it properly requires careful study of the particular system, close attention to the procedures for conducting each step of CBT operation, and time. The most difficult CBT operation is ballasting at the discharge port.

6.3.10 **CBT manual**

Each tank vessel, which operates in the CBT mode, is required to have a CBT operations manual specifically prepared for it. The required content and format of this manual is prescribed in the IMO publication Dedicated clean ballast tanks, revised specifications for oil tankers with dedicated clean ballast tanks and standard format for the dedicated clean ballast tank operation manual. An example CBT operation manual and diagram are included in the IMO booklet.
6.3.11 MARPOL 73/78 (Regulation 13F)

(1) This regulation shall apply to oil tankers of 600 tons deadweight and above:

a) for which the building contract is placed on or after 6 July 1993, or
b) in the absence of a building contract, the keels of which are laid or which
   are at a similar stage of construction on or after 6 January 1994, or

c) the delivery of which is on or after 6 July 1996, or

(d) which have undergone a major conversion:

i) for which the contract is placed after 6 July 1993; or

ii) in the absence of a contract, the construction work of which is
    begun after 6 January 1994; or

iii) which is completed after 6 July 1996

(3) Ballast and cargo piping

Ballast piping and other piping such as sounding and vent piping to ballast tanks shall not pass through cargo tanks. Cargo piping and similar piping to cargo tanks shall not pass through ballast tanks. Exemptions to this requirement may be granted for short lengths of piping, provided that they are completely welded or equivalent.

6.3.12 Ballast records

All details of ballasting operations must be recorded in the Oil Record Book. Dirty ballast operations are also recorded in the port log. The deck logbook is used to record:

- Dirty ballast taken on in port.
- Dirty ballast taken on in river or sea.
- Clean ballast taken on.
- Dirty ballast discharged at sea.

All entries must include the times, tanks, and pipelines used for the ballasting operations, and the vessel’s positions at the time of ballasting.

6.3.13 Preparing for heavy weather ballast - taking dirty ballast

Ballast quantities as low as 25% of the ship's dead weight may be sufficient for undocking operations in most ports. Ballasting will continue as the ship departs the discharging port until all the ballast required by the departure ballast plan is on board. In most cases, the draft and trim produced by the SBT or CBT capacity of the ship is sufficient to manoeuvre in port and proceed en route to the next loading port without undue fuel consumption or damage to the vessel. Additional ballast may be taken into the ship's cargo tanks if the master thinks it is necessary for the safety of the ship. This does not mean that the master can ballast dirty cargo tanks to maintain desired speed in adverse weather. The most elective ways to reduce damage in heavy weather are to reduce speed or alter course. Only when these measures have been taken may additional ballast be loaded in the cargo tanks to ensure the safety of the ship. When it is probable that additional ballast will be needed during the voyage, the appropriate tanks will be required to have been crude oil washed. Ballast water that has been put into a tank that has been crude oil washed, but not water rinsed, shall be regarded as “dirty ballast”
and handled accordingly. Ballast water shall not be put into tanks that have not been crude oil washed.
6.3.14 Crude oil tankers without CBT or SBT

Crude oil tankers without CBT or SBT must ballast cargo tanks before departure from the discharge port. Ballast should not be put in cargo tanks unless they have been crude oil washed and water washed. The selected cargo tanks are discharged early in the discharge program. A complete COW cycle is performed in the selected tanks, with particular attention to the thoroughness of the bottom wash. The tank fill and suction lines should be stripped, and then isolated with two valve-separation from any continuing cargo operations. The tank fill lines should be flushed to a slop tank (if available) before filling the selected tanks with ballast.

6.4 TANK CLEANING

6.4.1 Tank washing plan

The requirements for tank washing during the ballast voyage are determined primarily by the cargo orders for the next voyage and the cargo previously carried. When the prior cargo is compatible with the next cargo to be carried, tank washing may not be required. At the other extreme, if a clean product voyage follows a black oil cargo then preparation may require extensive tank washing, cleaning and even drying before the tank is ready for the next loading. Other reasons for tank washing include preparations for clean ballast, maintenance cleaning (to prevent sludge accumulation), leak detection, tank or piping repairs and shipyard cleaning. In laying out his tank cleaning plan the chief officer considers cargo requirements, ballast, repairs and maintenance. The most efficient program is one, which cleans as many tanks as possible for more than one purpose. For example, if the chief officer has the choice of cleaning and de-scaling one of two tanks for a cargo change, one of which has been recently inspected, he should clean the other tank so that it may be inspected during the de-scaling operation. Tanks, which were crude oil washed, require water washing before they can be filled with “clean” ballast.

6.4.2 Crude Oil Trading

General

Normally, cleaning is not necessary between different types of crude oils, or between successive voyages. All tanks should be re-stripped to the slop tank after the vessel has departed and reached warmer waters. This step alone will recover most of the residual cargo in the tanks. Crude oil residues may be the most difficult to wash from the cargo tanks. They combine the high hydrocarbon vapour characteristics of gasoline cargoes with a potential for leaving sediment and wax. Sediment must not be allowed to accumulate in the tanks. If heavy sediment was noted on the previous discharge report, the tanks should be bottom washed and checked for proper drainage. On trades involving crudes with heavy sediment, frequent washing of all cargo tanks will be necessary to control the accumulation in tank bottoms. Alternatively, lighter crudes without sediment will require little or no tank washing between cargoes. Tanks which have been crude oil washed require little water washing to prepare them for clean ballast and limited ventilation before entry. When it is important to minimise washing water volumes (i.e. when slop disposal ashore is required), then all tanks scheduled for water washing should be crude oil washed at the discharge port.
Salt-water contamination of crude oils
Salt is a contaminate of crude oils. It is important to have crude tanks as dry as possible before loading. This is particularly true if the specific gravity of the oil is high, i.e. near to that of water. Salt water is difficult to separate from heavy crude oils and it can cause significant problems in the refinery. Some crude oils requiring particular care in this respect are:

- Boscan
- Tia Juana Pasano
- Bachaquero virgin gas oil

Preparation of tanks for these and similar crude oils should be conducted as follows:

- Hot water wash tanks to remove all loose scale, sludge and sediment.
- Flush the entire cargo system with fresh water.
- Strip tanks dry prior to loading and drain all lines and pumps.
- Blow lines with air or inert gas.
- Give all tanks a fresh water wash.
- Drain and blow down lines a second time.

If shorelines are to be displaced to the ship, they should all be received into a single tank. Any slop from the previous voyage should be segregated. After loading, check each tank for water and record the results. If excessive water is found, give a letter of protest to the loading terminal.

6.4.3 Crude oils with API's near to that of water (API = 10.0)

- Drain all tanks as thoroughly as possible to remove the remains of the previous cargo. A bottom flush or bottom wash is also recommended. Tanks containing heavy deposits of sediment and scale should be gun-cleaned with water.
- Remove all scale/sediment. If tank entry is involved, tanks must be gas freed and rendered “safe for men and fire”.
- After discharge of ballast at the loading port, and the thorough stripping of tanks and cargo lines, drain all cargo pumps and pipeline systems.
- Purge pumps and lines with compressed air or inert gas, giving due consideration to the relevant safety regulations in force.
- Test all heating coils to make sure they are in good operational condition.
6.4.4 Cutback asphalt

Since water is a critical contaminant of this cargo, it is essential that no water remain in the cargo system. The entire cargo system to be used for asphalt should be given a line and tank flush with fuel oil prior to loading. If detailed charterers instructions are not provided, then proceed as follows:

- Arrive with tanks free of residues and gas free. Strip the tanks, lines and pumps as dry as possible. Cargo systems (lines, pumps, and strainers), must be drained, and then blown dry. All cargo valves must be opened and drained to the cargo tanks. The tanks must be free of pumpable water.

- At the loading terminal set the lines for loading and load 200 to 400 barrels of flushing oil into each cargo tank. Then transfer the oil from tank to tank, using the ship's cargo pumps, until all tanks have been flushed. Dispose of oil (ashore or commingle with other fuel oil), according to charterers or owner's instructions.

6.4.5 Crude condensate

Ras Tanura loadings - special problems

Some crude oil condensate that has a Naphtha base can form chemical compositions when loaded into cargo tanks that previously contained crude oil. This occasionally results in the presence of large quantities of un-pumpable asphalt residues at the discharge port. These residues are derived from the interaction of the condensate with the ROB from the previous crude cargo. Asphalt cannot be removed by ordinary cleaning methods, so the cleaning is very expensive. Therefore, naphtha base condensate should never be shipped in unclean tanks containing crude oil ROB.

When condensate is loaded on top of crude oil, or if being topped up with crude oil the concentration of the lighter component should not exceed 10% by volume of the total crude/condensate mixture. This arrangement must be agreed between owners/shippers/charterers prior to loading, because:

- A higher concentrator may cause significant fallout of heavy, high boiling hydrocarbons, making it impossible to drain the tanks at the cargo port.

- If a richer mixture is shipped, the high vapour pressure of the cargo may prevent the use of crude oil washing in the discharge port, as the P/V valves will lift. Higher tank pressures will prevent IGS from properly flowing to the tank. Such cargoes should only be carried in SBT vessels.

6.4.6 Crude oils to be used in the manufacture of lube oils or asphalt

- Gun clean all tanks with hot water - one full cycle.

- Thoroughly flush all pumps and pipelines with water and pump as dry as possible.

- Remove all sediment, loose scale and sludge from tank bottoms. If tank entry is required, tank atmosphere requirements for “safe for men; safe for hot work” must be met.

- Rinse the entire cargo system with fresh water. If time allows, give all tanks a fresh water rinse.
6.4.7 Fuel oil/"black oil" cargoes

Thorough draining is required when changing from crude oil to fuel oil or from a fuel oil with a higher number to one of a lower number, such as from No. 6 oil to No.4 oil. Draining is not required when changing from a fuel oil with a lower number to one with an equal or higher number. Accumulation of sediment noted on a discharge report is an indication of the need for bottom washing of black oil cargo tanks.

6.4.8 Absence of cargo preparation orders

If cargo-loading orders have not been received at the time the ballast voyage begins, the ship should perform only the minimum necessary preparations, including:

- Flush tank bottoms with water and strip flushings to the slop tank.
- Wash pumps and pipelines to the slop tank.
- Wash necessary tanks for clean ballast (if required).
- Load clean ballast (if required).
- Decant dirty ballast, stripping residues to slop tank in accordance with A~OL requirements.
- Flush pumps and pipelines to the sea.

6.4.9 Tank cleaning operation

General
The tank washing operation requires the closest co-operation between the chief officer, and the deck crew to operate efficiently and obtain the required result. The best results will be obtained if the chief officer prepares a preliminary plan and discusses the plan with the crew involved in the operation. The plan should be detailed enough to indicate the times of starting and finishing the washing operation in each tank and the sequence of tanks to be washed. Problem tanks should be scheduled for daylight hours; easy ones can be done at night. The deck crew may be able to offer suggestions on handling of the portable tank washing machines, such as where they have been known to become entangled in tank structure when the ship is rolling. Including the crew in the planning of the job makes them more interested in seeing it done well.

With proper planning and scheduling, an experienced crew is capable of conducting all of the mechanical aspects of the tank washing operation with minimal general oversight by the chief officer.

When the chief officer has reviewed his plan with the crew, he adds the final details, and then discusses it with the master. The final plan should include both a diagram of the program and a detailed schedule. On the diagram, mark the time each tank will start, the times of program changes, or portable machine “drops” and the time it will finish. Allow sufficient time between tanks for stripping. Indicate the time when tanks may be sounded to measure residues (not less than 30 minutes after finish washing and only with a grounded probe). When the master has approved the plan, copies are distributed to the watch officers, chief engineer, engine control room and one copy is posted on the crews (company), bulletin board.

With the program set out in advance, the chief officer is free to concentrate on verifying the safe conduct of the operation, checking the operation of fixed or portable machines and ensuring that the next tank is set up for washing before the previous tank is finished. His primary objective is the safety of the crew. This is particularly important when washing with
portable machines. The portable machines are heavy, and there are many opportunities for the crew to create hazardous static electricity conditions if their actions are not properly monitored and correct procedures followed. When washing with portable machines, the crew is exposed to the dangers of broken feet and hands, hot water burns and tank explosions. The crew must be carefully instructed in safe work practices and provided with the necessary protective equipment of prevent injury. All personnel on board should be notified that tank washing operations are to commence and that all safety precautions as when loading must be observed.

If the tank washing program is extensive, or the ballast voyage short, the tank washing operation should be started immediately after dropping the outbound pilot and continue non-stop until it is completed. Three or four men are required in each hose handling operation, so the watch and crew rotation will need some careful consideration. Handling the heavy machines and hoses repeatedly for eight to twelve hours at a time is demanding work.

6.4.10 Portable tank washing machines

When tankers were smaller and crews were larger, all tankers were cleaned with portable tank washing machines. Portable machines are connected to the end of a special tank washing hose. The machines have a bronze body and the hose couplings are bronze. The hoses are marked at intervals of five feet or two meters. A natural fibre line must be attached to the machine for support and ease of handling, even though the hose is fully capable of supporting the machine unaided.

The other end of the hose is connected to a hydrant on the deck tank washing fine or fire fine. The water should be started and the hose flushed through before the machine is placed in the tank. The machine is then lowered into the tank through a tank-washing opening and supported by a “saddle” placed over the opening. The hose is clamped into the saddle and the machine tether line is made up on the saddle clamp to support the machine.

Tank washing openings are strategically placed in the main deck to permit good coverage of the tank’s inner surface without permitting the machines to become entangled in the tank’s internal structure. The tank cleaning openings are normally covered by bolted circular covers with gaskets. The bolts are removed from all the plates to be used, but the plates should be kept in place until a machine is ready to be inserted into the opening and the plate replaced promptly after the machine is removed. The distance the machine is lowered into the tank depends on the size of the tank and the amount of washing required. For heavy cleaning, the machine may be placed at three or four successive levels, depending on the complexity of the tank structure. If the cargo tank is known to have a heavy accumulation of sediment, the machines should be lowered to the bottom first and washed for ten minutes to clear the limber holes of sediment, then raised to begin the normal wash.
At each level, the machines are operated through a full washing cycle. The washing pressure determines the cycle time. When all machines are ready, the engine room is asked to start up the tank washing pump and if necessary the tank washing heater.

Seawater is pumped at high pressure from the engine room through the heater (if required), into the deck washing or fire line and into the tank washing hoses. The force of the water passing through an impeller in the machine causes the offset nozzles to rotate in a vertical plane and the whole machine to rotate in a horizontal plane. The jets of water from the nozzles trace a pattern on the inside of the tank, which provides effective coverage of the entire surface within range of the jets. The maximum range of the jets is normally nine to ten meters. The washing pattern described by the dual nozzle rotation resembles a ball of twine.

Cycle times for the washing machines are a function of nozzle size and washing water pressure at the machine. The pressure at the machine will be lower than the pressure at the pump room or in the engine room. The only way to accurately measure the pressure is to have a portable gauge fitted to the wash water supply line on a spare tank washing outlet near the machine hose connections.

For effective tank washing the number of machines used at one time must not put more water into the tanks than the stripping pump is capable of removing. By referring to the discharge rate curves for the machines on his ship, the chief officer can determine the maximum number of machines his stripping pumps can keep up with.

Complete coverage of the tank surface may not be possible with machines lowered through the dedicated tank washing openings. It may be necessary to lower a machine through the tank hatch, or to actually enter the tank and tie off a machine in a corner of the tank to remove accumulations in hidden corners. Confined space entry procedures must be used!

It is a good idea to leave the main cargo suction/fill valve open while the tank is being washed, to drain any residual cargo from the branch line into the tank.

If clean ballast is to be loaded, each tank should receive a short flush from the sea immediately before or when starting the washing operation.
6.4.11 Fixed tank washing machines

Tank ships larger than 60,000 tonnes are difficult to wash effectively with portable machines. The number of deck openings required to provide adequate coverage and the depth of the tanks would require a long and strenuous effort which today's smaller crew's are not capable of supporting. Tank washing capability for these larger tankers is provided by fixed tank washing machines, sometimes referred to as “guns”. Fixed tank washing machines are mounted on the deck of the ship with control machinery outside the cargo tank and the rotating parts and spray nozzle inside the tank. Fixed washing machines are capable of higher washing pressures and longer effective reach than the portable machines. On crude carriers, they are carefully placed to provide a washing pattern that covers the maximum amount of the tank surface by direct impingement of the washing stream. In accordance with IMO COW system requirements the shadow areas of the tanks shielded from direct impingement cannot exceed 10% of the tanks horizontal surfaces and 15% of vertical surfaces. The washing sequence of the cargo tank is programmed into each machine, depending of its location in the tank. A tank cleaning operation with fixed machines requires only that the machines be set to the correct starting position and operated in the correct order, to provide a complete cleaning of the tank. The fixed machines can be used to crude oil wash, (COW), or to water wash the cargo tanks, according to the purpose of the washing. Because of the static electricity hazards of high-capacity tank washing machines, they must only be operated in properly inerteled tanks.
**6.4.12 Washing pressures, temperatures and times**

The tank washing operation consumes energy and time and erodes the tank coating or tank structure. It is important that the washing be thorough enough to properly prepare the tank(s) for the next cargo, but not excessive. Washing tanks with too high pressure or temperature, or for excessive time will not improve the result and may cause coating or steel deterioration, which, if repeated often enough, eventually becomes significant damage.

Maximum tank washing pressures are often dictated by the capacity of the tank-washing pump. Higher pressures will reduce machine cycle times and the overall tank washing time. High pressures will produce a more thorough cleaning. Washing pressure of 12 bars, is most desirable for washing crude or fuel oils from un-coated tanks. For washing clean product tanks, pressures of 9 to 10 bar are suitable. Washing pressure must be maintained below the maximum allowed for the tank coating material in coated tanks. To properly measure the tank washing pressure, a gauge must be fitted in the tank washing line near to the machine connection. Chief officers should refer to the owner's operating instructions to determine maximum washing pressures. If no guidance is provided, it should be requested from the owners.

Unless there is a special requirement, tanks should be washed with cold (ambient) seawater. Cold-water washing will normally leave behind only a waxy skin, which provides a protective film for the steel. Tepid water (between 30 and 65° C) is of no practical benefit since it has the disadvantages of both hot and cold water without providing the benefits of either.
Maximum tank washing temperatures are often dictated by the capacity of the tank washing heater and the number of machines in use. Higher temperatures will increase the effectiveness of difficult washing situations. Washing temperature must be maintained below the maximum allowed for the tank coating material in coated tanks. Modern coatings, which have been correctly applied to properly prepared surfaces, should have no washing water temperature limitation and some charterers will not accept any. If maximum permitted temperature information is not available for a ship with coated tanks, then use an upper limit of 50° C.

Tank washing times must be calculated based on the washing pressure at each machine. For portable machines, the tank should be washed until the machine with the lowest pressure has been able to complete the full cycle. The portable machines may then be lowered to the next “drop” level. Only by permitting the machines to complete their full cycle is complete washing ensured. Portable machines are usually left at each drop for a complete cycle, but may be operated at the lowest drop for two cycles to remove heavy residue or scale accumulation from the tank bottom. It is important to check the position indicators on fixed machines to ensure that they have completed their cycle before stopping the flow and starting the next machine.

6.4.13 Handling portable tank washing machines and hoses

Portable tank washing machines and hoses are rugged, precision equipment, which require proper care and handling to provide safe and effective performance. Machines should never be dragged along the decks; the best way to move them from storage to the tank washing area is by use of a hand tuck. They should not be used in tanks with complex structure while the ship is rolling. The rolling may cause the machines to strike tank framing; this could damage the machine, damage tank coating and cause dangerous sparks. The portable machine should be fitted with a natural fibre line of up to 16 mm diameter. This line is used to lower and retrieve the machine from the tank, instead of lowering and pulling it out by the hose. Machines should be flushed with fresh water after use and dried or given a coating of oil according to the manufacturers instructions.

Tank washing hoses should be drained and stored in a protected area between washing operations. Tank washing hoses couplings should be tightened and disconnected from the washing main using wrenches only, (not hammered on). Regular replacement of the washers will prevent leaking. To prevent static electricity hazards, the hose bonding wire continuity must be verified before each use and the hoses must remain connected to the washing main at all times while the washing machine is in the tank.

6.4.14 Tank coating protection

Modem epoxy tank coatings are tough and resistant to all of the cargoes and tank washing procedures to which they would normally be exposed. However, there are limitations associated with each coating and it is important that these limitations be readily available to the chief officer and that he ask for clarification of any questionable circumstances. For example, certain types of coatings are not approved for carriage of some jet fuels. Both the coating and the cargo will be damaged by loading such fuels into the coated tanks. Coatings are also subject to damage by washing with too high temperature and/or too high water pressure.

To prevent such damage, the pressure and temperature limits should be readily available to the chief officer and posted at the tank washing heater-pump in the engine room. The chief officer must remember that a ship's tank coatings represent a significant portion of the overall cost of the ship and require his diligent care to protect them from damage.
6.4.15 Washing with detergents

Detergents should be used only when absolutely necessary. They are normally applied to difficult tank washing situations, where absolute purity of the next cargo is required. They are injected into the tank washing line by a mechanical pump, mix with the washing water and act along with the water jet to remove the previous cargo clingage and residue. When using detergents, the chief officer must:

- Ensure that the personnel using the chemicals are adequately trained regarding their hazards and that necessary personal protective equipment is made available.
- Verify that the detergents may be safely used with the tank coatings.
- Advise the owner/charterer that the ship will arrive at the loading port with tank washing slops containing detergent.

Detergents are harmful or poisonous to marine life and should not be discharged overboard. The presence of detergent in the wash water increases the potential for static electricity accumulation. To avoid dangerous accumulations of static electricity, used wash water containing detergent should not be recirculated from the slop tank for tank washing. Many loading terminals will not accept slops containing detergents. For that reason alone, detergents should not be used unless absolutely necessary.

6.4.16 Washing bunker tanks

Washing bunker tanks is not normally required except to remove contaminated bunkers, or to clean the tank for repairs. Bunker tanks are not usually set up with the necessary tank washing openings and the draining of wash water must be accomplished with the bunker transfer pump. For these reasons, bunker tank washing may require even more planning than a normal cargo tank washing. Hoses must be rigged to transfer the wash water from the bunker system to the cargo stripping system. Since the bunker tank opening may be in the engine room special ventilation or ignition control procedures may be needed to ensure that there is no opportunity for an explosive atmosphere to be created and ignited.

6.4.17 Inert gas system (IGS) and vent lines

Part of cleaning a tanker for repairs or shipyard period involves washing out all tank vent lines and inert gas lines. Even if cargo has not entered these pipelines as a liquid, cargo vapours are liable to condense in the lines and form accumulations of hydrocarbons. Cargo tank vent lines are fitted with washout connections permitting them to be flushed back to the cargo tank before the cargo tank is washed. The same flush-out connections are fitted to the IGS line. A tank washing hose should be connected to each flush-out connection and the branch lines flushed either into the cargo tank (before tank washing) or back to the deck non-return valve, from which they must be pumped or drained to a cargo tank.

6.4.18 Tank atmospheres and static electricity

General

One of the pillars of tanker safety is the separation of hydrocarbon vapours from possible sources of ignition. The first line of defence in this separation is the integrity of the cargo tanks. With the vapours contained in a cargo tank, protected by intact bulkheads, decks and
gasketed hatches, there is little opportunity for an accidental source of ignition to ignite the vapours in the tank. Unfortunately, the process of tank washing provides opportunities for a source of ignition to occur inside the cargo tank through accumulation and discharge of static electricity. To maintain the safest possible tank washing operation, the procedures must:

- Establish and maintain a safe tank atmosphere and
- Eliminate accumulation or discharge of static electricity.

With these precautions, a double layer of safety protection is maintained. If one preventive measure fails, the second will protect the ship against explosion or fire. If only one preventive measure is used, its failure could result in a disaster.

### 6.4.19 Controlling tank atmospheres

After discharging, the empty cargo tanks can contain a range of gas mixtures. The tank may be stratified, with a too-lean mixture at the top, an explosive mixture in the middle levels and a too rich atmosphere at the bottom. The methods used to eliminate any explosive mixtures from cargo tanks are:

- Reduction of the oxygen level to below the minimum necessary to support combustion (11% oxygen), i.e. creating an oxygen deficient atmosphere, or,
- Reduction of the hydrocarbon concentration to below the lower explosive limit (LEL), i.e. creating a too lean atmosphere.

To monitor the tank atmospheres the ship must be equipped with tank sampling/testing equipment capable of accurately measuring the concentrations of oxygen and hydrocarbons. Spare equipment must be carried, along with suitable calibration kits. Tanker officers must be properly trained in the calibration and use of tank testing equipment.

 Owners must provide detailed operating procedures for tank atmosphere control directing how ventilation equipment will be operated, how tank conditions will be monitored and the tank atmosphere conditions under which tank washing may proceed.

### 6.4.20 Maintaining too-lean conditions

To maintain a tank in too-lean condition during tank washing, it must be thoroughly ventilated to well below the LEL before washing commences. Washing should not begin until the hydrocarbon vapour concentrations are below 15% LEL. During the initial ventilation period, the tank atmosphere will pass through the explosive zone. It is imperative that no sources of ignition be present near the tank or the vent exhaust during that interval. While washing with too-lean atmosphere, a number of precautions must be observed.

These precautions are important for all tank washing using a too-lean atmosphere condition and are absolutely essential when washing tanks of more than 10,000 cubic meters capacity:

- Flush the tank bottom with water and strip dry before washing begins.
- Wash only one tank at a time.
- Concentrate the vessel's tank ventilation in the tank being washed. If tank ventilation machinery stops, secure the washing operation.
- Ensure tank vapour concentration is below 15% LEL before starting the washing operation.
- Use portable tank washing machines; do not use permanent, high-pressure tank washing machines. Observe all precautions regarding tank washing hoses and machines.
- Ensure that the stripping system keeps up with the egress of wash water into the tank.
- Wash with clean, cold seawater. Do not recirculate water; do not heat the wash water; do not add detergents; do not steam the tank.
- Measure tank atmosphere frequently during washing (measuring equipment must have suitable intake filters to prevent internal moisture damage).
- Suspend tank washing if the hydrocarbon vapour concentration exceeds 40% LEL; resume when levels throughout the tank are again below 15% LEL.
- Vent tanks only through the tank venting system. If tanks are vented to a common header, isolate the tank being washed to prevent entry of gas from other tanks.
- Verify, that the expelled vapours are not accumulating dangerously elsewhere on the ship.

As long as relative winds exceed 10 knots, there is little possibility of dangerous accumulation of vapours. If necessary, change course to obtain a relative wind speed of 10 knots. During ventilation and washing, the same precautions used for loading must be in place, including:

- Remove all possible sources of ignition.
- Keep accommodation and machinery doors closed.
- Minimise the number of tank openings that are open at any one time.
- Have the fire fighting system in readiness.

The initial washing operation can be expected to stir up cargo residues and increase the LEL reading. After one hour of washing, enough residues will have been removed that there should be little possibility of again exceeding the 45% level. In any event, tank monitoring should continue until the washing program is complete.

### 6.4.21 Inert gas ventilation

If fixed, high-pressure tank washing machines are to be used, regular ventilation techniques cannot maintain a safe atmosphere; inert gas must be injected into the tank to reduce the oxygen level below that necessary to sustain combustion. With the tank inerted, it can be safely washed with high-pressure tank washing machines.

A slight positive pressure (not less than 100 mm water gauge) must be maintained on the tank being washed, to prevent entry of oxygen rich atmosphere into the tank.

The tank must be regularly checked to ensure that an atmosphere containing less than 8% oxygen is present at all times. If the oxygen concentration rises above 8%, tank washing must be suspended and the tank purged with IGS until the oxygen content is reduced to below 8%.

Some tank atmosphere testing equipment is incapable of accurately measuring hydrocarbon concentration in an oxygen deficient atmosphere. If hydrocarbon concentrations need to be measured in inerted tanks, the chief officer must ensure that his equipment is capable of giving accurate readings under such conditions.
If there is any reason to doubt that the tank is properly inerted, it should be considered a non-inerted tank and all necessary precautions observed.
6.4.22 Tank washing with uncontrolled atmospheres

When it is not possible to control the tank atmosphere in large cargo tanks, the following precautions must be observed:

- Use only low-capacity, portable tank washing machines.
- Use a maximum of four machines each having a flow rate less than 35 cubic meters per hour, or not more than three machines in one tank each having a flow rate of 35 to 60 cubic meters per hour.
- Verify tank-washing hose bonding wire continuity before hoses are used.
- Flush washing hoses with clean seawater before using. Use only cold, clean seawater for washing; do not heat or recirculate wash water. If hot water must be used, then tanks should be washed with cold water first and then ventilated before hot water washing; do not add chemicals.
- If cargo pumps are used to provide wash water, they must be thoroughly flushed beforehand.
- Strip tanks being washed continuously to avoid any build-up of wash water.
- Flush and drain all lines before ventilating tanks with fixed tank ventilation systems after washing.
- When draining tank-washing hoses do not uncouple the hoses from the washing main! Hoses must remain connected to maintain the electrical grounding of the machine and hose while it is in the tank. To drain the hose, loosen the coupling only enough to let the hose drain; then re-tighten the coupling while pulling the hose and machine out of the tank.
- Remove portable tank washing machines before ventilating tanks.

Whenever tanks are being washed in an uncontrolled atmosphere, the precautions regarding sources of ignition and static electricity, must be scrupulously observed! All chipping and scaling and any machinery repairs are prohibited on the main deck while tank washing or ventilation are in progress. All door and port openings onto the main deck must be closed.

6.4.23 Static electricity while tank washing

During a three-week period in 1969, a series of three super tanker explosions sank one ship and took several lives. All three explosions occurred while centre cargo tanks were being washed. The two vessels, which did not sink, required extensive, costly repairs. The exact cause of the explosions was never determined, but the most probable cause was accumulation and discharge of electrostatic charge while tank washing. The investigations, which followed, found that large electrostatic charges could develop while tank washing due to:

- Commencing washing with large accumulations of oil remaining in the tank.
- Adding chemical agents to the tank washing water.
- Recirculating tank-washing water.
- Washing large cargo tanks (greater that 10,000 cubic meters).
Static electricity, or more properly “electrostatic charging” can be produced during tank washing operations by:

- Accumulation of tank washings in the cargo tank. The oil/water mixture will be subject to charge separation and may produce an accumulated electrostatic charge.
- Spraying or splashing of oil. Crude oil washing will produce electrostatic charging in the cargo tank. Water washing of a tank that has not been adequately drained may also cause charge accumulation.
- Use of conductive ullage tapes to measure tank bottoms during tank washing. Permanently installed ullaging equipment should be used to verify correct stripping during tank washing. Wait one hour after tank washing (if artificial ventilation is used), before sounding a washed tank, five hours if only natural ventilation is used. Tanks may be sounded in less time if a natural fibre line and wooden sounding rod are used. No precautions are necessary if sounding inside a metal sounding pipe.
- Floating conductors in the tank. Dropped or lost sample cans which remain afloat in the tank do not accumulate charge, but can produce a path for the short circuit of an accumulated charge from the surface of accumulated tank washings to the tank structure.
- Steaming of cargo tanks. If cargo tanks are steamed using hoses that are not properly bonded to the ship's piping, an electrostatic charge will accumulate on the hose. The water droplets from the steam will accumulate electrostatic charge and may cause an incendiary spark if the tank is steamed too vigorously. Therefore tanks should be steamed only with fixed apparatus, only at low velocities and only when the tank is free of any grounded probes (including properly bonded tank washing machines).
6.4.24 Stripping during tank washing

General
Effective cleaning of cargo tank bottoms requires that they be continuously drained while washing. The ship's stripping pumps or eductors are used to remove tank-washing water throughout the tank washing process. For the pumps or eductors to do the job properly, a number of factors must be considered.

Washing trim
The ship must be correctly trimmed and listed. The best tank washing trim is a compromise among ship speed, hull bending and shear forces and effective tank draining. The ballast arrangement must not exceed maximum acceptable seagoing stress numerals. Excessive, trim will reduce speed more than necessary. The trim must be enough so that the wash water flows with enough vigour to carry sediment to the stripping suction inlet. 4 meters of trim may be adequate for a 40,000 tonnes ship, while 8 meters may be necessary for a 200,000 tonnes tanker. The ship should be listed so that the tank will drain toward the stripping suction. If stripping suctions are located in the port corners of the tank, then a port list of three or four degrees is needed. Poor draining will result if the ship is rolling. Additional list may be required so that the tank bottom is always inclined toward the suction inlet while rolling.

6.4.25 Stripping pump operation
Check the setting of the stripping system valves carefully before tank washing begins. All suction valves on the stripping line should be verified closed and the appropriate discharge valves open to transfer washings to the selected slop tank. Verify that the overboard discharge and overboard block valve (if fitted), are closed and lashed. Finally open the suction valve to the tank(s) being washed.

The stripping pump should be started before the tank washing machines are turned on to remove any residual oil from the tank before washing begins. It should be operated at moderate speed and frequently checked to see that it is not vapour bound, but is transferring the tank washings effectively to the slop tank.

While hot-water washing, the water from the stripping pump discharge should be warm or hot. If it is cold, the stripping pump is not keeping up with the washing operation. To prime the stripping pump, close the suction from the washing tank momentarily and open the stripping suction from an appropriate ballast tank. Then close the ballast tank suction and resume stripping the washing tank.

Float-type ullage gauges should be retracted to the stowed position when tank washing, to prevent damage from the washing jets. If these gauges need to be used to check for wash water accumulation, then the tank washing machines must be shut off before lowering the float. If an eductor is used for stripping, good suction will be available unless the mechanism becomes clogged with scale or other material from the tank.

Continue to run the stripping pump on a washed tank after the tank washing machines have been stopped. Watch the suction and discharge gauges of the stripping pump to detect when it has removed all free liquid from the tank and lost suction. If using a reciprocating pump with a stroke counter, the stroke rate will increase when the tank dries.

Do not sound the tank with portable ullage equipment to see if it is dry! Sounding tanks immediately after washing could produce an electrostatic discharge.

Do not sound tanks until they have been ventilated for one hour, or five hours have passed without ventilation.
6.5 SLOP-TANK OPERATIONS

6.5.1 Slop tank capacity
Before tank washing operations begin, the volume of space available in the slop tank must be determined and a rough estimate made of the washing time necessary to fill that volume. If the slop tank has a capacity of 2,400 tonnes available and four washing machines are to be used, each supplying 30 tonnes of water per hour, then the slop tank will be filled after less than twenty hours of tank washing. The slop tank will fill at a faster rate than the rate of washing water use, because it also receives the oil recovered from the cargo tanks along with the washing water. The slop tank capacity is usually 3% of the cargo carrying capacity of the ship and tankers over 70,000 DWT must have two slop tanks.

During tank washing, the slop tank must be regularly monitored to verify the amount of space remaining to receive tank stripping. In automated tankers, the slop tank level alarm should be set to alert the cargo control room operator at 90% capacity.

6.5.2 Closed-cycle and open-cycle washing
Most tank washing operations begin with open cycle washing. As the slop tank fills with tank strippings, it will begin to separate with the water layer on the bottom and the oil residue on top. After, time, the bottom of the tank contains water with very little oil and this water can then be recirculated as tank washing water. If this is done the washing operation becomes a closed-cycle one.

Closed cycle tank washing has the potential for producing static electricity. Closed cycle washing should not be used unless the tanks are properly inerted to less than 8% oxygen. Tank washing water should never be allowed to free-fall into the slop tank. The slop tank must be filled to cover the slop inlet pipe before washings begins.

The slop tank level must be regularly checked during closed-cycle operations, since the quantity of slops will increase slowly as the washing operation recovers oil residues from the cargo tanks.
6.5.3 Dirty ballast residues

After tanks have been washed for clean ballast and the clean ballast has been taken in, dirty ballast can be discharged. The last meter or two meters of dirty ballast in each tank is retained and transferred to the slop tank. The chief officer must ensure there is sufficient capacity in the slop tank before stripping the last of the dirty ballast.

6.5.4 Decanting the slop tank

During tank washing, the method used to decant the contents of the slop tank depends on the number of slop tanks on the vessel. If the ship has two slop tanks, a continuous decanting process can be used.

One slop tank is used to receive the tank washing strippings. It acts as a first stage separator, permitting the bulk of the oil to accumulate on the surface of the tank. When the first slop tank has reached a sufficient ullage, the decanting line to the second slop tank is opened. The comparatively clean water from the bottom of the first slop tank then flows by gravity to the second slop tank. As tank washing continues, the decanting process delivers more water to the second slop tank until it contains enough volume to begin discharging. If the tanker is outside prohibited zones and can discharge from the second slop tank within permitted discharge limits, then the second slop tank can be discharged through the oil discharge monitor to the sea. Depending on the ship's draft and the level of the overboard discharge, it may be possible to decant the tank by gravitation. This method is preferred because it makes it impossible to inadvertently discharge the whole of the slop tank contents overboard. The level of liquid in the slop tank will be automatically maintained at or above that of the overboard discharge or the sea level, whichever is higher.

If pumping is required to remove the decanted water from the second slop tank, then tank washing may have to be stopped while one of the stripping pumps is used to decant the tank. When the tanker has only one slop tank, or is using a single cargo tank for a slop tank, then the opportunity to perform continuous slop tank decanting depends on the arrangement of the delivery and suction lines in the tank. If the tank washing water is introduced into the slop tank at mid-height and at a point well removed from the slop tank suction bellmouth, then it may be possible to perform continuous decanting. If the used wash water is introduced to the slop tank through one of the regular suction/fill lines and bellmouth, then continuous decanting is not possible and batch decanting will be required.

Batch decanting of the slop tank involves continuous tank washing until the slop tank is filled with wash water. Washing is then stopped and the tank is allowed to settle until the water at the bottom is within acceptable discharge limits. This will normally take twelve to fourteen hours. The depth of the oil/water interface is measured using an approved oil/water interface detector.

(Full details of the use of the oil/water interface detector are contained in the OCIMF Clean seas guide for oil tankers)

The slop tank is then decanted through the ODM, by gravity or by pumping. Slow decanting continues until the water layer has been reduced to the minimum or until the permitted discharge limit is reached, whichever occurs first. Decanting is stopped and tank washing resumes. The washing followed by batch processing routine continues until all tank washing liquids and the tops of the dirty ballast tank contents have been processed. Throughout the slop tank filling and decanting process, the level of the slop tank(s) must be closely monitored to ensure that a safe ullage is maintained.
Slop tank settling and decanting will be less effective if the vessel is rolling or pitching. If this is the case, it may be necessary to accumulate wash water in another tank, or to suspend tank washing or slop tank-decanting operations until weather conditions have improved.
6.5.5 Pump room bilges

Pump room bilges may be transferred to the slop tank at any time during the ballast voyage so long as they do not contain any detergents, cleaners or emulsifiers used to clean the bilges. Pump room bilges should be maintained in a dry condition and frequently inspected to have the earliest indication of any cargo leaks from pipelines, valves, or from other defects. If the pump room is fitted with a gas or mist detection system (recommended), it is important to keep the bilges oil free. The gas detection system will then give timely warning of any new leakage to the pump room. The best way to keep pump room bilges continuously dry is by means of a small permanently installed pump (air or hydraulic), with a separate suction line and separate discharge line to the slop tank filling line. Bilges can then be maintained dry regardless of the ongoing use of the stripping pump(s).

6.5.6 Engine room bilges

Engine room bilge water accumulations should normally be treated and discharged through the engine room treatment system. If it is necessary (due to defect in the engine room treatment system) to transfer engine room bilge water to the slop tank, then the chief engineer must first obtain the master or chief officer's permission for the transfer. Engine room bilges should not be transferred if degreasers, or cleansers have been used to clean the bilges. Oil residues from the engine room may include heavier petroleum products than the cargo tank and pump room resides. Settling and decanting of the slop tank(s) may be adversely affected by these heavier oils. Engine room bilges should he transferred only after all other tank washing and ballasting operations are complete and the slop tank is ready for final heating and decanting.

6.5.7 Slop tank heating

Tank washing after a cargo of high pour point or high viscosity oil may encounter difficulty maintaining the recovered oil in a liquid state. The slop tank must be continuously heated to permit gravity separation and decanting and to keep the recovered oil liquid. It will usually be necessary to maintain maximum heat on the slop tank(s) while tank washing and decanting to keep the water and oil sufficiently hot. However as decanting proceeds the heat must be reduced to avoid overheating the oil. Recovered fuel oil should be heated to not more than 60°C and recovered crude oil (except some heavy crude oils), to not more than 43°C after removal of free water. High viscosity or high pour point slops must be continuously heated until disposed of If they are allowed to cool then heavy wax or sedimentation may occur, which cannot be restored to a liquid at any temperature available by on-board heating.

6.5.8 Load-on-top operations (LOT).

By a process of heating and careful decanting, the water content of the slop tank can be slowly reduced until only the top oil layer, the oil/water interface layer and a shallow bottom water layer are left. If the characteristics of the slop oil and the nature of the next cargo permit, the slops may be retained on board and the next cargo loaded on top of them. This is normally done with crude oil cargoes when the same or a similar crude will be carried on the next voyage. It may also be done with some products provided the cargo shipper is advised and approves of the procedure.

If there is any doubt about retaining the slops, the master must communicate this question to the owners and cargo owner or charterer and request their advice. When requesting advice, the master must advise the quantity of slops and the nature of their contents (including tetra-ethyl lead or detergents).
Charterer may wish to LOT, in which case full freight will be normally paid. If charterer does not wish to LOT, the slops must be segregated and freight will not be paid on the space/dead-weight used. Most charter parties provide for the charterer to make the decision regarding the disposition of slops. Charterers may require the slops to be discharged. The time required to do this normally constitutes laytime used.

6.5.9 Slops as bunkers

If slop residues are to be pumped ashore for final separation, with no compensation for the recovered oil or perhaps for a treatment charge, owners may be tempted to consider using the slops as fuel. The principal problems associated with using slops as fuel are safety risks and machinery damage.

The safety risk is using slops as fuel is due to the flash point of the slops. If the flash point is above 50°C, then there is no significant hazard. Crude oil slops, or petroleum product slops may have a flash point well below 60°C and can only be used for bunkers under special circumstances. The following precautions must be observed to legally use fuel with a flash point below 60°C:

- Heated fuel tanks must be vented to a safe position outside the machinery spaces, with weather deck vent outlets fitted with flame screens.
- Heated fuel tank drains must empty into spaces ventilated to prevent any accumulation of oil vapours at temperatures close to the flash point of the fuel.
- There must be no sources of ignition near the fuel tank vents or drain outlets.
- Fuel samples should be drawn and tested for flash point before each fuelling.

The consequences of failing to observe these precautions can be costly or catastrophic. From 1978 to 1983 at least three tanker explosions were attributed to use of bunkers with low flash points, including one explosion, which killed 76 persons. If port authorities find the atmosphere in bunker tanks to be in the explosive range, then the vessel may be ordered to vacate berth, clean out bunker tanks, obtain gas free certificates and take on new fuel before being permitted to load.

6.6 Purging and gas-freeing

General

It is generally recognised 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. Before starting to gas free, the tank should be isolated from other tanks. When either portable fans or fixed fans connected to the cargo pipeline system are used to introduce air into the tank, the inert gas inlet should be isolated. When inert gas system fan, drawing fresh air, is employed, both the line back to the inert gas source and the inert gas inlet into each tank being kept inerted should be isolated.

When tank washing is completed, the cargo tank will contain an atmosphere, which is not safe for men. If the tank has been ventilated during washing to maintain a too-lean atmosphere, it may still contain more hydrocarbon vapours than are permitted for “bare-face” entry.
Tanks, which have been ventilated during washing, are easier to prepare for entry. Ventilation is continued after washing is completed. The ventilation should be arranged so that the efficient exchange of tank atmosphere is achieved.

The most effective method of ventilating a tank is by extracting the heavier hydrocarbon vapours from the bottom of the tank, while allowing fresh air to enter from the top, displacing the tank atmosphere through a “Purge Pipe” extending from the base of the tank to open atmosphere.

This method can be used with either fixed or portable equipment as indicated. The advantage of the displacement method is that only a little more than one air exchange is required to ventilate the

### 6.6.1 General Procedures

The following recommendations apply to cargo tank gas freeing generally:

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

2. 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.

3. 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.

4. 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.

5. 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.

6. 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.

7. 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.

8. 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.

9. 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.

10. 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 LEL 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.

11. 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.

12. 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.

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

14. 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.

15. 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.

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

17. 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.

6.6.2 Gas Free for the Reception of Cargo

A tank, which is required to be gas free for receiving cargo, should be ventilated until tests confirm that the hydrocarbon gas concentration throughout that tank does not exceed 40% of the LEL.

6.6.3 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 LEL.

To ensure the dilution of the toxic components of inert gas to below their Threshold Limit Values (TLV), gas freeing should continue until tests with an oxygen analyser show a steady
oxygen reading of 21% by volume and tests with a flammable gas indicator show not more than 1% LEL.
Positive fresh air ventilation should be maintained throughout the period that personnel are in a tank, and frequent tests should be made of both oxygen and hydrocarbon content of the tank atmosphere.
When other tanks in an inert condition are either adjacent or interconnected (e.g. by a pipeline) to the tank being entered, personnel should be alert to the possibility of inert gas leaking into the gas free tank through, for example, bulkhead fractures or defective valves. The risk of this occurring can be minimised by maintaining a small but positive inert gas pressure.

6.6.4 Purging

When it is required to gas free a tank after washing, it should first be purged with inert gas to reduce the hydrocarbon content to 2% or less by volume so that during the subsequent gas freeing no portion of the tank atmosphere is brought within the flammable range. The tank may then be gas freed.
The hydrocarbon content must be measured with an appropriate meter designed to measure the percentage of hydrocarbon gas in an oxygen deficient atmosphere. The usual flammable gas indicator is not suitable for this purpose.
If the dilution method of purging is used, it should be carried out with the inert gas system set for maximum capacity to give maximum turbulence within the tank. If the displacement method is used, the gas inlet velocity should be lower to prevent undue turbulence.

6.6.5 Ventilation by dilution

The alternative method of ventilation (and the most commonly used on smaller tankers) involves blowing air into the top of the tank at one end and forcing the tank atmosphere out a deck opening at the other end of the tank. To be effective, an extension trunk must be used so that the air enters the tank at the bottom.
The old (hazardous) atmosphere is removed by dilution. The corners of the tank most distant from the ventilation fan will take a considerable amount of time to reach a safe condition. If the tank is large, with deep bottom framing, the framing bays distant from the fan may retain dangerous pockets of hydrocarbon vapour after the remainder of the tank passes the test for safe tank entry.
The least efficient method of tank ventilation involves blowing air into the top of the tank without extension trunking. Dilution is very slow with this method and dangerous gas pockets are likely to remain in the distant corners of the tank. This method should be used for small tanks only.
The atmosphere leaving, the tank must exit as an unimpeded vertical flow. If air is being forced out of a tanklid, the tanklid should be fully open. Tank atmospheres should not be exhausted under a catwalk or other structure, which would promote accumulations of dangerous vapour at deck level. Generally, a relative wind of more than ten knots will prevent any accumulation of vapours, but care must be taken when ventilating tanks near the superstructure if a relative wind from astern may produce a lee where the ventilation is taking place.
6.6.6 Gas Measuring Equipment

In order to maintain a proper control of the tank atmosphere and to check the effectiveness of gas freeing, a number of gas measuring instruments should be available on the ship. Depending upon the type of atmosphere being measured, at least two of each of the following portable instruments should be available:

- **With a too lean tank atmosphere:**
  - Flammable gas indicator capable of measuring hydrocarbon gas content to the lower flammable limit and with the scale graduated as a percentage of this limit.

- **With an inerted tank atmosphere:**
  - Gas indicator capable of measuring percentage volume of hydrocarbon gas in an inerted atmosphere.
  - Oxygen analyser.
With an over rich tank atmosphere:
- Gas indicator capable of measuring hydrocarbon gas concentrations above 15% volume in air.

In order to be able to check the effectiveness of gas freeing for tank entry the following instruments should be provided:
- A flammable gas indicator capable of measuring gas to the lower flammable limit and with the scale graduated as a percentage of this limit.
- An oxygen analyser.
- An instrument capable of measuring concentrations in the human toxicity range of toxic gases and calibrated in parts per million.

The instruments to be used for gas measurement should be calibrated and tested in accordance with the manufacturer's instructions before starting to tank clean or gas free. Tank atmosphere sampling lines should be, in all respects, suitable for and impervious to, the gases present and should be resistant to the effects of hot wash water.

6.7 SHIP/SHORE LIAISON

Liaison Between Tanker and Terminal Before Cargo Handling
Emphasis is placed on the fact that the completion of a safe and successful cargo handling operation is dependent upon effective co-operation and co-ordination between all the parties involved. Certain additional information relating to cargo, ballast and bunker handling should be exchanged before these operations begin. This Chapter covers the subjects about which additional information should be available, and the aspects upon which agreement should be reached.

6.7.1 Terminal’s advice to the tanker
The following information should be made available to the responsible officer:

Information in Preparation for Loading and Bunkering:
- Cargo specifications and preferred order of loading.
- Whether or not the cargo includes toxic components, for example H₂S, benzene, lead additives, mercaptans etc.
- Tank venting requirements.
- Any other characteristics of the cargo requiring attention, for example high true vapour pressure.
- Flashpoints (where applicable) of products and their estimated loading temperatures, particularly when the cargo is non-volatile.
- Bunker specifications including H₂S content.
- Nominated quantities of cargo to be loaded.
- Maximum shore loading rates.
Standby time for normal pump stopping.
- Maximum pressure available at the ship/shore cargo connection.
- Number and sizes of hoses or arms available and manifold connections required for each product or grade of the cargo.
- Proposed bunker loading rate.
- Communication system for loading control, including the signal for emergency stop.
- Limitations on the movement of hoses or arms.

Information in preparation for discharge:
- Order of discharge of cargo acceptable to terminal.
- Nominated quantities of cargo to be discharged.
- Maximum acceptable discharge rates.
- Maximum pressure acceptable at ship/shore cargo connection.
- Any booster pumps that may be on stream.
- Number and sizes of hoses or arms available and manifold connections required for each product or grade of the cargo and whether or not these arms are common with each other.
- Limitations on the movement of hoses or arms.
- Any other limitations at the terminal.
- Communication system for discharge control including the signal for emergency stop.

6.7.2 Tanker’s advice to the terminal

Before cargo handling commences the responsible officer should inform the terminal of the general arrangement of the cargo, ballast and bunker tanks, and should have available the information listed below:

Information in Preparation for Loading and Bunkering:
- Details of last cargo carried, method of tank cleaning (if any) and state of the cargo tanks and lines.
- Where the vessel has part cargoes on board, grade, volume and tank distribution.
- Maximum acceptable loading rates and topping off rates.
- Maximum acceptable pressure at the ship/shore cargo connection during loading.
- Cargo quantities acceptable from terminal nominations.
- Proposed disposition of nominated cargo and preferred order of loading.
- Maximum acceptable cargo temperature (where applicable).
- Maximum acceptable true vapour pressure (where applicable).
- Proposed method of venting.
- Quantities and specifications of bunkers required.
- Disposition, composition and quantities of ballast together with time required for discharge and maximum light freeboard.
- Quantity, quality and disposition of slops.
- Quality of inert gas (if applicable).

**Information in Preparation for Discharge:**
- Cargo specifications.
- Whether or not the cargo includes toxic components, for example H2S, benzene, lead additives, mercaptans etc.
- Any other characteristics of the cargo requiring special attention, for example, high true vapour pressure (TVP).
- Flashpoint (where applicable) of products and their temperatures upon arrival, particularly when the cargo is non-volatile.
- Cargo quantities loaded and disposition in ship’s tanks.
- Quantity and disposition of slops.
- Any unaccountable change of ullage in ship’s tanks since loading.
- Water dips in cargo tanks (where applicable).
- Preferred order of discharge.
- Maximum attainable discharge rates and pressures.
- Whether tank cleaning, including crude oil washing, is required.
- Approximate time of commencement and duration of ballasting into permanent ballast tanks and cargo tanks.

### 6.7.3 Agreed loading plan

On the basis of the information exchanged, an operational agreement should be made in writing between the responsible officer and the terminal representative covering the following:
- Ship’s name, berth, date and time.
- Name and signature of ship and shore representative.
- Cargo distribution on arrival and departure.
- The following information on each product:
  - Quantity.
  - Ship’s tank(s) to be loaded.
  - Shore tank(s) to be discharged.
  - Lines to be used ship/shore.
  - Cargo transfer rate.
  - Operating pressure.
  - Maximum allowable pressure.
  - Temperature limits.
  - Venting system.
Restrictions necessary because of:
- Electrostatic properties.
- Use of automatic shutdown valves.

This agreement should include a loading plan indicating the expected timing and covering the following:

- The sequence in which ship’s tanks are to be loaded, taking into account:
  - Deballasting operations.
  - Ship and shore tank change over.
  - Avoidance of contamination of cargo.
  - Pipeline clearing for loading.
  - Other movements or operations, which may affect flow rates.
  - Trim and draught of the tanker.
  - The need to ensure that permitted stresses will not be exceeded.

- The initial and maximum loading rates, topping off rates and normal stopping times, having regard to:
  - The nature of the cargo to be loaded.
  - The arrangement and capacity of the ship’s cargo lines and gas venting system.
  - The maximum allowable pressure and flow rate in the ship/shore hoses or arms.
  - Precautions to avoid accumulation of static electricity.
  - Any other flow control limitations.

- The method of tank venting to avoid or reduce gas emissions at deck level, taking into account:
  - The true vapour pressure of the cargo to be loaded.
  - The loading rates.
  - Atmospheric conditions.

- Any bunkering or storing operations.
- Emergency stop procedure.

A bar diagram is considered to be one of the best means of depicting this plan.

6.7.4 Inspection of ship’s cargo tanks before loading

Where possible, inspection of ship’s tanks before loading cargo should be made without entering the tanks.
A tank inspection can be made from the deck using ullage or sighting ports with, where applicable, the inert gas within the tank maintained at its minimum positive pressure. Care must be taken by the person inspecting not to inhale vapours or inert gas when inspecting tanks that have not been gas freed. Frequently tank atmospheres which are, or have been, inerted have a blue haze which, together with the size of the tanks, makes it difficult to see the bottom even with the aid of a powerful torch or strong sunlight reflected by a mirror. Other methods such as dipping and measuring the heel, or having the stripping line or eductors opened in the tank and listening for suction, may have to be used. It may sometimes be necessary to remove tank cleaning opening covers to sight parts of the tank not visible from the ullage ports but this should only be done when the tank is gas free, and the covers must be replaced and secured immediately after the inspection.

If, because the cargo to be loaded has a critical specification, it is necessary for the inspector to enter a tank, all the precautions contained in Section 11.4.2 must be followed. Before entering a tank, which has been inerted, it must be gas freed for entry and, unless all tanks are gas freed and the IGS completely isolated, each individual tank to be entered for inspection must be isolated from the IGS.

### 6.7.5 Agreed discharge plan

On the basis of the information exchanged, an operational agreement should be made in writing between the responsible officer and the terminal representative covering the following:

- Ship’s name, berth, date and time.
- Names and signatures of ship and shore representatives.
- Cargo distribution on arrival and departure.
- The following information on each product:
  - Quantity.
  - Shore tank(s) to be filled.
  - Ship’s tank(s) to be discharged.
  - Lines to be used ship/shore.
  - Cargo transfer rate.
  - Operating pressure.
  - Maximum allowable pressure.
  - Temperature limits.
  - Venting systems.
- Restrictions necessary because of:
  - Electrostatic properties.
  - Use of automatic shutdown valves.

This agreement should include a discharge plan indicating the expected timing and covering the following:

- The sequence in which the ship’s tanks are to be discharged, taking account of:
  - Ship and shore tank change over.
  - Avoidance of contamination of cargo.
- Pipeline clearing for discharge.
- Crude oil washing, if employed, or other tank cleaning.
- Other movements or operations, which may affect flow rates.
- Trim and freeboard of the tanker.
- The need to ensure that permitted stresses will not be exceeded.
- Ballasting operations.

- The initial and maximum discharge rates, having regard to:
  - The specification of the cargo to be discharged.
  - The arrangements and capacity of the ship’s cargo lines, shore pipelines and tanks.
  - The maximum allowable pressure and flow rate in the ship/shore hoses or arms.
  - Precautions to avoid accumulation of static electricity.
  - Any other limitations.

- Bunkering or storing operations.
- Emergency stop procedure.

A bar diagram is considered to be one of the best means of depicting this plan.

### 6.7.6 Communications

To ensure the safe control of operations at all times, it should be the responsibility of both parties to establish, agree in writing and maintain a reliable communications system. Before loading or discharging commences, the system should be adequately tested. A secondary stand-by system should also be established and agreed. Allowance should be made for the time required for action in response to signals.

These systems should include signals for:

- Identification of vessel, berth and cargo.
- Stand by.
- Start loading or start discharging.
- Slow down.
- Stop loading or stop discharging.
- Emergency stop.

Any other necessary signals should be agreed and understood.

When different products or grades are to be handled their names and descriptions should be clearly understood by the ship and shore personnel on duty during cargo handling operations. The use of one VHF/UHF channel by more than one ship/shore combination should be avoided.
6.7.7 Ship/shore safety check list

The purpose of the Ship/Shore Safety Check List is to ensure the safety of both ship and terminal and of all personnel and it should be completed jointly by a responsible officer and the terminal representative. Each item should be verified before it is ticked. This will entail a physical check by the two persons concerned and will be conducted jointly where appropriate. It is of no value if it is merely regarded as a paper exercise.

It is emphasised that some of the items on the Ship/Shore Safety Check List will require several physical checks or even continuous supervision during the operation. The Ship/Shore Safety Check List may be accompanied by an explanatory letter, inviting the co-operation and understanding of the tanker’s personnel. The letter should be given to the master or responsible officer by the terminal representative. The recipient should acknowledge receipt of the letter on a copy, which should then be retained by the terminal representative.
7 CARGO AND BALLAST PUMPS

Learning objectives
- that the suction action of a pump is really atmospheric pressure pushing the liquid into the inlet side of the pump
- how low vapor pressure of the liquid being pumped will improve suction
- that the discharge pressure will fluctuate when the liquid boils
- the meaning of head
- the meaning of NPSH
- the meaning of typical Q-H curve and the shore installation curve
- that the actual discharge rate also depends on static and dynamic back pressure of the shore installation
- the meaning of pressure surge
- that the system is liable to serious pressure surges if valve-closure time is equal to or less than the pipeline period

7.1 PUMP THEORY AND CHARACTERISTICS

7.1.1 Classification and selection of pumps

There are a number of different pump types. Each type has its own special quality and therefore certain advantages and disadvantages. The selection of pumps is determined by a thorough study of the capacity needs and under which operational conditions the pump will operate. The following factors are important when you evaluate these conditions:
- Estimated back pressure
- Capacity requirement
- Capacity range
- Requirement for installation and arrangement
- Expenses for purchase, installation and maintenance
- Availability of parts and service
- Suction terms
- Characteristics for the liquid to be pumped

Selection of the right pump for a determined purpose qualifies a close co-operation between the customer and the producer of the pump. The customer has a special responsibility to clarify all conditions concerning the pump installation, so the producer can choose the best pump from his product range with the best match.

When you choose a pump you must find out how much the pump needs to deliver under a specific condition. Definition of capacity range is important. Demand for capacity or capacity range and expected discharge pressure must be specified. The capacity requirement is determined by the intended use of the pump. The discharge pressure is determined by various conditions where the pump’s delivery pipeline design, the capacity of the pump and the liquid’s characteristics, is the essential.

Alternative installation locations of the pump are limited due to special demands from Class and Shipping Authorities and also from lack of space.
Purchase and installation cost is important. Future maintenance expenses, availability of parts and service now and over the next years, are also important and must be included in the evaluation of alternative pump supplies. The liquid’s properties and which other arrangements you have to consider, often limits the options. Density, viscosity and boiling point are important properties to consider. The liquid temperature and corrosive properties are important factors when pump material is selected. The pump’s suction condition is determined from where the pump is located in relation to the liquid to be pumped. A given suction pipe creates a certain resistance that will have influence on the pump capacity. The main principle is to minimise resistance on the suction side by decreasing the suction pipe length, have the largest diameter possible and few as possible restrictions in form of bends, valves and so on. The different types of pumps are divided into two main groups, displacement and kinetic pumps. The displacement pumps displace the liquid by reducing the volume inside the pump. An example is a piston pump where the piston is moving up and down inside a cylinder or when the screws revolve inside a screw pump. Kinetic pumps (kinetic energy is equal to “movement” energy) increase the liquid’s velocity through the pump. The diagram below gives a brief view of the different available groups and types of pumps. The diagram would be more comprehensive if the pumps were divided in all details according to number of rotors, design of pump inlet/outlet and flow directions.

A kinetic pump like the centrifugal pump increases the liquid’s velocity in the pump by means of a rotating impeller. A displacement pump, like the piston pump, mechanically displaces the liquid in the pump, either by help of a piston or screws. Resistance on delivery side gives a liquid pressure rise (pump delivery pressure). One should be aware of this difference for these two pump types. The pressure rise on a kinetic pump is restricted by the increase in velocity over the pump, which is controlled by the pump design. All kinetic pumps therefore have a designed or built-in limitation for maximum discharge pressure. The displacement pumps limitation depends only on available power and the constructional strength. In contrast to a kinetic pump, such a pump will operate against resistance with all its available power. A closed-delivery valve after a displacement pump is damaging. The same closed valve for a kinetic pump will not bring any immediate danger. Piston pumps and screw pumps have good suction capacity and are used where these characteristics are required. The weakness of these pumps is the complex construction and the relatively low capacity.
Centrifugal pumps are simply constructed with few parts and no valves. There are no immediate problems if the outlet of the pump is closed. These qualities result in relative low purchase and servicing costs. Operation at high speed makes the pump small in proportion compared to the capacity and flexibility in relation to the pump’s location.

The most negative side of using a centrifugal pump is the lack of self-priming capacity. This weakness is improved by constructional efforts and positioning, which consolidate the free flow of liquid. Location of a pump, for instance below the liquid level, can reduce the flow resistance. High viscosity liquids are therefore particularly difficult to pump due to this condition.

A centrifugal pump’s efficiency is high only within a small range. This is the reason it is especially important to have a clear understanding of what capacity range the pump will operate under, in connection with the selection of a centrifugal pump.

The differential pressure over each impeller is relatively low. Using so-called multistage pumps where several impellers are mounted in serial, increase the pump’s capacity to deliver against higher backpressure.

A centrifugal pump will, without a non-return valve on delivery side, give complete back flow at the time the pump stops. For all operators of centrifugal pumps, this relationship is important to know.

7.1.2 The ejector

The ejector design is simple and is used for stripping. This ejector has no revolving or reciprocating parts and is thereby especially easy to maintain.
The propellant (driving water), a liquid or gas, is forced through a nozzle into a mixer tube. The velocity of the propellant will naturally increase as it passes through the nozzle. Due to the propellant’s velocity and direction, plus the friction force between the propellant and the liquid, the surrounding liquid will be sucked into the ejector’s mixer tube. The mixer tube is connected to an expanding tube, the diffusor. Here some of the kinetic energy supplied to the liquid in the mixer tube is transformed into potential energy. The capacity depends on the friction force between the two mediums, suction head, delivery head and the propellant’s velocity. The ejector has the advantage that it does not lose the suction capacity even if it sucks air or vapour.

The ejector’s efficiency is between 30% and 40%. Even if the propellant’s efficiency is up to approximately 70%, the total efficiency for the whole ejector system is far less than compared to a pump system, such as a centrifugal pump. Another drawback with ejectors is that the propellant is mixed with the pumping liquid. This implies that if the ejector is to be used in cargo transfer operation, the cargo itself must be used as propellant liquid. The ejector is frequently used as a bilge pump in hold spaces. A common arrangement for a hold space is as follows:

The ejector is usually submerged in a bilge sump and the propellant is normally supplied from a seawater pump. Onboard gas carriers where the hull is the secondary barrier, the ejector may also be used to pump cargo from hold space. In that case, the liquefied cargo itself must be used as a propellant.

7.1.3 Tips

- Be aware that the ejector has a limitation on the propellant’s pressure. Higher pressure than recommended by the supplier may result in reduced suction capacity.
• Start the ejector by opening all valves on delivery side first, and then adjust the correct propellant pressure. The ejector’s suction valves should be opened last, which will prevent the propellant’s flow back into the tank that is to be stripped.
• Stop the ejector by using the opposite procedure.
As the drawing shows the ejector is positioned 3 meters above the liquid level. The liquid level in the slop tank is 15 meters above the ejector and the propellant's pressure is 8 bars. The ejector’s capacity can be found by use of the performance curve for the specific ejector.

In the performance curve the ejector capacity is set as a function of the propellant pressure. Observe that this curve has curves for different suction lifts. The different performance curves are marked with different suction lifts. The ejector’s suction lift in this example is 3 meters; this specific curve shall be used.

You can find the capacity of the ejector by drawing a vertical line from 8 bars on the scale for a delivery head of 15 meters and up to the performance curve with a suction lift of 3 meters. From this point of intersection, draw a horizontal line to the left and over to the ejector’s capacity side. The found capacity in this case is 600 m$^3$/h.
The ejector's Performance Curves

[Graph showing performance curves for an ejector]
7.1.5 Displacement pumps

Pumps are very old machines. The first types of pumps (screw pump and piston pump) are more than two thousand years old.

A pump’s purpose is for the transport of liquid, usually from a low level to a higher level. Its purpose can also be to press a liquid into a tank, which contains higher pressure than the surroundings. The pump increases the liquid’s energy. The increased energy is potential energy; the liquid is transported from a low level to a higher level. This is the kinetic energy, the liquid’s flow has increased as pressure energy, if the liquid is pumped into a tank with a higher pressure than its surroundings. As an example, the feed water pump to a boiler is working using these principles.

In addition to the mentioned increase of energy, the pump also has to maintain the energy which is lost due to streaming in the system.

As mentioned, kinetic pumps constantly have liquid streaming through the pump with pressure increasing simultaneously. In displacement pumps, a certain volume of liquid is branched off and moved from the pump’s delivery side. Then a pressure increase occurs. Screw pumps and piston pumps will be viewed further in this chapter. A wide range of displacement pumps is available, such as the lamella pump, ring pump, propeller pump, etc.

7.1.6 Piston pump

The piston pump is used for relatively small amounts of liquid with large delivery heads. When the piston is pulled upwards, a vacuum occurs inside the pump housing. The suction valve will then open and liquid streams into the pump. When the piston is pressed downward the pressure will increase, the suction valve will close, the delivery valve is set open and the liquid sent out of the pump. The liquid does not stream in a smooth flow as in a centrifugal pump, but accelerates and slows alternately. This is of inconvenience with long pipelines. The valve is a weak point. They are sensitive to liquid pollution and they also increase the resistance against streaming.

Usually, the piston pump is double acting. Because of the pump’s movements, the pump must have a relatively slow piston speed. The piston pump may sustain almost unlimited pressure. However, the limitation is the automotive power and the material strength. The piston pump does not have to be filled with liquid before starting. Make sure that all the valves on the delivery side are open before starting. The efficiency of piston pumps is higher than, for instance, centrifugal pumps. The piston pump is a well-known pump on board an oil tanker. This is the pump, which is used to pump cargo deposits ashore at the end
of the discharging operation. These oil deposits from cargo tanks, lines and cargo pumps are pumped ashore through a small diameter line.

### 7.1.7 Screw pump

The screw pump consists of two screws or more, where one of them is activated. The screws are placed inside a pump house. A common and well-known screw pump is the Swedish manufactured so-called IMO pump. This pump consists of one active screw placed in the middle and two symmetrical side screws. The screws tighten to each other and to the housing, but have no metallic contact. When the screw rotates, the threads are filled with liquid. The liquid is displaced by axial through the pump. In this pump, the side screw rotates in the opposite direction of the middle screw. These screws are working like an endless piston which constantly moves forward. The liquid is not exposed to rotation. The pump is self-priming, running almost soundless and with little exposure for wear and tear when pumping clean liquids. The screw pumps are used a lot as a lubricating pump, but are also used as a stripping pump on oil tankers.

![Screw pumps](image)

### 7.1.8 Centrifugal pump

**The centrifugal pump’s mode of operation**

A centrifugal pump consists of a rotating impeller inside a pump casing. The liquid inside the impeller is affected by the “blades”, and will be lead through the “blades” due to the centrifugal force. Energy in forms of kinetic energy (velocity energy) is added to the liquid. New liquid is constantly led into the impeller and put into rotation. A flow through the pump is established.
If the delivery pipeline from the pump is open to the atmosphere and has sufficient height, the liquid will adjust itself to a precise level given by the energy, which was added to the liquid through the impeller. Here, all kinetic energy is transformed into potential energy. The difference in liquid level is called net delivery head. A pump’s delivery head is dependent on the individual pump’s construction. If the level in the tank is lowered, the liquid level in the delivery pipeline will be correspondingly lower. Net delivery heads (H1, H2, H3) will be equal for the same pump provided that flow disturbance does not occur on the pump’s suction side.

However, the pump’s delivery pressure is dependent on the liquid’s density and delivery head. In this case, the liquid is water with a density (\( \rho \)) of 1000 kg/m\(^3\) and the head (\( H \)) is 100 meters, the manometer pressure (\( p_m \)) after the pump will be read at:

\[
p_m = \rho \times g \times H = (1000 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 100 \text{ m})
\]

\[
p_m = 981000 \text{ Pa} = 981 \text{ kPa}
\]

\[
p_m = 9.81 \text{ bars}
\]

One can see from the previous example that the delivery head of the pump is obtained from the pump itself, and that the delivery head is independent from the pump’s position or location. It is therefore natural that the centrifugal pump’s capacity always is given as a function of the pump’s delivery head.

If you bend the discharge pipe from the previous example, like the illustration below, the liquid will flow out of the pipe. Only a part of the added energy in the pump will “lift” the liquid. The rest of the energy is still in the form of kinetic energy. From the previous taught experiment, one can predict that the capacity of a centrifugal pump will be highest at minimal delivery head. The capacity curve (Q-H curve) will, in practice, follow this assumption, but the curve is not linear due to loss of energy in the pump.

If you ignore the pipe resistance, the capacity Q in this situation is determined by the delivery head (H). The delivery head here is the static height or the static backpressure, which the liquid has to lift.

In a real pipe system, bends and valves will create a resistance due to friction against free liquid flow. This resistance varies with the velocity and viscosity of the liquid, and is called the dynamic backpressure. The total pipe resistance, composed by the static and the dynamic backpressure, is called a system characteristic curve.
The intersection point between the system characteristic curve and the capacity curve is called the actual operation point.

It was previously mentioned that disturbances on the pump’s suction side would have influence on the capacity.

The conditions on the inlet side are very important for the centrifugal pump’s operation. A centrifugal pump has normally no self-priming qualities, meaning that the pump is not able to suck liquid from a lower level. Additional vacuum equipment connected to the pump will, however, improve the pump's self-priming qualities. When the inlet pipe and impeller is filled with liquid, the pumping process will be able to continue without this equipment. The liquid’s viscosity may ensure a continual flow into the pump. Too high resistance in the inlet pipe will cause the same operational disturbance. If the flow into the pump is less than the outlet flow, due to too high pipe resistance and/or too high viscosity, these factors will have considerable influence on the pump’s capacity.

If you start a pump, submerged in water like the sketch indicates, the pump will have a specific capacity at a specific delivery head. If you gradually lift the pump, the pump will, at a specific height, have a perceptible reduction in the capacity. When this occurs, the height of the pump above liquid level is called Net Positive Suction Head or NPSH.
The explanation of this phenomena is that when the pump is lifted up out of the water, the pipe length and the resistance at the inlet side increases. The increased resistance creates constant negative pressure on the inlet side of the pump. The liquid that accelerates from the centre of the impeller and out to the periphery increases this negative pressure. When the negative pressure reaches the liquid’s saturation pressure, the liquid starts boiling and a large quantity of vapour is created in the pump. The output flow from the pump become irregular, and will stop at huge vapour volumes. We say that the pump cavitates.

A centrifugal pump operates satisfactorily with approximately 2% gas in the liquid. But cavitation will always damage for the pump. The gas bubbles created in the liquid on the pump’s suction side will collapse when the pressure rises inside the impeller.

The consequences of cavity are:

- Vibrations and noise
- Reduced efficiency
- Pitting or cavity erosion inside the pump

As we have observed, the cavitation is destructive and must be avoided or controlled. To ensure limited or non-generation of vapour one must make sure that the liquid at the pump inlet has sufficient overpressure to avoid evaporation. The resistance at the pump inlet side should be made as low as possible. This can be done by constructing the pipeline as short as possible, limiting the number of bends and selecting a maximum diameter on the pipeline diameter. The pump should be positioned at the lowest possible level, and preferably below liquid level at the suction side.

A pump’s NPSH is variable and dependent on the flow. When the flow increases, the negative pressure generated inside the pump increases. A reduction of the flow will reduce the negative pressure. Reducing the pump’s capacity may therefore control cavitation.

A centrifugal pump’s capacity is adjusted by throttling the delivery valve. Throttling increases the pumps discharge pressure (backpressure) which causes reduced capacity. The capacity may also be adjusted by changing the pump’s rotation speed. Adjustments of the pump’s revolution move the capacity curve up or down. Reduction of the revolution moves the curve parallel downwards, an increase in revolution, upwards. Note that these relations are valid only if the flow conditions are unchanged.
7.1.9 The Pump performance diagram

All manufacturers supply a pump performance diagram with the pump delivery. The curves in the diagram are results from practical tests in the maker’s workshop and specifies:

- Type of liquid used in the test (generally water)
- Number of revolutions
- Type and size of impeller
- The optimal operation point

The operation point is normally set at the best possible efficiency, simultaneously within the pump’s predicted capacity range.

It is important to be aware that the pump’s diagram is made for a special liquid with specific properties. The capacity curve will be real for all liquids, provided the free flow to the pump inlet is not restricted due to for example too high viscosity. The power consumption curve will of course depend on the fluid’s density.
A pump’s condition is of course vital for the curve accuracy. There are a lot of methods to check the centrifugal pump’s condition. Monitoring the pump’s delivery head, capacity, power consumption and development of these is obvious. Detection of many minor operational disturbances may be difficult and not necessarily observed. Establishment of routines ensure continuous control of vibrations. Visual inspection of the pump and regular maintenance is important to prevent break down.

7.1.10 Draining and stripping system

The last stage during a discharging operation is the stripping, which means to empty the deposits of cargo in the cargo tanks, lines and pumps. Stripping is a part of the operation, which cannot be done with the cargo pumps in normal running. Well-known stripping systems are steam driven piston pumps, vacuum stripping and ejectors. The steam driven piston pump is an IMO demand on board crude oil tankers. This stripping pump empties the last deposits of cargo from the tanks and lines then pumps it ashore through the small diameter line. This pump will also be the last pump in use during the discharging operation. The vacuum stripping system is the most efficient method. On M/T Seagull this system is installed. The vacuum system makes use of the main cargo pumps and the main cargo lines.

7.1.11 Vacuum strip composition

The main line, just ahead of the cargo pump, on the free flow side is connected to a vacuum separator tank. The purpose with this separator tank is to support the cargo pump with liquid. The separator tank has a pipe connection to a vacuum tank fitted on a higher level in the pump room. This line is supplied with a valve. The vacuum tank is connected to a vacuum pump. This pump’s shaft leads via a gas proof joint to the engine room where the running unit is located. A pipe to pick up the exhaust from the separator tank leads from the vacuum tank to the slop tank.
7.1.12 Mode of operation

The separator tank works like a reservoir feeding the pump with liquid. The liquid level inside the separator tank will fall when the level in the cargo tank is getting lower than the height of the separator tank.
The void space above the liquid inside the separator tank will increase. In this stage, falling pump pressure should be observed before the vacuum system is activated.
At a fixed limit on the separator tank, the vacuum pump will start creating a vacuum in the void space above the liquid.
The valve between the separator tank and the vacuum tank will open and the liquid will be sucked into the separator tank because of the vacuum.
At the same time, the delivery valve is automatically (or manually) throttled. This is done to give time for the separator tank to refill itself.
The liquid in the separator tank supports the pump with liquid, even if the flow from the cargo tank is poor at times.
The vacuum stripping system provides good working conditions for the cargo pumps regarding feeding. This is achieved thanks to good co-operation between the cargo pump’s delivery valve and the vacuum pump.
The principles for different vacuum stripping systems is more or less the same, but please study the User’s Manual of the equipment on the specific ship.
Stripping arrangement for a deepwell pump system
7.1.13 Parallel operation of centrifugal pumps

The capacity requirement is usually higher than the performance of just one centrifugal pump. Additional pumps are then lined up and run in a parallel operation. The diagram below shows two equal pumps in parallel operation. We assume a symmetrical pipeline for both pumps.

The pump’s capacity curve (1) shows the relation between the delivery head and the flow rate for one pump. As both pumps are equal, the two pumps capacity curve is represented by the curve marked 1+2.

When equal pumps are run in parallel, the delivery head for the system will be equal to the delivery head for one pump. The capacity, however, will increase in proportion to the number of pumps. If, for instance one pump has a capacity of 1,330 m$^3$/hr. at a delivery head of 88 meters, two pumps in parallel will deliver 2,660 m$^3$/hr. and three pumps 3,990 m$^3$/hr. at the same head.

If the pumps are of different types or equal pumps are run at different speed, their individual performance curves will be different. This is no problem provided the point of intersection is outside the pumps individual point of intersection.

If, for instance increasing the back pressure alters the point of intersection, this may lead to one of the pumps running without delivering any cargo. If this situation occurs and continues, the pump may be damaged. If the system does not have any non-return valves and the backpressure increases further, a back flow will occur through the pump and into the cargo tank.

Even though the type of pumps is the same in a parallel operation, variation in rotational speed, asymmetric piping, variance in opening of valves, cavitation and variance of the pump’s condition may form the same condition.

Parallel operation

Pumps are operated in parallel when the time per unit will deliver more cargo than is possible to do with one pump. In this example, we will view how to find the delivery amount and delivery head by use of a pump curve. The system characteristic curve is shown on the pump curve diagram (next page).
The pump curve “A” for one pump shows in point “D1”, a delivery of 1,400 m$^3$/hour at a delivery head of 88 meters.
The pump curve “B” shows two pumps in parallel operation with a delivery of 2,250 m$^3$/hour at a delivery head of 116 meters.
To plot in pump curve “B” add the delivery amount of the two pumps at the different delivery heads. As shown in curve “A” the delivery at 20mlc. is 1,770 m$^3$/hour, point 1. Plot a new point at 20mlc. \((1,770 + 1,770) = 3540\) m$^3$/hour, point 11. In the same way, we are plotting the values according to the table above. When all the values are plotted, a new curve is drawn through the plotted points, curve “B”. Where the new curve is crossing the system curve, the delivery amount and delivery head for two pumps in parallel operation will be read. The same procedure stands for 3 or 4 pumps in parallel operation.
Starting pump number 2 will not double the capacity because a higher volume of flow creates higher dynamic resistance. The increase in capacity will then be relatively less for each pump added.

To achieve accurate plotting of two or more pumps in parallel operation, it is recommended to use a sheet of millimetre paper. Study the pump performance curve for the cargo pumps (or for any other pumps) on your ship.

### 7.1.14 Pump calculation

All pumps are delivered with pump curves from the supplier and it is important to be able to use these curves properly. On the example curve in this chapter, a curve is drawn for one pump which runs with a fixed revolution.
Also drawn is the curve for the pipe, which consists of static and dynamic backpressure. The static backpressure is caused by the difference between the shore tank’s liquid level and the vessel’s cargo tank’s liquid level. Friction resistance in valves, bends, pipes, etc causes the dynamic backpressure. Shore terminals usually have worked out characteristics for their installations (system curve). If the installation’s system curve or the vessel’s pump curve is on a transparent sheet, these can be applied to each other. For instance, the vessel’s curve is a transparency and is placed on the top of the terminal’s curve. Then the maximum delivery (at point of intersection) at existing conditions can be seen. From the example’s curve, in point “A” (point of intersection), the pump delivers $1,560 \text{m}^3/\text{hour}$ at a delivery head of $58 \text{mlc}$. The oil’s density in the example is $820 \text{kg/m}^3$. Out of this information, it is possible to find out what $58 \text{mlc}$ corresponds to in pumping pressure (manometer pressure) by use of the following formula:
\[ p = \rho g h \]

\( p \) = pump pressure
\( \rho \) = the liquid’s density \(- 820 \text{kg/m}^3\)
\( g \) = the earth’s gravity acceleration \(-9.81 \text{m/s}^2\)
\( h \) = delivery head \(-58 \text{m}l\)

The values used are just for this example. The denomination, which appears, is called Pascal (Pa). 100,000 Pa is equal to 1 bar.

**Calculate the manometer pressure:**
\[ p = \rho g h \]
\[ p = 820 \text{kg/m}^3 \times 9.81 \text{m/s}^2 \times 58 \text{m}l \]
\[ p = 466,563 \text{ Pa}. \]
\[ p = \text{4.7 bar. (4,66563).} \]

With a delivery flow of 1560 \text{m}^3/h and a delivery head of 58 \text{m}l, the manometer shows 4.7 bar. The increased pressure above the pump is calculated, which is (on oil tankers) approximately the same as the delivery pressure because the tank pressure is close to zero. To calculate the correct pressure, it is necessary to allow for the manometer height above the pump’s inlet and for the liquid height in the cargo tank above the pump’s height. In this example the following data is known in addition what already exists:

- Tank pressure = 0.1 bar (10000 Pa).
- Liquid level above pump inlet = 18 metres.
- Manometer height (manifold) above the pump inlet = 23 metres.

**The delivery pressure is now calculated based on the formula:**
\[ P = \rho g (h + x - y) + P_0 \]

\( P \) = delivery pressure
\( \rho \) = the liquid density \(-820 \text{kg/m}^3\)
\( g \) = the earth’s gravity acceleration \(-9.81 \text{m/s}^2\)
\( h \) = delivery head \(-58 \text{m}l\)
\( x \) = liquid level above the pump inlet \(-18 \text{m}\)
\( y \) = manometer height above the pump inlet \(-23 \text{m}\)
\( P_0 \) = tank pressure \(-0.1 \text{bar (10000 Pa)}\)

**The delivery pressure will be as follows:**
\[ P = \rho g (h + x - y) + P_0. \]
\[ P = 820 \text{kg/m}^3 \times 9.81 \text{m/s}^2 \times (58 \text{m} + 18 \text{m} - 23 \text{m}) + 10,000 \text{ Pa} \]
\[ P = 820 \text{kg/m}^3 \times 9.81 \text{m/s}^2 \times 53 \text{m} + 10,000 \text{ Pa} \]
\[ P = 436342 \text{ Pa} \]
\[ P = \text{4.4 bar (4,36342).} \]

These additional values normally give very small deviations, so in the further calculations these values are not included.
The dynamic backpressure may change, i.e. when throttling on the pump’s delivery valve. In this example, the discharge rate will be reduced to 1000m$^3$/h. Choose to do so by throttling the pump’s delivery valve, and when doing so, calculate the manometer pressure. First, draw a new curve (see the dotted curve) which crosses the pump curve at a delivery rate of 1000m$^3$/h, which creates the new intersection point “B”. From the point of intersection “B”, a horizontal line is drawn on the left side of the curve. The new delivery head is 98 metres. With the same formula as before the manometer pressure is calculated:

\[ p = xg \times h \]

\[ p = 820 \text{kg/m}^3 \times 9.81 \text{m/s}^2 \times 98 \]

\[ p = 788,331 \text{Pa} \]

\[ P = 7.9 \text{bar (7.88331bar)} \]

The conclusion is, by throttling the delivery valve to the manometer pressure, we get 7.9 bar with the delivery rate of 1,000m$^3$/h.

Out of the same formula, it is also possible to calculate the delivery head by reading the manometer pressure. An example using the same curve diagram, the manometer pressure is 6.3bar which compares to \((6.3 \times 100,000) = 630,000 \text{ Pa}\).

**Calculate the delivery head by turning the formula** \( p = xg \times h \), to:

\[ h = \frac{p}{xg} \]

\[ h = 630,000 \text{ Pa} : \left(820 \text{kg/m}^3 \times 9.81 \text{m/s}^2\right) \]

\[ h = 78.3 \text{ mlc}. \]
When a valve on a liquid line is closed too quickly, the pressure inside the line increases to a hazardous high level very quickly. Quick changes to the liquid flow in a pipeline may lead to a pressure surge resulting in a rupture in the pipeline system. This surge pressure can be recognised by a “knock” in the pipeline. This type of pressure peak is generated very quickly in the pipeline, faster than a common safety valve is capable to relieve. The consequence may be the breakdown of the pipeline system and thereby high risk of pollution, fire and personal injury. Pressure surge may appear if:

- The emergency shutdown valves are activated and closed too quickly. (ESD/Emergency Shut Down)
- Fast closing/opening of manual or remote operated valves.
- Fast variation of the volume flow resulting that a non-return valve starts hammering.
- When a pump is started and stopped.
The pressure in a cargo transfer system has three components; the hydrostatic pressure, the cargo tank pressure and the pressure generated by the pump. The hydrostatic pressure and the cargo tank pressure will mainly be constant and we will refer to these as “static pressure”. If the flow suddenly is varying due to, i.e. too fast valve closure, the moving liquid that has a specific velocity and mass will hit a “wall” inside the valve (the valve seat or the valve flap). The kinetic energy of the moving liquid will immediately convert into potential energy by compression of the liquid against the valve seat. How fast the pressure peak is generated depends on the velocity and the density of the liquid.

A pipeline of 250 meters and 150 mm in diameter is used for water transfer at a capacity of 400 m$^3$/hrs. The total mass of the moving liquid inside the pipe is 4400 kg and moves with a velocity of 6.3 meters/second. If a valve is closed immediately, the kinetic energy will convert almost immediately to potential energy. The pressure surge may reach approximately 40 bars within 0.3 seconds.

If the liquid is a condensed gas or crude oil, vapour may be present. These vapour bubbles will collapse when the pressure increases. The collapsed bubbles will generate pressure waves that will also be transmitted through the pipeline system. In an opposite case where the pressure is decreasing rapidly, a volatile liquid will start boiling. The above mentioned cases illustrate why it is especially important that the valves and pumps are cautiously operated so neither dangerous pressure peaks nor pressure drops are generated.

The enclosed diagram on the next page is from ITC Tanker Safety Guide. It shows a normal cargo operation and pressure in the pipeline. The maximum pressure is at the pump outlet. This pressure is the sum of the hydrostatic pressure and the pressure generated by the pump. Due to friction in the pipeline, the pressure will gradually decrease toward the cargo manifold. If the ESD valve is activated and the valve is closed too quickly, the liquid flow will stop quite quickly. The liquid’s kinetic energy will convert into potential energy immediately when the liquid hits the valve seat. A pressure peak is generated and will be transmitted at the speed of sound (the only way possible) back towards the pump. When the wave of pressure reaches the pump, some of the pressure will unload through the pump, but the resistance here will also operate as a “wall”. The pressure is rebuilt and reflected back towards the ESD valve again. A new pressure peak is generated with additional increased pressure. A “knock” will occur each time a pressure top is generated against a “wall”. All personnel that operate valves or pumps must be observant of these phenomena and of the liquid pressure, which may occur consequently.

The progress and the length of the pressure surge depends on the system. If the wave of pressure is allowed to move between two valves without pressure relief, a maximum pressure surge will be generated.

The most vulnerable parts in the system are the shore connections and loading/discharging arms. The operative personnel normally work nearby the manifold area. A rupture in this area may easily lead to personnel injury. (Please note that control of cargo hoses is dealt with on page 4 in this chapter.)

Maintenance and testing of the ESD-valves’ closing time is the most important of the above mentioned causes. Closing time of the ESD-valves, which is too short, may lead to generation of a dangerous pressure surge. Always consult the terminal representatives about the required pipe line period.
7.2.1 Development of pressure surge

Diagram I  Pressure profile - normal flow

Diagram II  Time = 0  ESD valve closes rapidly

Diagram III  Time = 1/2 - 1/a  Surge halfway up pipeline; higher pressures reflected downstream to ESD

Diagram IV  Time = 1/a  Surge reaches pump, pump stops. Some relief through pump

Diagram V  Time = 3/2 - 1/a  Surge reflected to ESD valve

Diagram VI  Time = 2 - 1/a  Maximum surge pressure at ESD valve

Figure A8.1 Development of pressure surge in a line after instantaneous valve closure
The closing time of ESD valves should be as short as possible to prevent overflow and spillage. But not so fast that a risky pressure surge occurs. Necessary time for a safe closure of valves can be calculated based on the expected maximum pressure surge when the pressure wave has passed forward and backward through the pipeline. The speed of the sound is set to 1,320 m/s. If the pipeline is 2 km, the calculated time for maximum pressure surge at closure of the ESD valve is:

\[ T = \frac{2 \times L}{\text{Speed of sound}} = \frac{2 \times 2,000 \text{ m}}{1320 \text{ m/s}} = 3 \text{ s} \]

The maximum pressure surge will occur 3 seconds from closure of the ESD valve. This time is called a “pipeline period”. It is assumed that the safe closing time is five times a pipeline period, so the closing time should at minimum be:

\[ 5 \times 3 \text{s} = 15 \text{ seconds} \]

### 7.2.2 Cargo hoses

The cargo hoses are normally the weakest part in a pipeline system transferring cargo. The responsibility for the cargo hose condition on board lays with the ship. It is important to be aware of this fact, in case a cargo hose is lent out to a third party or is used in transferring cargo between ships.

Hoses for cargo should be cleaned and dried before storing. The storage area should be dry and out of the sun, if you want to take care of the hoses as long as possible. Poor cleaning and storage is generally the cause of damage and consequently replacement. A cargo hose prototype is tested with the products, pressure and temperature for which the hose type is approved. The cargo hoses should be tested yearly at a pressure that is 1,5 times the maximum working pressure.

The normal procedure for yearly testing is:

1. The hose is laid out on deck, blinded off and filled with water.
2. The hose is pressurised with 1,5 times the working pressure.
3. The hose is checked for leakage.
4. Electric bonding is checked.
5. Linear expansion for the hose is measured (measure for strength)
6. The test result is logged.

If there is no leakage, bonding is okay and the linear expansion is less than the limitation set by the manufacturer, the hose is approved.
8 EMERGENCY PROCEDURES  
(STCW Code, section A-V/1 paragraphs 10, 14)

Learning objectives:
that every oil tanker greater than 150 tonnes must have an oil pollution emergency plan
that if an emergency occurs the immediate action must be to: 
raise the alarm
provide information to the command centre
shut down all cargo operations and close valves
remove all craft from alongside
that planning and preparation are essential for dealing successfully with emergencies
the need for realistic drills to be undertaken

8.1 EMERGENCY PLAN

Regulation 26 of Annex I of MARPOL 73/78 requires that oil tankers of 150 tons gross tonnage or more and all ships of 400 tons gross tonnage or more carry an approved shipboard oil pollution plan (SOPEP). The International Convention on Oil Pollution Preparedness, Response and Co-operation, 1990, also requires such a plan for certain ships.

Regulation 16 of Annex II of MARPOL 73/78 makes similar stipulations for all ships of 150 tons gross tonnage and above carrying noxious liquid substances in bulk: they are required to carry on board an approved marine pollution emergency plan for noxious liquid substances. The latter should be combined with a SOPEP, since most of their contents are the same and the combined plan is more practical than two separate ones in case of an emergency. To make it clear that the plan is a combined one, it should be referred to as a shipboard marine pollution emergency plan (SMPEP).

The Guidelines for the Development of Shipboard Marine Pollution Emergency Plans have been developed by IMO to help Administrations and shipowners meet these requirements.

8.1.1 General

All tankers and terminals should have procedures ready for immediate implementation in the event of an emergency. The procedures must anticipate and cover all types of emergency that might be encountered in the particular activities of the tanker or terminal. Although the main aim of the procedures will be to respond to a fire, all other possible emergencies such as hose or pipeline bursts, cargo overflow, pump room flooding, men overcome by gas within tanks, breakouts of vessels, weather or blackouts, must be covered. Similarly, while the deployment of fire-fighting equipment will be prominent in any emergency procedures, equipment such as breathing apparatus, resuscitation apparatus and stretchers must also be covered, together with details of means of escape or exit.

The procedures should be familiar to the personnel involved, who should be adequately trained and clearly understand the action they would be required to take when
responding to the emergency. This can best be achieved by regularly exercising the plan. Exercises will also serve to highlight the need for any revisions to be made to the plan, associated emergency procedures and further training requirements. Care should be taken when formulating an emergency plan to ensure that procedures to alert people or to arrange equipment do not depend too heavily on one man doing a number of tasks simultaneously.

8.1.2 Preparation

Planning and preparation are essential if personnel are to deal successfully with emergencies on board tankers. The master and other officers should consider what they would do in the event of various types of emergency, such as fire in cargo tanks, fire in the engine room, fire in the accommodation, the collapse of a person in a tank, the ship breaking adrift from her berth, the emergency release of a tanker from her berth etc. They will not be able to foresee in detail what might occur in all such emergencies but good advance planning will result in quicker and better decisions and a well organised reaction to the situation.

The following information should be readily available:

- Type of cargo, amount and disposition.
- Whereabouts of other hazardous substances.
- General arrangement plan.
- Stability information.
- Fire-fighting equipment plans.
8.1.3 Emergency Organisation

An emergency organisation should be set up which will come into operation in the event of an emergency. The purpose of this organisation will be in each situation to:

- Raise the alarm.
- Locate and assess the incident and possible dangers.
- Organise manpower and equipment.

The following suggestions are for guidance in planning an emergency organisation, which should cover the following four elements:

**Command Centre**
There should be one group in control of the response to the emergency with the Master or the senior officer on board in charge. The command centre should have means of internal and external communication.

**Emergency Party**
This group should be under the command of a senior officer and should assess the emergency and report to the command centre on the situation, advising what action should be taken and what assistance should be provided, either from on board or, if the ship is in port, from ashore.

**Back up Emergency Party**
The back up emergency party under the command of an officer should stand by to assist the emergency party as instructed by the command centre and to provide back up services, e.g. equipment, stores, medical services including cardio-pulmonary resuscitation etc.

**Engineering Group**
This group should be under the command of the chief engineer or the senior engineering officer on board and should provide emergency assistance as instructed by the command centre. The prime responsibility for dealing with any emergency in the main machinery spaces will probably rest with this group. It may be called on to provide additional manpower elsewhere. The plan should ensure that all arrangements apply equally well in port and at sea.

8.1.4 Preliminary Action

The person who discovers the emergency must raise the alarm and pass on information about the situation to the officer on duty who, in turn, must alert the emergency organisation. While this is being done, those on the scene should attempt immediate measures to control the emergency until the emergency organisation takes effect. Each group in the emergency organisation should have a designated assembly point, as should those persons not directly involved as members of any group. Personnel not directly involved should stand by to act as required.
8.1.5 Ship’s Fire Alarm Signal

At a terminal the sounding of the ship’s fire alarm system should be supplemented by a series of long blasts on the ship’s whistle, each blast being not less than 10 seconds in duration, or by some other locally required signal.
8.1.6 Fire-Fighting Equipment Plans

Fire-fighting equipment plans must be permanently displayed in prominent positions showing clearly, for each deck, the location and particulars of all fire-fighting equipment, dampers, controls, etc. These plans should also be displayed, or be readily available, at the access points to the ship when it is in port.

8.1.7 Inspection and Maintenance

Fire-fighting equipment should always be ready for immediate use and should be checked frequently. The dates and details of such checks should be recorded and indicated on the appliance as appropriate. The inspection of all fire-fighting and other emergency equipment should be carried out by a responsible officer, and any necessary maintenance work completed without delay. As soon as possible after an incident there should be a thorough check of all the equipment used. All breathing apparatus used should be checked and the bottles recharged. Foam systems should be flushed through etc.
# EMERGENCY PLAN

## LIFEBOAT & GENERAL ALARM:

### PORT LIFEBOAT
- **Chief Officer**: Boat Commander / Deputy Launching / Rescue Team
- **3rd Officer**: Engine Room / Engine Room / Engine Room / Engine Room
- **Engineer**: Engine Room / Engine Room / Engine Room / Engine Room

### STBD LIFEBOAT
- **Chief Officer**: Boat Commander / Deputy Launching / Rescue Team
- **3rd Officer**: Engine Room / Engine Room / Engine Room / Engine Room
- **Engineer**: Engine Room / Engine Room / Engine Room / Engine Room

## ALLOCATION TO LIFEBOATS:

<table>
<thead>
<tr>
<th>3rd Officer</th>
<th>Responsibilities</th>
</tr>
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<tbody>
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## LOCATION OF EQUIPMENT

- **Location**: 
  - Emergency Kit: 
  - Fire Extinguisher: 
  - Portable Fire Extinguisher: 
  - Emergency Lights: 
  - Emergency Lamp: 
  - Fire Blanket: 
  - Fire Hose: 
  - Fire Hydrant: 

## GENERAL EMERGENCY INSTRUCTIONS

- In case of fire, sound the fire alarm and evacuate all personnel to the lifeboats immediately.
- Keep calm and follow the designated routes.
- Do not use elevators.
- Follow the instructions given by the designated emergency personnel.

## FIRE & EMERGENCY ALARM:

### EMERGENCY LIGHTS:

- In case of fire, turn on all emergency lights to ensure visibility.
- Keep emergency lights close to the exits.

### FIRE HYDRANTS:

- Regularly check and maintain fire hydrants to ensure they are in working condition.
- Keep hydrants free from obstructions.

### SAFETY近くのEBD:

- Keep emergency blankets and first aid kits near the exits.
- Provide emergency supplies to those in need.

### COMMUNICATIONS:

- Ensure all communication equipment is functioning properly.
- Keep communication channels clear and free from noise.

### ASSIGNMENT FOR FIRE ALARM:

- Assign specific areas for each team member to ensure quick response.
- Keep emergency exits clear and accessible.

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**SQUAD 1**
- **Squad Leader**: 3rd Officer
- **Members**: Safety No. 3, Safety No. 5, Safety No. 9, Safety No. 13, Safety No. 15, Safety No. 17

**SQUAD 2**
- **Squad Leader**: 3rd Officer
- **Members**: Safety No. 4, Safety No. 6, Safety No. 8, Safety No. 11, Safety No. 14, Safety No. 16

**SQUAD 3**
- **Squad Leader**: 3rd Officer
- **Members**: Safety No. 21, Safety No. 23, Safety No. 25, Safety No. 27, Safety No. 29, Safety No. 31

**EMERGENOIR**
- **Squad Leader**: 3rd Officer
- **Members**: Safety No. 7, Safety No. 19

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**CO2 ALARM**

- **Engine Room**
  - Cargo Compressor Room, E.U. Motor Room and Cargo Control Room, etc.

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**APPENDIX**

- Firefighting equipment: 
  - Fire extinguishers: 
  - Fire blankets: 
  - Fire hoses: 
  - Fire alarms: 

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**COMMENTS**

- Regular drills and training ensure effective emergency response.
- Maintain emergency equipment and supplies.
- Keep emergency exits clear and accessible.

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**NOTES**

- Emergency personnel must remain calm and follow the established procedures.
- Keep emergency equipment ready at all times.
- Regular training sessions for emergency personnel.
8.1.8 Training and Drills

Ship’s personnel should be familiar with the theory of fire-fighting and should receive instruction in the use of fire-fighting and emergency equipment. Practices and drills should be arranged at intervals to ensure that personnel retain their familiarity with the equipment. If an opportunity arises for a combined fire practice or conference with shore personnel at a terminal the master should make an officer available to show the shore personnel the location of portable and fixed fire-fighting equipment on board and also to instruct them on any design features of the ship which may require special attention in case of fire.

8.2 FIRE ON A TANKER AT SEA OR AT ANCHOR

Ship’s personnel who discover an outbreak of fire must immediately raise the alarm, indicating the location of the fire. The ship’s fire alarm must be operated as soon as possible. Personnel in the vicinity of the fire should apply the nearest suitable extinguishing agent to attempt to limit the spread of the fire, to extinguish it, and thereafter to prevent re-ignition. If they are unsuccessful, their actions should very quickly be superseded by the operation of the tanker’s emergency plan. Any cargo, ballast, tank cleaning or bunkering operations should be stopped immediately and all valves closed. Any craft alongside should be removed. After all personnel have been evacuated from the vicinity, all doors, openings and tank apertures should be closed as quickly as possible and mechanical ventilation should be stopped. Decks, bulkheads and other structures in the vicinity of the fire, and adjacent tanks that contain petroleum liquids or are not gas free, should be cooled with water. The tanker should be manoeuvred so as to resist the spread of the fire and allow it to be attacked from windward.

8.3 FIRE ON A TANKER AT A TERMINAL

8.3.1 Action by Ship’s Personnel

If a fire breaks out on a tanker while at a terminal, the tanker must raise the alarm by sounding the recognised alarm signal consisting of a series of long blasts on the ship’s whistle, each blast being not less than 10 seconds in duration, unless the terminal has notified the ship of some other locally recognised alarm signal. All cargo, bunkering, or ballasting operations must be stopped and the main engines and steering gear brought to a stand by condition. Once the alarm has been raised, responsibility for fighting the fire on board the ship will rest with the master or other responsible officer assisted by the ship’s crew. The same emergency organisation should be used as when the ship is at sea with an additional group under the command of an officer or senior rating to make preparations, where possible, for disconnecting metal arms or hoses from the manifold. On mobilisation of the terminal and, where applicable, the civil fire-fighting forces and equipment, the master or other responsible officer, in conjunction with the professional fire fighters, must make a united effort to bring the fire under control.
8.3.2 Action by Terminal Personnel

On hearing a tanker sounding its fire alarm, the person in charge of a berth must immediately advise the control room. The control room personnel will sound the terminal fire alarm, inform the port authority and commence shutting down any loading, discharging, bunkering or deballasting operations, which may be taking place. The terminal’s fire emergency plan will be activated and this may involve shutting down cargo, bunkering, and ballast handling operations on ships on adjacent or neighbouring berths. All other ships at the terminal should be informed of the emergency and, where considered necessary, make preparations to disconnect metal arms or hoses and bring their engines and steering gear to a state of readiness.

Where there are fire-fighting tugs, the terminal control room will summon them to assist in fighting the fire until a decision is made by the person in overall control whether or not to use them to assist in the evacuation of unaffected ships. The terminal control room will be responsible for summoning any outside assistance such as the civil fire brigade, rescue launches, medical aid and ambulances, police, harbour authority and pilots.

8.4 FIRE OR EXPLOSION ON A BERTH

8.4.1 Action by Vessels

Should a fire or explosion occur on a berth, the ship or ships at the berth must immediately report the incident to the terminal control room by the quickest possible method (VHF/UHF/telephone contact, sounding ship’s siren etc.); shut down all cargo, bunkering, deballasting and tank cleaning operations; and drain all arms or hoses ready for disconnecting.

The ships’ fire mains should be pressurised and water fog applied in strategic places. The ships’ engines, steering gear and unmooring equipment must be brought to a state of immediate readiness. A pilot ladder should be put over on the offshore side.

8.4.2 Action by Vessels at Other Berths

On hearing the terminal alarm being sounded or on being otherwise advised of a fire at the terminal, a ship whose berth is not involved in the fire should shut down all cargo, bunkering and ballasting operations; bring her fire-fighting capability to a state of readiness; and make engines, steering gear and mooring equipment ready for immediate use.

8.5 JETTISON OF CARGO

The jettison of cargo is an extreme measure justified only as a means of saving life at sea or for the safety of the vessel. A decision to jettison cargo should therefore not be taken until all the alternative options have been considered in the light of available information on stability and reserve buoyancy.

If it is necessary to jettison cargo the following precautions should be taken:

- Engine room personnel should be alerted. Depending on the circumstances prevailing at the time, consideration should be given to changing over engine room intakes from high to low level.
Discharge should take place through the sea valve and where possible on the side opposite to the engine room intakes.

All non-essential inlets should be closed.

If discharge must be from the deck level, flexible hoses should be rigged to extend below the water surface.

All safety precautions relating to normal operations, which involve the presence of flammable gas in the vicinity of the deck, must be observed.

A radio warning should be broadcast.
9 INERT GAS SYSTEM (IGS)

(STCW Code, section A-V/1 paragraph 10)

Learning objectives
- which oil tanker must be provided with an inert gas system
- the inert gas system
- the inert gas plant
- the scrubber
- the inert gas blowers
- the inert gas pressure regulating valve
- the non-return devices
- the inert gas distribution and venting
- gas-analysing, recording and indicating equipment
- operations
- meters, indicators and alarms
- emergency procedures
- maintenance and testing

9.1 GENERAL

Fire and explosion are among the greatest threats to the mariner; a tank ship carrying crude oil, refined petroleum, or chemicals is an even greater threat. Fortunately, a properly designed, installed, operating, and maintained inert gas system (IGS) will completely prevent fire and explosion in an intact ship tank. Combustion is impossible without oxygen; if there is some way to keep the oxygen below about 8 percent, the ship will be free of danger from explosions in intact tanks. Typically, this is done by adding to the tank atmosphere a gas that has less oxygen (often 5 percent or less) than air, which has an oxygen concentration of 21 percent. Of course, when a tank is opened, as in a collision, oxygen can enter the tank regardless of the IGS. In the 1920's and 1930's, one American petroleum company suffered several tank ship fires and decided to inert the cargo tanks of its ships. Reportedly, its vessels have not had any intact cargo tank fires since that time.

In the mid1970’s, a series of tank ship accidents led to the International Conference on Tanker Safety and Pollution Prevention (TSPP) of 1978 and the passage of the Port and Tanker Safety Act of 1978 (PTSA). International rules are contained in Chapter II-2, Regulation 62 (Inert Gas Systems) of the International Convention for the Safety of Life at Sea (SOLAS), 1974. The first set of amendments to SOLAS 74 were adopted and came into force on 1 September 1984; under them, a ship must satisfy applicable requirements to receive a SOLAS Safety Certificate. The second set of amendments to SOLAS 74 come into effect on 1 July 1986; they have only a minor effect on the IGS requirements.

Regulation 60 of SOLAS Chapter II-2
Cargo tank protection
1 For tankers of 20,000 tonnes deadweight and upwards the protection of the cargo tanks deck area and cargo tanks shall be achieved by a fixed deck foam system and a fixed inert gas system in accordance with the requirements of regulations 61 and 62, except that, in lieu of the above
installations, the Administration, after having given consideration to the ship's arrangement and equipment, may accept other combinations of fixed installations if they afford protection equivalent to the above, in accordance with regulation I/5.

2 To be considered equivalent, the system proposed in lieu of the deck foam system shall:
   .1 be capable of extinguishing spill fires and also preclude ignition of spilled oil not yet ignited; and
   .2 be capable of combating fires in ruptured tanks.

3 To be considered equivalent, the system proposed in lieu of the fixed inert gas system shall:
   .1 be capable of preventing dangerous accumulations of explosive mixtures in intact cargo tanks during normal service throughout the ballast voyage and necessary in-tank operations; and
   .2 be so designed as to minimize the risk of ignition from the generation of static electricity by the system itself.

4 Tankers of 20,000 tonnes deadweight and upwards constructed before 1 September 1984 which are engaged in the trade of carrying crude oil shall be fitted with an inert gas system, complying with the requirements of paragraph 1, not later than:
   .1 for a tanker of 70,000 tonnes deadweight and upwards 1 September 1984 or the date of delivery of the ship, whichever occurs later; and
   .2 for a tanker of less than 70,000 tonnes deadweight 1 May 1985 or the date of delivery of the ship, whichever occurs later except that for tankers of less than 40,000 tonnes deadweight not fitted with tank washing machines having an individual throughput of greater than 60 m³/h the Administration may exempt such tankers from the requirements of this paragraph, if it would be unreasonable and impracticable to apply these requirements, taking into account the ship's design characteristics.

5 Tankers of 40,000 tonnes deadweight and upwards constructed before 1 September 1984 which are engaged in the trade of carrying oil other than crude oil and any such tanker of 20,000 tonnes deadweight and upwards engaged in the trade of carrying oil other than crude oil fitted with tank washing machines having an individual throughput of greater than 60 m³/h shall be fitted with an inert gas system, complying with the requirements of paragraph 1, not later than:
   .1 for a tanker of 70,000 tonnes deadweight and upwards 1 September 1984 or the date of delivery of the ship, whichever occurs later; and
   .2 for a tanker of less than 70,000 tonnes deadweight 1 May 1985 or the date of delivery of the ship, whichever occurs later.

6 All tankers operating with a cargo tank cleaning procedure using crude oil washing shall be fitted with an inert gas system complying with the requirements of regulation 62 and with fixed tank washing machines.

7 All tankers fitted with a fixed inert gas system shall be provided with a closed ullage system.

8 Tankers of less than 20,000 tonnes deadweight shall be provided with a deck foam system complying with the requirements of regulation 61.

9.2 THE INERT GAS SYSTEM

There are several ways to inert a tank. The simplest would be to add a pure non-flammable gas, such as nitrogen or carbon dioxide, to the tank atmosphere. Unfortunately, these pure gases tend to be expensive, the costs of their storage aboard ship tend to be high, and re-supply in some ports is difficult. Thus, most "inerted" ships use the gases from a fuel burner, from the ship's propulsion equipment (flue gas), or from a unit dedicated to producing inerting gas (an inert gas generator (IGG)). The following general description of an IGS includes components that may vary, depending upon the manufacturer. Use of combustion gases as the inerting medium proves
advantageous due to its availability as needed and much lower cost, if sufficient fuel
and properly adjusted and operated equipment is provided. Its disadvantage is that the
raw combustion gases are impure and must be treated before use in the cargo tanks.
This is especially important for product carriers, in which cargo purity is critical and
some cargoes may react with impurities in the inert gases. Each IGS has several
components intended to remove these impurities. For example, sulphur in the fuel
appears in the inert gas in the form of sulphur oxides, sulphurous acid, and sulphuric
acid. If not removed, they will attack the metal of the tank and gradually destroy it.
Passing the inert gas through a water-filled device called a scrubber removes most of
these acids.
9.2.1 Sources

Possible sources of inert gas on tankers and combination carriers are:

- Uptake gas from the ship’s main or auxiliary boilers.
- An independent inert gas generator.
- A gas turbine fitted with an afterburner.

9.2.2 Quality

A final oxygen level of 8% or less will be more easily achieved if the oxygen content of the inert gas in the inert gas main is considerably less than 8%. Ideally the inert gas should not contain oxygen but this is not possible in practice.

When using flue gas from a main or auxiliary boiler, an oxygen level of less than 5% can generally be obtained, depending on the quality of combustion control and the load on the boiler.

When an independent inert gas generator or a gas turbine plant with afterburner is fitted, the oxygen content can be automatically controlled within finer limits, usually within the range 1.5% to 2.5% by volume and not normally exceeding 5%.

Whatever the source, the gas must be cooled and scrubbed with water to remove soot and sulphur acids before being supplied to the cargo tanks.

The International Convention for the Safety of Life at Sea (SOLAS 1974), as amended, requires that inert gas systems be capable of delivering inert gas with an oxygen content in the inert gas main of not more than 5% by volume at any required rate of flow; and of maintaining a positive pressure in the cargo tanks at all times with an atmosphere having an oxygen content of not more than 8% by volume except when it is necessary for the tank to be gas free. Existing systems are only required to be capable of
producing inert gas with an oxygen content not normally exceeding 5% by volume, and of maintaining the tank inerted at all times except when it is necessary for the tank to be gas free.

9.3 INERT GAS PLANT

The inert gas system referred to in SOLAS regulation 60 shall be designed, constructed and tested to the satisfaction of the Administration. It shall be so designed and operated as to render and maintain the atmosphere of the cargo tanks non-flammable at all times, except when such tanks are required to be gas-free. In the event that the inert gas system is unable to meet the operational requirement set out above and it has been assessed that it is impracticable to effect a repair, then cargo discharge, deballasting and necessary tank cleaning shall only be resumed when the “emergency conditions” laid down in the Guidelines on Inert Gas Systems are complied with.

The system shall be capable of:

- Inerting empty cargo tanks by reducing the oxygen content of the atmosphere in each tank to a level at which combustion cannot be supported;
- Throughout this regulation the term cargo tank includes also slop tanks.
- Maintaining the atmosphere in any part of any cargo tank with an oxygen content not exceeding 8% by volume and at a positive pressure at all times in port and at sea except when it is necessary for such a tank to be gas-free;
- Eliminating the need for air to enter a tank during normal operations except when it is necessary for such a tank to be gas free;
- Purging empty cargo tanks of a hydrocarbon gas, so that subsequent gas-freeing operations will at no time create a flammable atmosphere within the tank.
- The system shall be capable of delivering inert gas to the cargo tanks at a rate of at least 125% of the maximum rate of discharge capacity of the ship expressed as a volume.
- The system shall be capable of delivering inert gas with an oxygen content of not more than 5% by volume in the inert gas supply main to the cargo tanks at any required rate of flow.

The inert gas supply may be treated flue gas from main or auxiliary boilers. The Administration may accept systems using flue gases from one or more separate gas generators or other sources or any combination thereof, provided that an equivalent standard of safety is achieved. Such systems should, as far as practicable, comply with the requirements of this regulation. Systems using stored carbon dioxide shall not be permitted unless the Administration is satisfied that the risk of ignition from generation of static electricity by the system itself is minimized.
9.4 SCRUBBER

A flue gas scrubber shall be fitted which will effectively cool the volume of gas and remove solids and sulphur combustion products. The cooling water arrangements shall be such that an adequate supply of water will always be available without interfering with any essential services on the ship. Provision shall also be made for an alternative supply of cooling water. Filters or equivalent devices shall be fitted to minimize the amount of water carried over to the inert gas blowers. The scrubber shall be located aft of all cargo tanks, cargo pump rooms and cofferdams separating these spaces from machinery spaces of category A.

9.4.1 Boiler Uptake

These valves are located near the main boiler uptake to isolate the IGS scrubber from the boiler uptake. Alternatively, if a dedicated IGG is used, this valve will be located near the IGG; it is closed when the IGS system is not operating. Associated with each boiler uptake valve is a steam soot blowing system. A spectacle blank is also fitted between the boiler uptake valve and the IGS scrubber to ensure complete isolation of the IGS plant and cargo. This is very important to ensure that inert gas is not introduced into the system during maintenance.

9.4.2 IGS Scrubber

The raw inert gases are hot and contain soot, sulphur oxides, sulphurous acid, and sulphuric acid; all of these can be harmful to the cargo and the cargo tanks. The scrubber cools the gases and removes the contaminants by bubbling the gases through large quantities of seawater (there must be two sources of water for the scrubber). The gases are then sprayed with additional quantities of water, or rise through a packed bed of ceramic forms, plastic shapes, or metal trays through which seawater falls, increasing the efficiency of the water in cleaning the inert gas. The warm, acidic, dirty seawater is then piped overboard. If the scrubber is provided with a heater to prevent the water from freezing, an automatic control system is installed to prevent its overheating. The scrubber also acts as an automatic safety device by preventing a backflow of gas to the boiler uptake or the IGG.

9.4.3 Demister Units

The gas from the scrubber has significant amounts of moisture, both from the burning process and from bubbling through the seawater in the scrubber. The demister is located close to the scrubber to remove entrained water from the IGS gas stream. If this water is not removed, it increases the corrosion rate in the system's piping, valves, and cargo tanks. Water may also contaminate the cargo. The demister may consist of "pads" or "mattresses" of woven polypropylene or fibreglass, or centrifuge separation (cyclone dryers). There are many designs, which vary considerably.
9.5 INERT GAS BLOWERS

At least two blowers shall be fitted which together shall be capable of delivering to the cargo tanks at least the volume of gas required by paragraph 3. In the system with a gas generator the Administration may permit only one blower if that system is capable of delivering the total volume of gas required by paragraph 3 to the protected cargo tanks, provided that sufficient spares for the blower and its prime mover are carried on board to enable any failure of the blower and its prime mover to be rectified by the ship's crew.

Two fuel oil pumps shall be fitted to the inert gas generator. The Administration may permit only one fuel oil pump on condition that sufficient spares for the fuel oil pump and its prime mover are carried on board to enable any failure of the fuel oil pump and its prime mover to be rectified by the ship's crew.

The inert gas system shall be so designed that the maximum pressure, which it can exert on any cargo tank, will not exceed the test pressure of any cargo tank. Suitable shutoff arrangements shall be provided on the suction and discharge connections of each blower. Arrangements shall be provided to enable the functioning of the inert gas plant to be stabilized before commencing cargo discharge. If the blowers are to be used for gas freeing, their air inlets shall be provided with blanking arrangements. The blowers shall be located aft of all cargo tanks, cargo pump rooms and cofferdams separating these spaces from machinery spaces of category A.

9.5.1 Fan Units

Two or more independent blowers are located near the demister to draw the inert gas through the scrubber and the demister and deliver it to the IGS distribution system at the required pressure. Since the greatest need for inert gas is during offloading, the blower capacity is set at 125 percent of the maximum rated capacity of the cargo pumps. This provides a margin of safety to ensure that no air enters the cargo tanks. This capacity may be provided by two blowers of equal size, or by one large and one small blower. Separate inlet and discharge valves are fitted to each blower unit. On most plants, the valves are hand operated, but on some the discharge valves are combined with the main and auxiliary pressure regulating valves.
Special consideration shall be given to the design and location of scrubber and blowers with relevant piping and fittings in order to prevent flue gas leakages into enclosed spaces.
9.6 **INERT GAS PRESSURE REGULATING VALVE**

A gas-regulating valve shall be fitted in the inert gas supply main. This valve shall be automatically controlled to close as required. (SOLAS Chapter II-2 paragraphs 19.3 and 19.4.) It shall also be capable of automatically regulating the flow of inert gas to the cargo tanks unless means are provided to automatically control the speed of the inert gas blowers required. (SOLAS Chapter II-2 paragraph 7.9.2). The valve referred to shall be located at the forward bulkhead of the forward most gas-safe space through which the inert gas supply main passes.

The pressure-regulating valve is used to adjust the pressure between the IGS and the cargo tanks. An over-pressurized cargo tank can rupture if the pressure in the IGS value is too high. It is also important to prevent backflow from the cargo tanks, which could lead to inert or cargo gases entering the machinery spaces. A fire or explosion could occur if cargo gases mix with air and enter the boilers, the engines, or the IGG. The pressure-regulating valve is installed to regulate the flow of inert gas to the IGS deck main, maintain the IGS pressure, and prevent gas backflow when the IGS malfunctions or is shut down. The valve position may be controlled either manually or automatically. For automatic control, the IGS pressure is used to set the valve in a pneumatic, hydraulic, or electric feedback control to maintain a constant pressure regardless of the rate cargo discharge.

9.7 **NON-RETURN DEVICES**

At least two non-return devices, one of which shall be a water seal, shall be fitted in the inert gas supply main, in order to prevent the return of hydrocarbon vapour to the machinery space uptakes or to any gas-safe spaces under all normal conditions of trim, list and motion of the ship. They shall be located between the automatic valve and the aftermost connection to any cargo tank or cargo pipeline. The devices shall be located in the cargo area on deck.

The water seal shall be capable of being supplied by two separate pumps, each of which shall be capable of maintaining an adequate supply at all times.

The arrangement of the seal and its associated fittings shall be such that it will prevent backflow of hydrocarbon vapours and will ensure the proper functioning of the seal under operating conditions.
Provision shall be made to ensure that the water seal is protected against freezing, in such a way that the integrity of seal is also not impaired by overheating. A water loop or other approved arrangement shall also be fitted to each associated water supply and drain pipe and each venting or pressure sensing pipe leading to gas-safe spaces. Means shall be provided to prevent such loops from being emptied by vacuum. The deck water seal and loop arrangements shall be capable of preventing return of hydrocarbon vapours at a pressure equal to the test pressure of the cargo tanks. The second device shall be a non-return valve or equivalent capable of preventing the return of vapours or liquids and fitted forward of the deck water seal. It shall be provided with positive means of closure. As an alternative to positive means of closure, an additional valve having such means of closure may be provided forward of the non-return valve to isolate the deck water seal from the inert gas main to the cargo tanks.

Usually located on the main deck, the deck water seal is the primary safeguard to automatically prevent a reverse flow of cargo gas from a tank to the boilers, the engines, or the IGG. The deck water seal offers a positive break in the system by means of a water trap. This permits inert gas to be delivered to the main deck while preventing gas backflow, even when the IGS is shut down. The regulations require two independent water supplies for the deck water seal. When the IGS is operating, the scrubber pump supply is used; the second supply, normally the salt-water service pump, is used when the IGS is not operating. Each pump must be capable of operation at all times. The deck water seal is provided with a heater to prevent the water from freezing and an automatic control system that prevents overheating of the seal. Although not required, a demister is usually fitted to remove entrained water. There is always a water layer through which the inert gas bubbles

There are three general types of deck water seals: wet, dry, and semidry.

(1) The wet seal is described in Figure 9.1.

It is deemed the most reliable and is the only type generally approved for use on most vessels.
(2) The semidry seal operates dry after the IG flow displaces the water. Venturi action returns the water when a gas block is needed as described in Figure 9.2. This type of seal has been approved for U.S. vessels on a case-by-case basis, if the unit is quick acting, has no moving parts, and has no sensors that are subject to failure.
(3) The dry seal operates normally dry and is filled with water when the IG plant is shut down or when tank pressure exceeds the IG pressure. This system requires more operating parts, reacts slower and is not deemed as reliable as the wet type. Dry seals are not approved for use on U.S. vessels. See Figure 9.3 for a more complete description.

In the dry type seal, the water is drained from the seal when the IG plant is in operation (gas flowing to the tanks), and filled with water when the IG plant is either shut down, or the tank pressure exceeds the IG blower discharge pressure. Filling and drainage are performed by automatically operated valves controlled by the levels in the water seal and the drop tank, and by the operating state of the blowers. Vessels must be equipped with seals that are completely passive in operation, so that failure of sensors, control systems, or moving parts cannot cause failure to establish a seal. Active seals, such as the dry seal shown above, are not acceptable.
9.8 INERT GAS DISTRIBUTION AND VENTING

9.8.1 General
The inert gas main may be divided into two or more branches forward of the non-return devices. The inert gas supply main shall be fitted with branch piping leading to each cargo tank. Branch piping for inert gas shall be fitted with either stop valves or equivalent means of control for isolating each tank. Where stop valves are fitted, they shall be provided with locking arrangements, which shall be under the control of a responsible ship's officer. The control system operated shall provide positive indication of the operational status of such valves.

9.8.2 Gas Distribution
When the inert gas is clean, cool, and water-free, it is pressurized and sent to the various cargo tanks. The distribution system contains backflow prevention devices, control valves, alarms, and automatic shutdowns. These alert personnel to a malfunction and, when necessary, shut down the system before a dangerous condition is developed in the tanks. Such conditions involve the oxygen concentration, the temperature and pressure of the inert gas, the water flow to and water level within the scrubber, and the backflow prevention devices (water seals). Because IG systems are complex and subject to malfunction, it is important for ships' crews to inspect and maintain them in good working order.

9.8.3 Combination carriers
In combination carriers, the arrangement to isolate the slop tanks containing oil or oil residues from other tanks shall consist of blank flanges which will remain in position at all times when cargoes other than oil are being carried except as provided for in the relevant section of the Guidelines on Inert Gas Systems.

9.8.4 Overpressure or vacuum
Means shall be provided to protect cargo tanks against the effect of overpressure or vacuum caused by thermal variations when the cargo tanks are isolated from the inert gas mains. Piping systems shall be so designed as to prevent the accumulation of cargo or water in the pipelines under all normal conditions. Suitable arrangements shall be provided to enable the inert gas main to be connected to an external supply of inert gas.

9.8.5 Venting, inerting, purging
The arrangements for the venting of all vapours displaced from the cargo tanks during loading and ballasting shall consist of either one or more mast risers, or a number of high velocity vents. The inert gas supply main may be used for such venting. The arrangements for inerting, purging or gas-freeing of empty tanks shall be to the satisfaction of the Administration and shall be such that the accumulation of hydrocarbon vapours in pockets formed by the internal structural members in a tank is minimized and that:

◆ On individual cargo tanks the gas outlet pipe, if fitted, shall be positioned as far as practicable from the inert gas/air inlet. The inlet of such outlet pipes
may be located either at deck level or at not more than 1 m above the bottom of the tank;

- The cross-sectional area of such gas outlet pipe shall be such that an exit velocity of at least 20 m/s can be maintained when tanks are being simultaneously supplied with inert gas. Their outlets shall extend not less than 2 m above deck level;

- Each gas outlet shall be fitted with suitable blanking arrangements;

If a connection is fitted between the inert gas supply mains and the cargo piping system, arrangements shall be made to ensure an effective isolation having regard to the large pressure difference, which may exist between the systems. This shall consist of two shutoff valves with an arrangement to vent the space between the valves in a safe manner or an arrangement consisting of a spool-piece with associated blanks. The valve separating the inert gas supplies main from the cargo main and which is on the cargo main side shall be a non-return valve with a positive means of closure. One or more pressure/vacuum-breaking devices shall be provided to prevent the cargo tanks from being subject to:

- A positive pressure in excess of the test pressure of the cargo tank if the cargo were to be loaded at the maximum rated capacity and all other outlets are left shut; and

- A negative pressure in excess of 700 mm water gauge if cargo were to be discharged at the maximum rated capacity of the cargo pumps and the inert gas blowers were to fail.

Such devices shall be installed on the inert gas main unless they are installed in the venting system or on individual cargo tanks. Means shall be provided for continuously indicating the temperature and pressure of the inert gas at the discharge side of the gas blowers, whenever the gas blowers are operating.
This subsystem consists of a single inert gas main running the entire length of the cargo deck, starting at the deck isolating valve aft and ending at the vent valve forward. One or more pressure/vacuum devices are fitted to the inert gas main to prevent the cargo tanks from being over or under-pressurized. The inert gas main contains a means for receiving an outside source of inert gas when the IGS is not functioning. From the inert gas main, individual branch lines run to the cargo tanks. Stop valves or equivalent closures are fitted at each branch line, so that each cargo tank can be isolated from the inert gas system. If there is a connection between the inert gas main and the cargo piping system, there must be valves or similar closures to isolate the systems from one another.

Each tank vessel has a venting system that is capable of venting vapours displaced from the cargo tanks during loading and ballasting. There are also pressure/vacuum (P/V) valves to protect the cargo tanks from overpressure or vacuum resulting from thermal variation when the cargo tanks are isolated from the inert gas mains.

Some of the possible arrangements are:

(1) A single common venting system, using the IGS deck main and branch lines from each tank and venting to the atmosphere through one or more mast risers or high velocity vents. Precautions must be taken to prevent an arrangement by which tank vents can be blocked off;

(2) A common venting system, using a separate vent main and vent lines from each tank, with the system venting to the atmosphere through one or more mast risers or high velocity vents; or

(3) Individual vents on each tank, using either standpipes (vent stacks) or high velocity vents.

9.9 GAS-ANALYSING, RECORDING AND INDICATING EQUIPMENT

Instrumentation shall be fitted for continuously indicating and permanently recording, when the inert gas is being supplied:

- The pressure of the inert gas supply mains forward of the non-return devices; and
The oxygen content of the inert gas in the inert gas supply mains on the discharge side of the gas blowers.

The devices shall be placed in the cargo control room where provided. But where no cargo control room is provided, they shall be placed in a position easily accessible to the officer in charge of cargo operations.

In addition, meters shall be fitted:

- In the navigation bridge to indicate at all times the inert gas pressure forward of the non-return devices and the pressure in the slop tanks of combination carriers, whenever those tanks are isolated from the inert gas supply main; and
- In the machinery control room or in the machinery space to indicate the oxygen content of the inert gas in the inert gas supply mains on the discharge side of the gas blowers.

Portable instruments for measuring oxygen and flammable vapour concentration shall be provided. In addition, suitable arrangement shall be made on each cargo tank such that the condition of the tank atmosphere can be determined using these portable instruments. Suitable means shall be provided for the zero and span calibration of both fixed and portable gas concentration measurement instruments.

For inert gas systems of both the flue gas type and the inert gas generator type, audible and visual alarms shall be provided to indicate:

- Low water pressure or low water flow rate to the flue gas scrubber;
- High water level in the flue gas scrubber;
- High gas temperature;
- Failure of the inert gas blowers;
- Oxygen content in excess of 5% by volume;
• Failure of the power supply to the automatic control system for the gas regulating valve and to the indicating devices;
• Low water level in the water seal;
• Gas pressure less than 100 mm water gauge. The alarm arrangement shall be such as to ensure that the pressure in slop tanks in combination carriers can be monitored at all times; and
• High gas pressure forward of the non-return devices.

For inert gas systems of the inert gas generator type, additional audible and visual alarms shall be provided to indicate:
• Insufficient fuel oil supply;
• Failure of the power supply to the generator;
• Failure of the power supply to the automatic control system for the generator.

Automatic shutdown of the inert gas blowers and gas-regulating valve shall be arranged on predetermined limits being reached.

Automatic shutdown of the gas-regulating valve shall be arranged in respect of failure of the inert gas blowers.

In respect of the oxygen content of the inert gas exceeds 5% by volume, immediate action shall be taken to improve the gas quality. Unless the quality of the gas improves, all cargo tank operations shall be suspended so as to avoid air being drawn into the tanks and the isolation valve shall be closed.

Alarms shall be fitted in the machinery space and cargo control room, where provided, but in each case in such a position that they are immediately received by responsible members of the crew.

In respect of low water level in the water seal the Administration shall be satisfied as to the maintenance of an adequate reserve of water at all times and the integrity of the arrangements to permit the automatic formation of the water seal when the gas flow ceases. The audible and visual alarm on the low level of water in the water seal shall operate when the inert gas is not being supplied.

An audible alarm system or automatic shutdown of cargo pumps shall be provided to operate on predetermined limits of low pressure in the inert gas main being reached.

Tankers constructed before 1 September 1984, which are required to have an inert gas system, shall at least comply with the requirements of regulation 62 of chapter II-2 of the International Convention for the Safety of Life at Sea, 1974.

Detailed instruction manuals shall be provided on board, covering the operations, safety and maintenance requirements and occupational health hazards relevant to the inert gas system and its application to the cargo tank system. The manuals shall include guidance on procedures to be followed in the event of a fault or failure of the inert gas system.

9.10 OPERATION

9.10.1 Introduction

The purpose of an IG system is to keep the oxygen content of the vapour space below the level needed for combustion. For crude carriers, the oxygen content of the inert gas
delivered to the cargo tanks should be no more than 5 percent, to ensure that there is not enough oxygen in the tank to support combustion.

On board oil tankers required to have an inert gas system the cargo tanks should preferably at all times be inerted and have a tank atmosphere with an oxygen content not exceeding 8% by volume except when the tanks need to be gas-free.

This means that during normal operation of oil tankers the following operational modes frequently take place:

- Inerting of empty tanks
- Inerting during loading and simultaneous discharge of ballast
- Inerting during loaded sea voyage
- Inerting during discharging and ballasting
- Inerting during tank cleaning
- Purging prior to gas freeing and use of the IGS during gas freeing.

The vessel used as an example in this paper is fitted with so-called “purge pipes” for ventilation and purging. (see Fig. 1 on page 19 of this chapter)

On board vessels without purge pipes but with stand-pipes (i.e. vent pipes from deck level and about 2500 mm up vertically from deck level), these pipes are to be opened instead of the purge pipes mentioned in this paper.

The vessel is not fitted with SBT (Segregated Ballast Tank) capacity according to MARPOL 73/78, and ballast water has to be carried in cargo oil tanks on ballast voyages.
9.10.2 **Inerting of empty gas-free tanks**

Start up the inert gas plant according to instructions. Close all tank hatches and check proper function of $O_2$ analyser. Open the lids or hatch covers on standpipes or purge pipes on tanks to be inerted.

Open fan discharge valve (6) and main isolating valve (10) (see Fig. 1 on page 19 of this chapter).

If the gas pressure control valve (7) is on “automatic”, there is now a risk of “overload” of the scrubber due to a limited pressure drop in pipes and tanks. The “overload” of the scrubber may result in “carry over” of water or high-temperature trip of the plant.

Because of the above, it is therefore sometimes necessary to control the pressure manually to reduce the gas flow during the first part of the inerting, until a minimum gas backpressure is established in the tanks. When this minimum gas pressure for stable operation is established, the inert gas plant can be operated automatically at full capacity.

The oxygen content in the tanks should be checked frequently, at least every half hour. The inerting should be continued until the gas leaving the tank has had an $O_2$ content of less than 8% for a minimum of 30 minutes. This is because of the possibility of local air pockets in the tanks.

When all tanks are satisfactorily inerted, the tanks should be put under a slight overpressure, normally 300-600 mm W.G., and the plant closed down according to instructions and the tank isolating valves closed.
Fig. 1 indicates the plant in operation

9.10.3 Inerting during loading and simultaneous discharge of ballast water

The vessel is supposed to arrive at the loading port with all cargo tanks inerted.

If the ship is fitted with a central gas vent outlet, all tanks to be loaded are connected to the vent system.

In case only local P/V valves are fitted, the valves are checked and adjusted for evacuation of gas through the high-speed valves.

It should be checked that all tank hatches are closed and possible float level indicators are operable.
9.10.4 Discharge of ballast

Discharge of ballast can be done either before or during the loading. During discharge of ballast, before loading is commenced, the inerting procedure is the same as during discharge of cargo. See below.

At simultaneous loading of cargo and discharge of ballast, the loading capacity is normally higher than the ballast water discharge capacity. This means that the inert gas volume available in the usage space above the oil level in the tanks being loaded is more than sufficient for the inert gas needed in the ballast tanks during discharge. By simply connecting the ballast tank to the cargo tanks with the inert gas lines on deck, inert gas will flow from the cargo tanks to the ballast tanks. See Fig. 2.

The inert gas system can be operated if required, but will normally not be required to deliver any gas to the deck lines.

If by chance the ballast discharge rate is higher than the loading rate, the inert gas system must be in operation and the deck pressure adjusted sufficiently high to give a positive outflow of inert gas through the ventilation mast (or the individual P/V valves on the tanks). This is to avoid air being sucked into the tank system by a possible under pressure in the ballast tanks.

Figure 2 Condition: Simultaneous loading and deballasting
9.10.5 Loading

During loading without deballasting it is normally not necessary to operate the inert gas system.

Fig. 3 indicates this operation with stopped inert gas system.

The ventilation mast P/V valve should be in the open position or bypassed during this operation. This is to allow free flow of the inert gas above the oil level to the atmosphere during the loading.

When the loading operation is finished, the bypass valve must be closed and the P/V valve adjusted to normal operating conditions. If the ship is fitted with individual P/V valves on the tanks, these should be adjusted to normal operating conditions accordingly.

At this moment the 'usage' volume in the tanks is filled with inert gas mixed with hydrocarbon gases at about atmospheric pressure. If this mixture of inert gas and hydrocarbon gas has an oxygen content of 8% by volume or below, this atmosphere is non-explosive and safe.

In order to start the loaded voyage with positive pressure in the tanks, the IGS has to be started and tanks purged to a pressure of 300-600 mm W.G.
9.10.6 **Loaded sea voyage**

During the loaded voyage the cargo tanks should, as far as possible, be kept inerted with a positive pressure. This positive pressure may, however, be disturbed by several factors. The most common are:

- Leakages in valves and hatch covers
- Change of pressure in the tanks due to temperature variations (i.e. day and night and sea/air temperature changes)
- Rolling and heaving in rough sea.

The effect of the different conditions as mentioned above is partly a pressure drop in the tank (escape of inert gas) and partly the risk of ingress of air into the tanks (temperature aspiration and local underpressure in tanks due to rolling and heaving). Consequently, the oxygen content and the tank pressure should be frequently checked during the sea voyage. The frequency should depend on weather and deck equipment conditions.

“Topping up” of the tank inert gas pressure may be done by starting up the inert gas system, or by using a special “topping up” inert gas generator, if fitted, or by starting up the IGS. The volume needed for this topping-up operation is normally small in loaded condition. “Topping up” is demonstrated in Fig. 4.

![Figure 4 Condition: “Topping up” tanks](image-url)
9.10.7 Discharging

When the vessel arrives at the discharge port, the inert gas system should be tested and ready for operation in due time for discharge.

Before pumping of cargo oil is started, the inert gas system should be in operation and connected to the deck line, with the pressure control in the “automatic” position.

Since the ullage volume is normally small in loaded condition, the desired overpressure is reached in a short time (minutes).

All deck openings and hatches should be closed, all P/V valves should be in the operating position and bypass valves should be closed.

When the pumping (discharge) starts, the pressure in the usage volume will drop. Now the control valve (7) will start operating and will open, for inert gas to compensate the pressure drop and keep a constant pre-selected pressure in the tanks. After some time the required pressure is established. At this moment the volume delivered from the inert gas system is equal to the delivery by the cargo pump. This condition is illustrated in Fig. 5.

If, for any reasons, access to the cargo tanks is necessary during discharge, the following procedure should be followed:

- Reduce the inert gas pressure by adjusting the set point of the pressure control valve.
- When the tanks' inert gas pressure is reduced to near atmospheric pressure, a suitable ullage hatch has to be opened carefully.
- When reading is finished, the hatch may be closed and the pressure raised, if desired.

When discharge and stripping are finished, the tanks should be put under the desired positive pressure.

### 9.10.8 Ballasting during discharge of cargo

Normally, taking in ballast while discharging may save time. This is normally done in the last period (during stripping) of the discharge. This means that some tanks displace inert gas while some consume inert gas. During the stripping of the last tanks, the discharge rate is normally less than the ballast rate. In this case there is a surplus of inert gas, and the inert gas system may, if desired, be stopped. In case of the reverse, the inert gas system must be in operation to prevent air from being sucked into the tanks. See Fig. 6.

The procedure for these operations is the same as for discharging cargo. In case the ballasting rate exceeds the stripping rate, however, the bypass valve in the ventilation line must be open (or, in the case of individual P/V valves, the valves must be opened). The inert gas pressure will in this case be reduced to atmospheric pressure.

Fig. 6 indicates the positions of the different main valves in the system during this operational mode. The capacity of the inert gas system should always be adjusted to give positive outflow of inert gas through the ventilation mast. This is done to prevent air from being sucked into the tanks.

When the vessel is ballasted, the bypass valve should be closed and the pressure of inert gas in the tank raised to the desired level before the main isolating valve is closed and the inert gas plant is stopped.

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**Figure 6 Condition: Simultaneous discharge and ballasting**
9.10.9 **Ballast voyage**

After the vessel has left the discharge port, the inert gas system should be in operation for purging of all cargo tanks to reduce the concentration of hydrocarbon gas. The operation should be controlled by checking the concentration of hydrocarbons in the gas leaving the purge pipes, or with tests taken at different levels in the tanks. When the tanks have been purged and the concentration of hydrocarbon gas has been checked to be below about 2.5% by volume, the tanks should be pressurized and the inert gas system closed down.

The tank pressure and oxygen concentration should be monitored during the voyage and new purging or 'topping up' should be done when necessary.

9.10.10 **Tank cleaning**

The oxygen content in the tank atmosphere should always be checked before any tank cleaning is started. No tank cleaning, either with the cargo oil - Crude Oil Washing (COW) - or with water, should be started unless the oxygen content is 8% by volume or less, measured in the tanks.

For tankers with Crude Oil Washing systems, the following procedure is to be complied with.

Before each tank is crude oil washed, the oxygen concentration shall be determined at a point 1 metre from the deck and at the middle region of the ullage space; neither of these determinations shall exceed 8% by volume. Where tanks have complete or partial wash bulkheads, the determinations should be taken from similar levels in each section of the tank. The oxygen level of the inert gas being delivered during the washing process shall be continuously monitored. If, during crude oil washing:

(i) The oxygen level of the inert gas being delivered exceeds 8% by volume; or

(ii) The pressure of the atmosphere at the tanks is no longer positive, then the washing must be stopped until satisfactory conditions are restored.
In Fig. 7 the conditions during tank cleaning are shown.

9.10.11 Gas-freeing

When access to the cargo tanks is necessary for inspection, repair, etc., the inert gas or inert gas/hydrocarbon gas mixture has to be replaced with fresh air. This replacement is called “gas-freeing”.

The gas freeing is normally carried out by one or more of the following three methods:

1. By portable tank ventilators
2. By permanently installed tank ventilators blowing air into tanks through the cargo oil piping system
3. By using the fans of the inert gas system with suction from fresh air instead of from the scrubber.

Whatever method is being used for gas freeing, the following steps should be taken:

1. Hydrocarbon gas concentration to be measured in each tank to be gas-freed.
2. If the concentration of hydrocarbon gas is 2.5% by volume or less, ventilation with fresh air may start immediately.
3. If the concentration of hydrocarbon gas is above 2.5% by volume, the tanks should be purged with inert gas until the concentration is 2.5% by volume or less before ventilation with fresh air starts.
4. Ventilation should continue until the concentration of hydrocarbon gas is 5% LEL or less and the oxygen level is 21% by volume before the tank is certified gas-free.

Gas freeing can take place either by a dilution method or by a displacement method, as indicated on Figs. 8 and 9.

![Figure 8 Gas-freeing by dilution method](image1)

![Figure 9 Gas-freeing by the displacement method](image2)

Using the dilution or mixing method, the fresh air is blown, at high pressure, into the tank at deck level, forced down to the bottom of the tank and vented out at deck level. See Fig. 8.

By the displacement method the air is blown in slowly at deck level and is forced out of the tank near the bottom, through the purge pipe. See Fig. 9.

Although a turbulent mixing flow is wanted if using the dilution method, the opposite is wanted if using the displacement method. Consequently, the different methods require different air inlet nozzle arrangements where the fresh air enters the tank.

9.10.12 **Gas-freeing with portable tank ventilators**

If the vessel is fitted with standpipes, the displacement method for gas freeing should be used.

This means that no particular requirement has to be put on the blowers except that they should give as little turbulence in the air inlet area as possible, for minimum mixing between the tank atmosphere and the fresh air.

If the mixing method is used, the inlet air should have an inlet speed sufficient to force the air jet down to the bottom of the tank (30-40 m/second). If this is not possible, the blower should be fitted with canvas hoses or similar to bring the fresh air outlet to the tank bottom. See Figs. 8 and 9.

9.10.13 **Gas-freeing using permanently installed ventilators**

Fig. 10 shows the principle of ventilation with permanently installed ventilators through the vessel's cargo oil piping system.

The tank isolation valves should be closed, or the connection between the tanks and the inert gas system blind-flanged, during this operation.
9.10.14 Gas-freeing with the inert gas fans

The modern IGS is generally fitted with a fresh air suction duct to the suction side of the fans. This can be connected to the fans instead of the normal suction line to the scrubber. When the fresh air ducts are connected to the fans, the inert gas system is started in the normal way. Close the openings on deck, but open the lids of the purge pipes or adjust local PN valves to the 'open' position. The bypass valve in the ventilation mast should be closed.

Fig. 11 shows a plant using the displacement method for gas freeing.

This method is normally fast and efficient provided the mixing effect at the air inlet is not too extensive.

For a plant using the mixing method the result is dependent upon the inlet air velocity and the fact that the air jet penetrates to the bottom of the tank.

The gas freeing should be continued until the oxygen content in the gas leaving the tanks (through purge pipes or stand-pipes) has been measured as 21 % by volume for at least 30 minutes.

This should, however, *not* be considered sufficient for safe entry of personnel into the tanks.
No tank should be entered before all parts of the tank are checked for possible pockets of remaining inert gas or hydrocarbon gases. If in doubt, fresh air breathing apparatus should be used.
9.11 EMERGENCY PROCEDURES

In the event of malfunction or total failure of the IGS, special attention must be paid to all steps of the cargo-handling process.

9.11.1 Emergency Procedures

In the event of total failure of the inert gas system to deliver the required quality and quantity of inert gas and maintain a positive pressure in the cargo tanks and slop tanks, action must be taken immediately to prevent any air being drawn into the tank. All cargo tank operations should be stopped, the deck-isolating valve should be closed, and the vent valve between it and the gas pressure-regulating valve should be opened and immediate action should be taken to repair the inert gas system.

In the case of tankers engaged in the carriage of crude oil (with a high H2O content) it is essential that the cargo tanks be maintained in the inerted condition to avoid the hazard of pyrophoric iron sulphide ignition. If it is assessed that the tanks cannot be maintained in an inerted condition before the inert gas system can be repaired, an external supply of inert gas should be connected to the system through the arrangements required by SOLAS Regulation 62.11.5 as soon as practicable, to avoid air being drawn into the cargo tanks.
In the case of product carriers, if it is considered to be totally impracticable to effect a repair to enable the inert gas system to deliver the required quality and quantity of gas and maintain a positive pressure in the cargo tanks, cargo discharge and deballasting may only be resumed provided that either an external supply of inert gas is connected to the system through the arrangements required by SOLAS Regulation 62.11.5, or the following precautions are taken:

.1 In the case of tankers built on or after 1 September 1984, the venting system is checked to ensure that approved devices to prevent the passage of flame into cargo tanks are fitted and that these devices are in a satisfactory condition.

.2 In the case of tankers built before 1 September 1984 the flame screens are checked to ensure that they are in a satisfactory condition.

.3 The valves on the vent mast risers are opened.

.4 No free fall of water or slops is permitted.

.5 No dipping, ullaging, sampling or other equipment should be introduced into the tank unless essential for the safety of the operation. If it is necessary for such equipment to be introduced into the tank, this should be done only after at least 30 minutes have elapsed since the injection of inert gas ceased. All metal components of equipment to be introduced into the tank should be securely earthed. This restriction should be applied until a period of five hours has elapsed since the injection of inert gas has ceased.

In the case of product carriers if it is essential to clean tanks following a failure of the inert gas system and inerted conditions as defined in SOLAS Regulation 62.2.2 cannot be maintained, tank cleaning should be carried out with an external supply of inert gas connected to the system. Alternatively, if an external supply of inert gas is not connected to the ship, the following precautions should be taken:

.1 Tank washing should be carried out only on one tank at a time.

.2 The tank should be isolated from other tanks and from any common venting system or the inert gas main and maximum ventilation output should be concentrated on that tank both before and during the washing process. Ventilation should provide as far as possible a free flow of air from one end of the tank to the other.

.3 The tank bottom should be flushed with water and stripped. The piping system including cargo pumps, crossovers and discharge lines should also be flushed with water.

.4 Washing should not commence until tests have been made at various levels to establish that the vapour content in any part of the tank is below 10% of the lower flammable limit.

.5 Testing the tank atmosphere should continue during the washing process. If the vapour level rises to within 50% of the lower flammable limit, washing should
be discontinued until the vapour level has fallen to 20% of the lower flammable limit or less.

.6 If washing machines with individual capacities exceeding 60 m31hour are to be used, only one such machine shall be used at any one time on the ship. If portable machines are used, all hose connections should be made up and bonding cables tested for continuity before the machines are introduced into the tank and should not be broken until after the machines have been removed from the tank.

.7 The tank should be kept drained during washing. If build-up of wash water occurs, washing should be stopped until the water has been cleared.

.8 Only clean, cold seawater should be used. Recirculating systems should not be used.

.9 Chemical additives should not be used.

.10 All deck openings, except those necessary for washing and designed venting arrangements, should be kept closed during the washing process.

During cargo operations in port, more stringent regulations of the port Authorities shall take precedence over any of the foregoing emergency procedures.
The attention of the ship's master should be drawn to Regulation 11 (c) of Chapter 1 of the 1978 SOLAS Protocol in the event of the inert gas system having become inoperative."

9.12 MAINTENANCE AND TESTING

As inert gas causes asphyxiation, great care must be taken to avoid the escape of inert gas into any enclosed or partly enclosed space.

Before opening the system, it should if possible be gas freed and any enclosed space in which the system is opened up should be ventilated to avoid any risk of oxygen deficiency.

Continuous positive ventilation must be maintained before and during the work. No one should be allowed inside the scrubber or deck water seal until the atmosphere has first been tested and an oxygen level of 21% by volume obtained. In addition, while personnel are working inside a scrubber tower, the atmosphere must be continuously monitored for oxygen content and personnel should be under constant supervision.

9.12.1 Internal inspection of IG system

One must appreciate the potential for introducing "dirty" or corrosive gas into the IGS by improper operating procedures or poor maintenance practices. This situation will create an environment for rapid system degradation or component failure. The following policy is not intended to be applied during routine testing of the IGS. Internal inspections are anticipated on biennial inspections for certification and dry-dockings. This cycle is considered a minimal requirement, as many manufacturer instruction
manuals recommend that owners inspect various components of the IGS on an annual, semi-annual, or weekly basis.

9.12.2 Scrubber

Where feasible, all access plates and internal components such as demister pads and scrubber trays shall be removed. Soot and scale deposits shall be removed prior to the inspection. The following areas and internal components should be given close attention:

1. Internal coatings should be completely intact. Check for signs of chipping or cracking, particularly around internal fastenings.
2. Inspect gas inlet pipe in the scrubber water seal for corrosion and holes or leaking flanges, especially above the water level, that would allow gas to bypass the seal and render it ineffective.
3. Closely inspect the internal area at the bottom of the scrubber for corrosion, especially in way of the effluent discharge line. Check the discharge line for clogging.
4. Inspect float switches, temperature sensors, Venturi slots, impingement plates, packed trays, and demisters (as applicable) for damage, wastage, and corrosion.
5. Ensure that the water heater (used to prevent water freezing) and its control system are in good condition.
6. Inspect fresh and saltwater inlet piping for corrosion or wastage, and especially for holes or leaking flanges. Check spray nozzles for clogging and intact condition.

9.12.3 Valves

Boiler uptake (or IGG) valves, blower inlet and discharge valves, recirculating valves, pressure regulating valves, deck mechanical non-return valves, deck isolating valves, and IGS isolating valves shall be disassembled for inspection. Valve internals shall be inspected for cleanliness, and for signs of corrosion or erosion. Careful attention should be given to "butterfly" mechanisms to ensure free, smooth operation and proper seating. Check non-return valve seals. If accessible, either through inspection ports or disassembled components, the internal areas of the inert gas main and branch lines shall be checked for excessive scale buildup or soot deposits, which could result in a critical gas pressure drop between the IGS blowers and the cargo tanks.

9.12.4 Deck water seal

This shall be disassembled. Internal coatings shall be inspected for intactness; housing and heating coils, for corrosion; gas inlet pipes, for corrosion, holes, or leaking flanges (especially above the water level) that would permit gas to bypass the seal; and drain lines, for clogging or corrosion. The demister pads must be clean and free of soot and scale deposits. Check that the heater (used to prevent water freezing) and its control system are in good condition.

Only the wet type of water seal is permitted; in this type there is always water present in the device and the inert gas flowing through the seal always bubbles through a layer of water. Semidry seals, in which water is not always present, are approved for most
vessels on a case-by-case basis. "Dry" water seals and the double block-and-bleed assemblies are normally not permitted aboard most vessels.

9.12.5 Blowers
The inspection ports and access plates on all blowers shall be opened. Blower impellers, bearings, and casings shall be checked for corrosion or excessive buildup of deposits that may cause blade failure. If accessible, fresh water flushing spray nozzles shall be checked for intactness or clogging; the blower drain piping, for corrosion or clogging.

9.12.6 P/V valves
P/V valves shall be disassembled and inspected for corrosion and the choking of flame screens from soot, oil entrainment, and rust. The forward pressure release valve shall be disassembled and the butterfly mechanism inspected for free, smooth operation and proper seating. If feasible, the liquid filled, pressure/vacuum breaker shall be drained and inspected for sludge, sediment, or soot deposits that could render the component ineffective. High velocity vent installations shall be inspected for internal deposits or corrosion that may reduce venting capacity or prevent tight closure.
9.12.7 Flue Gas Uptakes

If accessible, the flue gas uptake should be inspected for clogging from soot deposits when the boilers, engines, or IGG's are secured. On systems with IGG's, the combustion chamber shall be checked for soot, scale, or fuel deposits that could indicate improper combustion control or a distorted fuel spray pattern. Check the equipment used for the calibration of the fixed and portable gas concentration measurement devices.

9.12.8 Operational Inspections Procedures

Externally inspect the condition of all piping and components, including scrubber, fans, valves, bellows expansion pieces, standpipes, and screens, for signs of corrosion and gas/effluent leakage.

a) Observe all IGS blowers in operation for proper operation and for excessive bearing noise or vibration. Ensure that the scrubber room ventilation system is operating.

b) Observe the operation of both the salt-water scrubber pump and the pump used to provide an alternate salt water supply.

c) If the scrubber design uses a water seal, check for proper water level. Some foreign vessels are fitted with water sprays only, but U.S. vessels must have a wet type water seal.

d) Observe the deck water seal for automatic filling and check the water level with the local gauge, if possible. Check for the presence of water carryover (especially in the wet and semidry types) by opening the drain cocks on the IG main during operation. Check that the heater coil for cold weather operation is operational.

e) Check the operation of all remotely operated or automatically controlled valves, particularly the flue gas isolating valves. Check that there are functioning indicators showing whether the valves are open or shut.

f) If possible, check the level of the liquid in the pressure/vacuum breaker.

g) Check to ensure that all salt water supply pressure gauges, oxygen and gas pressure recorders, and temperature and pressure gauges are fully operational. The fixed inline oxygen analysing equipment will be calibrated during the operation of the IGS. Observe a calibration check of the equipment by a qualified member of the ship's crew. Spot-check several recordings made since the last inspection during normal system operation for compliance with oxygen and pressure level requirements.

h) Examine the blower drives, the seawater pumps, valves, and strainers for the scrubber and the water seal; the piping connections at the scrubber; water seals; and the shell plating.

i) Observe that all portable instruments are properly calibrated and operating as required by the manufacturer instruction manual. These may include an oxygen analyser, a combustion gas indicator, and a hydrocarbon gas indicator. Sample points should be provided for the use of portable instruments for monitoring cargo tank atmospheres.
j) If an IGG is used, examine the automatic combustion control system, the combustion chamber and its mountings, the forced draft fan, and both fuel oil service pumps.
9.12.9  Operational Tests

The operation of both audible and visual alarms should be observed in the cargo control room, the engine control room, and the pilothouse. Simulation may be necessary for some tests. However, simulation tests of the alarm panel shall not be accepted as evidence of satisfactory operation of the following alarm and safety shutdown systems:

01) High oxygen content of gas in IGS main; alarms activated at an 8 percent concentration.

02) Low gas pressure in IGS main downstream of all nonreturn devices; alarms activated at 100mm (4 inches) water gauge. An automatic shutdown of the cargo pumps may be fitted on some vessels. Also, high gas pressure in the IGS main downstream of all nonreturn devices.

03) A low level water alarm, high level water alarm, or low flow pressure alarm fitted to the deck water seal to shut down the IGS blowers automatically.

04) IGS blower high discharge temperature alarm that will automatically shut down the IGS blowers and the gas regulating valve; alarms activated at temperatures indicated in approved operation manual.

05) High gas pressure of the inert gas supply forward of the nonreturn devices.

06) IGS blower failure alarm and automatic shutdown of main or regulating valve.

07) Power supply failure for the automatic control system gas regulating valve and the indicating devices showing the proper quantity and quality of the inert gas supply.

08) Insufficient fuel oil supply to the IGG and the failure of the power supply to the IGG.

9.12.10  Pressurization of IG Systems

The operational requirements require the master to ensure that the IGS is operated as necessary to maintain a positive pressure on the cargo tanks. This requires the tank to be sealed at all times except when the tank is either gas free or carrying a cargo that cannot produce a flammable atmosphere. For certain cargoes, the cargo purity is of critical importance; thus, the cargo tanks must be gas freed and entered prior to loading. In such instances, standard gas freeing procedures must be followed.

The high costs of crude oil and petroleum products can require cargo level measurement and cargo sampling before and after loading, and before and after the cargo is transferred.

When manual measurement or cargo sampling is being conducted, no cargo or ballasting operation shall be performed. The following requirements shall apply:

a) A minimal number of small tank openings may be uncovered for as short a time as necessary to perform measurement or sampling.

b) If tanks are thus opened prior to cargo transfer, the tanks shall be repressurized before beginning the transfer.

c) If tanks are thus opened after cargo transfer, the tanks shall then be repressurized before beginning another transfer or the vessel leaves port.
d) Neither cargo transfer nor movement of the vessel shall begin until all conditions have been checked and are in order.

e) During cargo transfer operations, the oxygen content and pressure of the inert gas in the IG main shall be continuously recorded.

f) These instructions shall be contained in the system-operating manual.