1

THE OIL TANKER

1.1 INTRODUCTION

Historically oil transportation by sea is of recent origin, and it can safely be said that its development has been a dramatic one. It began less than 100 years ago, with simple and primitive units.

The first tank ships were small with numerous small tanks and a confusion of lines and heavy, manually operated valves. The idea of treating/protecting tank material, safe tank atmosphere (inert), equipment for tank washing, or attempt against oil pollution, was quite unknown. A common expression used, when pumping oil-containing water out from the cargo tanks and bilge water from the machine room, was “Back to nature”. The needs for war power, accelerated the development, and the so-called T-2 tankers of about 16500 dwt. fulfilled the demands and needs by the war industry for effective and uncomplicated transport of oil. As often the case, the military needs accelerated development. The interest for oil transportation emerged also from civil industries. The post war years have allowed tremendous development with respect to size and technique.

Toward the end of the fifties, ships were in a process of change. The era of mid ship tankers was waning, and the so-called breechloader increased in numbers. Machinery and accommodation were located astern, and all volume capacity forward was reserved for cargo, which is of course what provides the income.

Simultaneously with changes to the superstructure aft, there was also a radical process of change with regards to size. That again led to need for other progressive systems. However, fuel demanding steam turbines substituted diesel engines that served the needs of smaller ships.

Turbine tankers dominated the large tank market until the so-called oil crises in the mid-seventies, which created a need for developing diesel motors of sufficient
efficiency. Diesel motors were now both improved with regards to their efficiency and fuel consumption. It also became profitable to change over engines on the large tank ships.

Along with the large tankers a new problem emerged, namely tank atmosphere. Accidents of explosive nature were experienced, and no one could establish the cause, ref. Reksten’s “Kong Haakon VII”. In time it was apparent that gas in empty tanks caused problems with regards to static electricity e.g. while washing tanks. As a result of this, a need for using inert gas in tanks arise. We could continue endlessly to list examples of accidents and incidents that have occurred prior to new demands and restrictions. This applies here, in the same way as in society in general, and unfortunately all too often “nothing happens until there has been an accident”.

Meanwhile knowledge luckily increases with time, and gradually we have ensured safer and better equipment on board ships.

1.2 TYPES OF OIL TANKERS

Oil carriers can be divided in different groups based on size and usage. There are a lot of different types of coastal oil carriers between 12 - 15 000 dwt. and huge oil carriers on 400 000 dwt and above.

Oil carriers in coastal traffic are simple ships between 200 and 12 - 15 000 dwt. for fast and efficient transportation of oil products.

The next group is also regarded as small oil carriers, between 6000 - 35 000 dwt., but with a greater geographic cruising range. These carry mostly products.

The so-called medium-sized ships have tonnage between 35 000 and 160 000 dwt. These are ships that, in large, serve the market for oil products, but they can also carry crude oil.

We can say that ships up to 40 - 50 000 dwt mainly carry clean products (white oils).

Ships between 50 000 and 130 000 dwt. carry some times clean products, but mainly alternate between crude oil and dirty products (e.g. different fuel oils). In this group we find the so-called “Handy size” carriers. This expression means that they are flexible as regards to type of cargo and that they are flexible to enter most ports both with regards to draught and the size of the quay structures.

Oil carriers on 130 000 - 160 000 dwt. are mostly used to carry crude oil.

In the group of large units we find the VLCCs with a tonnage on 160 000 - 300 000 dwt. With the description (Very Large Crude Carrier), this means that these carriers only handle crude oil. They are suitable for long distance voyages with a large loading capacity. Another advantage is that most of them can sail through the Suez channel in ballast.

The very large ones on 300 000 dwt and above is called ULCC (Ultra Large Crude Carrier). These carriers are so huge that there are only some places with deep-sea quays a suitable distance from the coast that can serve these oil carriers.

In the USA, there are few ports that can serve large oil carriers and because of this a new industry has been established. Large oil carriers lay some distance from the coast and smaller ships are “lightering” the large oil carriers to transport the oil to the stated terminal. This is called lightering. Some times the large carriers are lightered to a certain draft to be able to enter the port for discharging the balance cargo directly to the tanks ashore. Normally, the ULCCs must discharge the whole cargo by lightering.
The above mentioned division is only for ships carrying oil. In addition, there are a lot of other varieties of combination ships. One type is OBO (Ore, Bulk, Oil). This means that the ship can carry ore, other bulk cargo or oil.

We have further O/O, which simply means Ore/Oil. This ship can carry either ore or oil. A third type is the so-called ProBO and can carry different oil products, bulk or ore.

Due to the technical development on the oil fields offshore, there have also been changes in the oil carriers transporting the oil from the fields to the terminals. The idea
of efficiency and operational safety has been one of the elements in the development of shuttle-tankers, or “buoy loaders” as it is called in Norwegian. We have the typical carrier with the mooring and the hose pipe connection on the bow, but we also have center loaders where the hosepipe is connected under mid-ship. This gives us great flexibility to take care of big vertical movements in a strong swell.

At the end of the 90’s, we also got production carriers, which carry crude oil and refine the different products on board.

Different types of oil carriers for different use:

Oil carriers have been built in several types, due to the type of cargo they shall carry. If we start with oil in its most elementary shape, which is crude oil, this product is carried in large and very simple carriers.

It is simple because there are relatively few tanks but large tanks. The material in the tanks is steel, which have anodes as protection. The construction is rough with big and very solid cargo line valves and pumps. It is made to handle big stress during loading and discharging from high-speed flow, and considerable wear and tear due to sand and other particles in the oil.

Normally, crude oil carriers are constructed to take large quantities of crude oil. Very often this is unit cargo or uniform cargo, even if most of the ships have the opportunity to load 4 different cargoes. This means that the tanks are usually divided into 4 groups, each with there own pipeline, which can be separated by valves during loading and discharging.

The tanks are divided into compartments, traditionally, with the center tank in the middle of the ship and wing tanks on each side.

The figure below shows an example with 4 center tanks and 10 wing tanks, where the center tanks/wing tanks are divided on each side by the longitudinal bulkhead and the tanks in the length direction are divided by the transverse bulkhead. We can see at mid ship that WT3 p/s are tanks for segregated ballast, which has the line system separate from the loading lines. In addition to segregated ballast tanks, this ship type must use some of the cargo tanks for departure/arrival ballast. In addition to taking cargo, the wing tanks at the aft are slop tanks, which are used to collect oil deposits and washing water during tank cleaning.

Clean Ballast

The figure below shows a ship type with another typical arrangement - double hull - where the space between the cargo tanks and the ship side are separated into tanks for ballast which are independent from the cargo tanks. This is what we call SBT (Segregated Ballast Tanks).
Due to a number of technical reasons, there is a great difference in cargo handling of crude oil and products refined from crude oil. There is no reason why oil carriers, which have had crude oil or dirty products (black oil), for instance fuel, cannot carry clean products. It will, of course, take some time and a lot of work with big expenses to clean and get the tanks and pipes approved. That is why the so-called crude oil carriers take the crude oil from the field to the refinery, and that the product carriers handle different refined products for consumption or further processing.

There are a lot of different product carriers due to the different amounts and type of oil products that need to be carried. Large ships usually have relatively few and big tanks to carry large amounts of different types of cargo on long voyages. The smaller ships have a lot of small tanks to carry different products on each voyage.

The figure shows a schematic picture of a product carrier.

**Product carrier**

Most ships carrying refined products have deepwell pumps and a separate line system for each tank to be able to carry as many different types of cargo as there are tanks. The vapor return is also separated from each tank, but more strict environmental regulations have made it illegal to release vapor into the atmosphere. That is why the carriers have lines for “return gas” that gather the gas from the tanks and lead it back through the manifold and ashore. This is called the “vapor return system”.

Another difference between crude oil carriers and product carriers is the inert gas system. Crude oil carriers make the inert gas directly from the flue gas of the ship’s boiler. Because of the demands for cleanliness of the oil products, ships carrying products must use separate generators so the inert gas will be sufficiently clean and free from soot.
1.3 Tanker Terminology

The International Safety Guide for Oil Tankers and Terminals provides a reasonably comprehensive list of tanker terminology. There may be other terms or definitions which are not listed or which may require further elaboration; these can be added to the list or dealt with during presentations.

For convenience, the list of “Technical Terms from The International Safety Guide for Oil Tankers and Terminals” is reproduced below.

**Antistatic additive**
A substance added to a petroleum product to raise its electrical conductivity above 100 picoSiemens/meter (pS/m) to prevent accumulation of static electricity.

**Approved equipment**
Equipment of a design that has been tested and approved by an appropriate authority such as a government 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 surfaces of tank interiors 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 these guidance notes the terms "combustible" and "flammable" are synonymous.

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

**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 unreacted 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 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 these guidance notes the terms "flammable" and "combustible" are synonymous.

**Flammable range (also referred to as "Explosive ranges")**
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 the laboratory in standard apparatus using a prescribed procedure.

**Foam (also referred to as "Froth")**
An aerated solution which is used for fire prevention and firefighting.

**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.

**Froth**
See "Foam".

**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 it was gas-free for a specific purpose.

**Grounding**
See "Earthing".

**Halon**
A halogenated hydrocarbon used in fire-fighting which inhibits flame propagation.

**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.

**Hazardous zone**
See "Hazardous area".
**Hot work**
Work involving sources of ignition or temperature 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, sand-blasting equipment, or 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% or less by volume by 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 gas plant to cargo tanks, to vent gases to atmosphere and to protect tanks against excessive pressure or vacuum.

**Inert gas plant**
All equipment specially fitted to supply, cool, clean, pressurize, monitor and control delivery of inert gas to cargo tank systems.

**Inert gas system (IGS)**
An inert gas plant and inert gas distribution system together with means for preventing back flow 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 an 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 broke design capacity**
The percentage of the breaking strength (when new) of the mooring rope or wire it carries, at which the winch brake is designed to yield. May be expressed as a percentage or in tonnes.

**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 (140-F) or above as determined by the closed-cup method of test.

**OBO, OILIORE**
See "Combination carrier".

**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.

**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 a 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 (PIV valve)**
A device which provides for the flow of the small volumes of vapor, 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 content; 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 with incandescence when exposed to air which is capable of igniting flammable hydrocarbon gas/air mixtures.

**Reid vapor pressure (RVP)**
The vapor pressure of a liquid determined in a standard manner in the Reid apparatus at a temperature of 100° F (37.8° C) and with a ratio of gas to liquid volume of 4:1.

**Responsible officer (or person)**
A person appointed by the employer or the master of the ship and empowered to take all decisions relating to his specific task, having the necessary knowledge and experience for that purpose.

**Resuscitator**
Equipment to assist or restore the breathing of a man overcomes 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.

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

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

**Static accumulator oil**
An oil with an electrical conductivity less than 100 picoSiemens/meter (pS/m), so that it is capable of retaining a significant electrostatic charge.

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

**Static non-accumulator oil**
An oil with an electrical conductivity greater than 100 picoSiemens/meter (pS/m), which renders it incapable of retaining a significant electrostatic charge.

**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.

**Tension winch (automated or self-tensioning mooring system)**
A mooring winch fitted with a device which may be set to maintain the tension on a mooring line automatically.

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

**Terminal representative**
The 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 nearly all workers may be repeatedly exposed, for a normal 8-hour workday or 40-hour workweek, day after day, without adverse effect.

**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 vapor pressure (TVP)**
The true vapor 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 air to support and propagate combustion. Sometimes referred to as upper explosive limit (UEL).

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

**Vapor seal system**
Special fitted equipment which enables the measuring and sampling of cargoes contained in inerted tanks without reducing the inert gas pressure.

**Volatile petroleum**
Petroleum having a flash point below 60° C (140° F) 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 specified period in a defined area.
2 PETROLEUM PROPERTIES AND HAZARDS

Organic chemistry mostly deals with chemical compounds containing carbon.

2.1 THE PERIODIC SYSTEM

The periodic system is built on the principle that the electrons in the outer shell determine the chemical properties of a material. An atom consists of protons, neutrons and electrons. Protons and electrons form the atomic nucleus. The electrons move with high velocity around the nucleus, at different levels and orbital. The levels are numbered from K to Q and called electron shells. At maximum, there can be 8 electrons in the outer shell. There are equal numbers of protons as electrons in an atom, meanwhile the number of neutrons may vary.

The periodic table arranges the 106 elements in increasing number of electron shells. Each vertical column is one of the periodic table’s main groups. The number of electrons in the outer shell is always equal to the atom’s main group number. Two of the main elements in the periodic system are Hydrogen and Helium, and fall under group IA and VIIA. The atomic models are illustrated as follows:

Carbon falls under group IVA and has 4 electrons in the outer shell. The elements in the group IA have only one electron in the outer shell. It is therefore easy to emit one electron to elements within group VIIA, which has seven electrons in the outer shell and is “short of” one electron to fill up the outer shell. Such mutual sharing of an electron is called ion bonding. An example for such a bonding is when
Sodium (Na) and Chlorine (Cl) bond with one another and form Sodium chloride or cooking salt.

\[
Na + Cl \longrightarrow Na^+ + Cl^- \longrightarrow NaCl
\]

Sodium “emits” the only electron to Chlorine, and is thereby positively charged. Chlorine “receives” the electron and is thereby negatively charged. We call this mutual sharing of electrons, **covalent bonding**. Covalent bonding is common in both organic and inorganic chemical reactions. When two or more atoms bond together, they form a **molecule**.

There are 8 **side groups** between the main groups IA and IIA. All the elements in the side groups are metals, and they easily form alloys with one another.

The rows in the periodic chart indicate the **periods**. The 7 periods indicate the number of electron shells. Sulphur is located in row 3 (period number 3) and has thereby 3 shells. We also look at the electron shells as the electrons’ energy level.

The elements in group VIIA are named **noble gases**. Noble gases occur only in atomic form. Most inorganic elements are metals. The metals form metal bonding where the atomic are organized close together. The individual element has numbers from 1 to 106. The periodic system’s number is the element’s **atomic number**. The atomic number also indicates the total number of electrons in the atom.
# The Periodic Table

## Main Group 1-2

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## Rare Earths

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**Explanation**

- Atomic number
- Atomic weight
- Oxidation state
- Symbol
- Name
2.1.1 Carbon
You find the element Carbon in the main group IVA/period number 2, which has four electrons in the outer shell number 2. The atomic number for carbon is 6, which means there are totally 6 electrons divided between two electron shells with 4 electrons in the outer shell, and 2 electrons in the innermost.
There are many isotopes of carbon. Isotopes have the same number of protons, but different number of neutron in the atomic nucleus. There are two natural forms of Carbon, graphite and diamond. Carbon is not particular reactive in room temperature. When heated, it will easily react with for example, Oxygen. We say that carbon is combustible. The different products of the combustion are dependent of accent to oxygen.

\[
\begin{align*}
C + O_2 & = CO_2 + 393 \text{ kJ} & \text{(at complete combustion)} \\
C + 0,5 O_2 & = CO + 113 \text{ kJ} & \text{(at incomplete combustion)}
\end{align*}
\]

Both reactions are exothermic, that means heat is produced in the chemical reaction. Both reaction products are also gases. Carbon dioxide, CO\(_2\), is the product of complete combustion of carbon and carbon monoxide, CO, which is the product of incomplete combustion of carbon.
A partly incomplete combustion produces both less heat and more formation of carbon monoxide than a complete combustion. Carbon monoxide is odorless and a very poisonous gas that always is present in a real combustion process. Inert gas produced in an inert gas generator or flue gas plant onboard will always contain carbon monoxide due to incomplete combustion, especially when the air excess is reduced.
Poisoning of carbon monoxide occurs because the hemoglobin in the blood reacts much easier with CO than with oxygen. When you breathe a mixture of these two gases, CO is thereby first absorbed in the blood and seizes the absorption of oxygen. The result of this poisoning is a sort of suffocation at very low concentrations. These relations are very important to notice. You must always check the cargo tank atmosphere for carbon monoxide before personnel are allowed to enter the tank.

2.1.2 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 (H\(_2\)), 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:
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 connected to the hydrogen atom’s single “arm”, and creates hydrocarbon compounds.

Some of the hydrocarbon compounds are naturally created; other are 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 Paraffins
- Alkyls
- Alkanes, also called Olefins
- Alkynes, also called Acetyl ides
- 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.

2.1.3 Alkanes
Alkanes are the simplest hydrocarbon compounds and is the major part of crude oil and natural gas. The carbon atom’s four arms are united to the hydrogen atoms’ single arm and has this general molecule-formula:

\[ C_nH_{2n+2} \]  where “n” is a positive integer.

All alkanes compounds have the ending “-ane”. 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.

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, \( C_3H_8 \).

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 366319 different ways.

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.

\[ n\text{-Butane, } C_4H_{10} \]

\[ \text{iso-Butane, } C_4H_{10} \]

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.

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### 2.2 Physical Properties

**True vapor pressure (TVP)**

All crude oil and usual petroleum products are essentially mixtures of a wide range of hydrocarbon compounds. The boiling points of the 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 elements. The volatility is characterized by the vapor pressure. When transferring a petroleum product to a gas-free tank it begins to vaporize, that is, it liberates gas into the space above it. This gas has also a tendency to re-dissolve in the liquid. The pressure exerted by this gas is called the equilibrium pressure of the liquid, usually referred to simply as the **vapor pressure**.

The vapor pressure of a pure compound depends only upon its temperature. With a mixture of compounds, the vapor pressure depends on the temperature, elements and the volume of the gas space in which vaporization occurs.
The true vapor pressure (TVP) or bubble point vapor pressure is the equilibrium of vapor pressure of a mixture when the gas/liquid ratio is effectively zeroed. The highest vapor pressure 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 begins to boil. The TVP of a petroleum mixture gives a good indication of its ability to give rise to gas, but unfortunately it is a property which still is extremely difficult to measure.

2.2.1 The Reid Vapor Pressure (RVP)

Testing is a simple and generally used method for measuring the volatility of petroleum liquids. Measurement of the RVP is conducted at 37,8°C (100°F). The greater the RVP value, the more volatile is the oil. Normally crude oil has a RVP of between 0,1 and 0,8kg/cm².

A sample of liquid is put into the test container at atmospheric pressure. The volume of liquid should be one fifth of the container’s total volume. Then the container is sealed and immersed in a water bath, which is heated to 37,8°C. The container is then shaken in order to mix the liquid properly and the rise in pressure due to vaporization can be read on the attached pressure gauge. This pressure gauge gives a close approximation in bars.

Because the liquid’s vapor pressure is at 37,8°C, RVP is useful for generally comparing the volatility of a wide range of petroleum liquids. However, it has, small value as a means of estimating the likeliness of 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 mentioned, in some cases, correlation exist between TVP, RVP and temperature.

For safety measures against fire on ships, the Norwegian Maritime Directorate in the Regulation of December 3rd, 1979 uses 61°C as limit value for flash point and 2,8kg/cm² for vapor pressure at 37,8°C. The oil referred to in this regulation is:

Mineral oils with a flash point below 61°C, such as kerosene, benzene, gasoline and crude oil or other flammable liquids with a flash point below said limit.

Mineral oils with a flash point of 61°C or higher, such as marine gas oils, fuel oil, diesel oil, lubricating oil, which give off flammable gases when heated.

Oils and fats of animal or vegetable origins, such as whale oil, groundnut oil, linseed oil etc., which give off flammable gases when heated.

The liquid chemicals referred to are:
Chemicals with an absolute vapor pressure lower than 2,8kg/cm² at 37,8°C.

The condensed gases referred to are:
Chemicals with an absolute vapor pressure of 2,8kg/cm² or higher at 37,8°C.

2.2.2 Flash Point

The flash point for oil is the temperature at which it is possible to ignite the vapor above the oil. In other words, the flammable gas concentration above the oil is close to the lower explosive limit. Determination of the flash point is done with a special apparatus and according to specific rules.

A sample of liquid is gradually heated in a special pot and a small flame is repeatedly and momentarily applied to the surface of the liquid. The temperature is recorded when a small flame initiates a flash or flame across the liquid surface, thereby indicating the presence of a flammable gas.
In this test, the space above the liquid is kept closed except for the brief moments when trying to ignite the liquid’s surface. This test is called “Closed cup Flash Point”. When we do the test with the liquid surface permanently open to the atmosphere, the result of such a test is called “Open cup Flash Point”. Because of the greater loss of gas to the atmosphere in the open cup test, the open cup flash point is always a little higher (about 6°C) than the closed cup flash point. The restricted loss of gas in the closed cup apparatus also leads to a much more consistent result than can be obtained in open cup testing. For this reason, the closed cup method is generally favored. However, open cup test figures, still may be found in the registration of various national administrations, in classification society rules and other such documents.

If the temperature is increased further beyond the flash-point, the liquid will obtain a temperature so high that the evaporation will take place fast enough to support a flame. This is called “The Burning Point”.

For refined products, the flash point increases from light to the heavy hydrocarbons, for gasoline it is about –50°C and for kerosene over +60°C. The flash point for liquids is used in rules and regulations for transportation and storage.

Crude oil from various sources may have quite different flash points, usually between –10°C and +30°C.

2.2.3 Flammability
The burning process means that hydrocarbon gases react with the oxygen in the air to produce carbon dioxide and water. This reaction gives enough heat to form a flame which goes through the mixture of hydrocarbon gas and air. When the gas above a liquid hydrocarbon is ignited, the heat that is 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 that is burning and continuously being replenished by the liquid.

2.2.4 Flammable Limits
A hydrocarbon gas mixture and air cannot be ignited and burned unless its composition lies within a range of gas-in-air concentrations, known as the “flammable range”. The lower limit of this range is known as the “LEL” (lower explosive limit). The “LFL” (lower flammable limit) is also used. This level means that hydrocarbon concentration has an insufficient amount of hydrocarbon gas to support and propagate combustion. The mixture is “too lean”.

The upper limit of the range known as the “UEL” (upper explosive limit), or also known as “UFL” (upper flammable limit). This level means that the hydrocarbon concentration has an insufficient amount of air to support and propagate combustion. The mixture is “too rich”.

Between these two areas, the mixture is flammable and results in a fire or explosion, if ignited. With hydrocarbon gases from crude and sediments, it is usually assumed that the upper explosion limit lies at about 10% by volume of hydrocarbon gas-in-air and the lower explosion limit at about 1% by volume of hydrocarbon gas.
2.2.5 Air

The mixture of gases found in the atmosphere is given the name air. The ratio of mixture between various gases is the same, independent of time and place, except for the water vapor content, which can have great variations.

<table>
<thead>
<tr>
<th>ELEMENTS IN AIR</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen, N2</td>
<td>78.09%</td>
</tr>
<tr>
<td>Oxygen, O2</td>
<td>20.93%</td>
</tr>
<tr>
<td>Argon, Ar</td>
<td>0.93%</td>
</tr>
<tr>
<td>Carbon dioxide, CO2</td>
<td>0.03%</td>
</tr>
<tr>
<td>Other gases</td>
<td>0.02%</td>
</tr>
<tr>
<td>AIR</td>
<td>100%</td>
</tr>
</tbody>
</table>

There may be a significant amount of water vapor in the air. Different results are measured depending on whether water or moisture is removed or not. The amount of water vapor, which the air may contain, will depend very much on the temperature. The air is saturated with water vapor when the air contains a maximum amount of water vapor at a certain temperature. Saturated air being cooled will release the excess water in droplets.

At high humidity and high temperature, there will be a reduction of oxygen and other gases that is caused by the increased water vapor content.

The atmospheric pressure will influence the measurement result when using gas-measuring instruments. For example, when using a portable oxygen analyzer that is calibrated to read 21% oxygen by volume in clean air at atmospheric pressure, the reading will increase as the atmospheric pressure increases.

To compensate for the changes in atmospheric pressure, the instrument has to be calibrated with clean air from time to time. The air pressure, depending on the instrument’s measuring principle will also influence the instruments used for measuring hydrocarbon gases.

<table>
<thead>
<tr>
<th>TEMPERATURE</th>
<th>WATER VAPOUR CONTENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>-20°C</td>
<td>0.1 vol%</td>
</tr>
<tr>
<td>0°C</td>
<td>0.9 vol%</td>
</tr>
<tr>
<td>20°C</td>
<td>2.3 vol%</td>
</tr>
<tr>
<td>40°C</td>
<td>7.3 vol%</td>
</tr>
<tr>
<td>60°C</td>
<td>19.7 vol%</td>
</tr>
<tr>
<td>80°C</td>
<td>46.7 vol%</td>
</tr>
<tr>
<td>100°C</td>
<td>100 vol%</td>
</tr>
</tbody>
</table>

The risk of fire or explosion is drastically increased if air is replaced by pure oxygen. As known, oxygen leakage during welding has resulted in several fatal accidents. However, when reducing the oxygen below 21% oxygen by volume, the fire and explosion hazard is reduced. When reducing the oxygen content to below 10.8% by volume, fire and explosion cannot take place even though both hydrocarbon gas and ignition sources are present.
2.2.6 Hydrocarbon gases

Crude oil is formed from plants and animals residues and contains several thousand different chemical compounds. Most of these materials consist of only the elements hydrogen (H) and carbon (C) called by the common name hydrocarbons. The simplest hydrocarbon is methane, which is the main element of natural gas. Butane, propane and ethane are also composed of hydrogen and carbon atoms and they are all called hydrocarbon gases. For example butane, \( \text{C}_4\text{H}_{10} \) means that this gas contains a total of 4 carbon atoms and 10 hydrogen atoms. Hydrocarbons with up to 4 carbon atoms are gases at room temperature and atmospheric pressure. From 5 to 16 carbon atoms the hydrocarbons are liquids, and above 16 carbon atoms, the hydrocarbons are solid materials such as wax and asphalt. When the crude oil is taken out of a well, hydrocarbon gases and solid materials are dissolved in the oil. When reducing the pressure, gases will bubble out. To separate these gases the crude must pass through one or more processing units (stabilizers). The crude oil is called “stabilized crude”, but even stabilized crude oil will give off hydrocarbons from the surface. Methane gas is lighter than air. Ethane gas has approximately the same density as air. The gases butane and propane from higher hydrocarbons are heavier than air. The gas mixtures given off from crude oil, sludge and sediments are all heavier than air. Until such gas mixtures have been mixed with air inside inert gas, the highest hydrocarbon concentration will appear near the bottom.

“Spiked crude oil” (also called “enriched” or “tailored” crude) is crude oil that has had hydrocarbons added in gas or liquid form. The spiked crude may contain rather large amounts of added hydrocarbons and therefore emit heavy gasses under certain conditions (during loading, crude oil washing, discharging).

2.3 Hazards from Petroleum Cargo

The toxic hazards to which personnel are exposed in tanker operations arise almost entirely from exposure to various kinds of gasses. TLV (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 “PEL” (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. 1 ppm corresponds to one-millionth part by volume pollution in air. Compared with a value quoted in percent by volume, we find that 1% by volume = 10,000ppm. List of TLV (PEL) are adjusted from time to time, so take into consideration the experience gained. Keep the list up to date at all times.
**Ingestion**
There is a very slight risk of swallowing significant quantities of liquids during normal tanker operations. The oral toxicity from petroleum is low, but if swallowed it causes acute discomfort. Liquid petroleum may be drawn into the lungs during vomiting resulting in serious consequences.

**Skin contact**
Petroleum products cause skin irritation and remove essential oils from the skin, leading to dermatitis. Oil can also cause serious skin disorders from repeated and prolonged contact. The effects of a gas mixture from crude oil include headache, eye irritation, reduced sense of responsibility and dizziness similar to drunkenness. Higher concentrations may lead to paralysis, numbness and death.

**To avoid direct contact, always wear appropriate protective clothing and equipment!!!!!**

**2.3.1 Petroleum gases**
The toxicity of petroleum gases has a wide variation depending on the major hydrocarbon constituent of the gas. For a short period of time the human body can tolerate a somewhat higher concentration than the corresponding TLV. Toxicity can greatly be influenced by the presence of some minor compounds, such as benzene and hydrogen sulphide.
A TLV of 300ppm, corresponding to about 2% LEL is established for gasoline vapors. Such a figure may be used as a general guide for petroleum gases, but must not be used for gas mixtures containing benzene or hydrogen sulphide.
The following are typical effects found at higher concentrations:

<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 as 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></td>
<td>Paralysis and death occur very rapidly.</td>
</tr>
</tbody>
</table>

**Benzene**
Aromatic hydrocarbons include benzene, toluene and xylene. These substances can be found in varying amounts, in many typical petroleum cargoes, such as gasoline’s, naphtas, special boiling point solvents, turpentine, substitutes, white spirits and crude oil.
Benzene primarily presents an inhalation hazard. It has poor warning qualities. Benzene can be absorbed through the skin and is toxic if ingested.
For handling cargo that contains benzene, use the described operation procedures for this kind of hydrocarbon.
Hydrogen sulphide (H₂S)
If the vessel is carrying sour crude, it is absolutely essential to check the tank(s) atmosphere for hydrogen sulphide before entering.
A lot of crude oil comes out of the well with high levels of hydrogen sulphide, but is usually reduced by a stabilization process before the crude oil is delivered to the vessel.
This stabilization may, however, decrease over time.
The nose has no trouble detecting the smell from hydrogen sulphide at low concentrations, which is like the smell of rotten eggs, but the sensory cell in the nose is immediately put out of function if higher concentrations are inhaled.
The effects of the gas at concentrations in air in excess of the TWA (Time Weighted Average) are, as follows:

<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>Severe 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 minutes, loss of consciousness and possible death after 30-60 minutes exposure.</td>
</tr>
<tr>
<td>700 - 900 ppm</td>
<td>Rapid unconsciousness, death occurs a few minutes later.</td>
</tr>
<tr>
<td>1000 - 2000 ppm</td>
<td>Instantaneous collapse and cessation of breathing.</td>
</tr>
</tbody>
</table>

Persons over exposed to H₂S vapor should be taken to clean air, as soon as possible.
The adverse effects of H₂S can be reversed and the probability of saving the persons life improved, if prompt action is taken. For handling cargoes containing hydrogen sulphide follow the operation procedures described for such a cargo.

2.3.2 Toxic Elements in Inert Gas
Inert gas’s low oxygen content is the main hazard. Inert gas produced by combustion, either in a stem boiler or in an inert gas generator, contains a various amounts of toxic gases, which may increase hazard to the personnel exposed to it. Follow the precautions to protect personnel against toxic hazards. These precautions do not include the requirements for direct measurement of the trace flue gas element’s concentration. This is because when gas that is freed from a tank, the hydrocarbon gas concentration is about 2% by volume to 1% LEL. Until there is a steady 21% by volume oxygen reading, it is sufficient to dilute these elements to below their TLV’s.

Nitrogen Oxides
Flue gas contains approximately 200ppm (0,02%) by volume of mixed nitrogen oxides. Nitric oxide (NO) is generally removable by water scrubbing. This gas is colorless with a weak smell at its TLV of 25ppm. Nitrogen dioxide is even more toxic with a TLV of 3ppm.
Sulphur Dioxide

When a high sulphur fuel is burned to produce flue gas, these oils contain about 2000ppm of sulphur dioxide. As the flue gas passes the scrubber, the sulphur dioxide will be reduced to between 2 and 5ppm. Sulphur dioxide irritates eyes, nose and throat and may also cause breathing difficulties. It has a distinctive smell at its TLV of 2ppm.

Carbon Monoxide

Carbon monoxide (CO) is normally present in flue gas at a level of only a few parts per million, but at abnormal combustion conditions and slow running it can give rise to levels in excess of 200ppm. This gas is an odorless gas with a TLV of 50ppm. It is insidious in its attack, restricting the blood’s oxygen uptake, causing a chemically induced form of asphyxiation.

Oxygen Deficiency

For several reasons the oxygen content in enclosed spaces may be low. On oil tankers the most obvious one is that the space is in an inert condition. Also it can be due to a lack of oxygen based on chemical reactions, such as rusting or the hardening of coatings.

When the available oxygen decreases below 21% by volume, breathing tends to become faster and deeper. Symptoms indicating that an atmosphere is oxygen deficient may not give adequate 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.

Entry into spaces with oxygen less than 21% by volume must never be permitted.
3 OIL CARGO CONTAINMENT AND HANDLING

3.1 TANK ARRANGEMENTS

To effectively use the hull’s shape and volume, and for safety reasons, on modern ships the cargo tanks are placed ahead of the superstructure, engine room and the pump room. In the pump room, we have the cargo pumps and the ballast pumps with the pipelines respective to the cargo tanks and the ballast tanks. The driver device for the pumps is placed in the engine room, and they are connected with gas-tight bulkhead parts. Diesel-electric engines or steam turbines mostly drive the pumps.

The tank arrangement can vary from ship to ship depending on the purpose of the specific ship. On the large crude oil carriers it is most common to find centre tanks and wing tanks. The figure on the next page shows the drawing of M/T “Seagull”, a typical crude oil carrier. We can see 4 centre tanks and 10 wing tanks organised in 5 pairs, for the cargo. The shaded wing tanks mid ship are WT3 p/s and the FPT are tanks for segregated ballast. This means that they have lines that are separated from the cargo line system. This will be properly dealt with later on. This oil carrier has the possibility to carry 4 different cargoes, with double valve segregation on the bottom line’s crossover lines.

There are still some oil carriers that are equipped with the so-called “Free Flow – system”, which is a system without ordinary bottom lines. This is a very simple line system where the cargo flows from tank to tank through bulkhead valves and flows to the pumps from the centre tanks nearest the stern. In addition, there is a separate line that allows the tanks in the fore part to be discharged first, in order to achieve a stern trim.

On the ships where this system is fitted, the efficiency of the crude oil washing will be considerably lower. To fulfil the demands for stripping capacity, it is necessary to have a separate stripping line with lines directed to each tank. This Free Flow system possibly necessitates that “heavy weather ballast” must be pumped to a shore based installation in the loading port.
3.1.1 Slop Tanks

The slop tanks are a part of the cargo tank system. They can also be used to collect cargo deposits, sludge after crude oil washing, oily water after washing the cargo tanks and the connected pipeline systems.

In accordance with the regulations, all oil carriers should be equipped with slop tanks. Carriers on 70 000 dwt. and above should have 2 slop tanks. These are placed as the two stern most wing tanks. The lines and other equipment are also designed to use the tanks for loading. For the crude oil cargo, we talk about “Load On Top”, which means that we are loading on top of the remnants from the last voyage. This will be explained later.

We have some special equipment for slop handling, in addition to the ordinary system with lines for loading and discharging together with inert gas lines and P/V-valves controlling the pressure/vacuum on the tanks:

- Line connection to the stripping line/stripping pump to empty the settled water after water washing the tanks and lines. Settling means separation of water and oil, so the lighter oil will be placed on top of the water.

- A balance line connects one tank to another. When the content in the primary slop has reached a certain level, the water will flow over to the secondary slop. This system is used when washing cargo tanks. The water in the bottom will flow to the secondary slop when it reaches the balance line’s level. From here, the water can gently be pumped overboard through monitoring equipment (ODME), which will close the overboard valve and open up to the slop tank if the water is dirty. This will be explained later.

As mentioned earlier, crude oil carriers over 70 000 dwt. should have 2 slop tanks. The capacity should be 3 % of the total cargo volume, if the carrier uses the cargo tanks for ballast (CBT). On ships with segregated ballast tanks the requirement is 2 %.

We can use M/T Seagull as an example. This is a CBT carrier and a total cargo volume on approx. 220 000 m3.

Minimum slop capacity will be \((220 000 \times 3) : 100 = 6600 \text{ m}^3\).

![Slop Tank System Diagram]

This picture is an example of a slop tank system. We can see that the port slop is the primary tank and the starboard slop is the secondary tank. Both tanks are connected to the ordinary
discharging line system on line number 3. The balance line and the return line, from the
ejector, can easily been seen in the picture. “High overboard line” has access from all 4
discharging line systems and from the stripping pump. ODME is connected and works in
accordance with the regulations in force. From the primary slop it is also possible to drop
liquid to CT4 when necessary. It is very important that you are familiar with the system on
board your ship

3.2 PIPING ARRANGEMENTS

3.2.1 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.

3.2.2 Line system in cargo tank
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 torsion 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 force, 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 likes 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.

**Suction (bellmouth, “elephant foot”)**
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. Again M/T Seagull is used in the example. 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). In the wing tanks on M/T Seagull the main suctions are placed in the middle and one stripping suction is placed toward the centre 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 avoids or reduces 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.

3.2.3 Valves

On board oil tankers there are three main types of valves being used: the gate valve, the globe valve and the butterfly valve.

The gate valve works like a gate which blocks the pipe cross wise, and stops the liquid flow. In open position, the gate is lifted into the gatehouse. This type of valve is, for example, used on lines leading over board. It provides safe and solid tightening and is very efficient, but bothersome and slow to operate.

The globe valve is also a commonly used valve on board oil tankers. Usually this globe valve is used in the pressure/vacuum system where the valve supervises the pressure condition in the tanks. The valve opens when the pressure is reaching a certain set point and also opens to the atmosphere when reaching a set vacuum point. This valve is common on the inert gas plant, on the main inert gas line and as P/V valve for the cargo tank.

The globe valve is also produced as a non-return valve. This 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.

3.2.4 Lines over all

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).

M/T Seagull 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. The bottom lines pass from tank to tank through the bulkheads by liquid proof couplings. 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.

3.2.5 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 2 and page 8 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.
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: the centrifugal pump does not have any ability of suction. Follow the drawing on page 6.

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 (CBT) 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 back pressure 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. Crosswise of
these risers, you will find two more cross over lines in the pump room on M/T Seagull.

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, M/T Seagull is equipped with a vacuum
stripping system, which gives the cargo pumps good working conditions.

**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 change to risers. When they appear on the main deck,
the names are deck lines.

As mentioned before, M/T Seagull has separate main line systems with the possibility to carry
four grades of oil. Each main line represents its own system with the same mutual place
located in the different parts of the ship.

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. On M/T
Seagull, you will see on the drawing that the forward manifold is numbered as no.1. 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.
M/T Seagull 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.

**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. (See part 10, chapter 3, page 4).

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.

**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.
3.3 PUMP TYPES

3.3.1 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.
3.3.2 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.
3.3.3 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.
3.4 PUMP CHARACTERISTICS

3.4.1 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 lead 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:

\[
\begin{align*}
\rho = \rho \times g \times H & = (1000 \text{ kg/m}^3 \times 9.81 \text{ m/s}^2 \times 100 \text{ m}) \\
p_m & = 981000 \text{ Pa} \\
p_m & = 981 \text{ kPa} \\
p_m & = 9.81 \text{ bars}
\end{align*}
\]

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 off 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 pump’s 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.

3.4.2 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.

3.5 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.

3.5.1 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.
3.5.2 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
Stripping arrangement for cargo systems with a separate pump-room
3.6 MEASURING OF CARGO LEVEL

To ascertain the liquid level in a tanker's cargo oil tanks, it is necessary to measure manually, mechanically or electronically:-

(a) 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".

(b) 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".

In the older tankers, ullaging with a tape or ullage stick was common practice. Fast loading or discharging with numerous tanks open at once, meant that several members of the crew had to be out on deck to check the liquid level in the tanks at frequent intervals. The amount of manpower required was considerable, particularly when loading fast. The risks of affixiating personnel continuously leaning over open ullage hatches could not be ignored.

Automatic tank gauging systems used in oil tankers are largely adapted from similar systems used by the oil industry ashore.

The Whessoe Float System was probably the most common of the automated tank gauge systems. In the earlier versions, the float was suspended from a special hatch by means of an ordinary ullage tape. The tape was passed over a flywheel directly under a clear view screen complete with screen wiper. The other end of the tape was secured to a weight suspended in a tube filled with cleaning solvent, extending to the bottom of the tank.

The Float is heavier than the weight in air, but when the tank is being filled or emptied it floats on the top of the liquid rising or falling as the liquid level alters. The tape records the ullage automatically.

The Float System is tried and reliable, and a broken tape at once lets the operator know he must revert to hand-ullaging. A reasonable amount of maintenance will keep the system trouble-free.

The steel tapes provided by the manufacturers have the measurement scales either painted on them, or embossed on the actual metal. The latter types are less likely to be defaced by contact with inert gas or other corrosives.

Larger and more modern ships fitted with the Float Ullage System are equipped with a remote read-out in a central control room. There are a large number of automated tank-gauging systems based on hydrodynamic principles. Such systems have a marked similarity, and it should suffice if we cover them in outline.

Each tank is fitted with one or more open-ended pipes connected to a read-out gauge and reservoir in the control room. The length of the gauge and the type of liquid, with which it is filled, depends on the accuracy required. A small gauge using a heavy liquid like mercury, can be used where accuracy is not required. Where accuracy is required, such as when topping-up tanks, a larger gauge and a lighter liquid are used together, with a separate pipe to cover the upper section of the tank.

How do such systems work? The open-ended pipe in the tank is connected to a liquid reservoir in the base of the gauge glass. Nitrogen or another suitable gas is inserted into the pipe until it has purged all the air and fills the whole length of pipe. The end of the pipe is restricted, but the gas is allowed to leak out of the open end in the tank. Changes in liquid level within the tank result in changes of pressure on the gas in the tube, which is in turn transferred to the liquid in the gauge glass, and the liquid level can be read off the calibrated gauge.

Experience with a number of gauge systems manufactured in different parts of the world, has been varied. While some have been reasonably accurate, others have proved to be
undependable and are mistrusted by tanker officers, some of whom continue to ullage by hand in preference to utilizing such systems.
It is not possible to determine here the relative merits of individual systems, but before condemning equipment, the operator should take all the necessary steps to service, check out, and calibrate equipment according to the manufacturers instructions. Lack of use and disinterest are certain not to lead to the successful ironing out of problems in the system.

**Electronic Ullaging Devices.**
At one time there was considerable reservation about the use of electronic sensors either for use as high and low liquid level alarms, or for ullaging. Improved technology combined with a better understanding of the problem has been instrumental in producing some remarkably accurate equipment.
The author inspected a fully-automated vessel which had two independent electronic ullage systems fitted in each tank. If the two systems differed more than 3 cm. a warning signal was given. A more recent development in this field was introduced by a Swedish Company which used in-tank radar to measure ullages and soundings.

3.6.1 Tank radar unit
Ullage is measured by a radar signal reflected against the content level; temperature and interface can also be indicated.
3.7 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.

3.7.1 Cargo Heating Systems.

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 sea water 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 sea water, 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 cat walk 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 center tanks on both sides, while they are subject themselves to the cooling action of the sea, not only through the bottom plating, but 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 center tanks. This is particular true in some of the more modern vessels, where the coils are passed through the longitudinal bulkheads between the center 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 varies 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
Diagram of cargo heating system
4. OIL TANKER OPERATIONS

4.1 Loading

Normally it is hectic on an oil tanker’s ballast voyage in connection with new a transport order. There is continuous communication between charterer, shipper and the vessel to make the transport. One of the first questions, which appear, is how much the vessel is able to load. These kinds of messages are usually marked “Urgent”, and a rapid answer is needed. It is important to act on this message as soon as possible, because there are many companies competing in the market with available tonnage. And history shows that many cargoes have slipped away due to hesitation on such applications.

The cargo quantity is calculated from the vessel’s dead weight or from the total cargo tank capacity. The dead-weight is the summary of bunkers, fresh water, stores, and cargo/ballast. The amount of cargo to load is then the dead weight at the loading mark or other given draught minus the summary of fresh water, bunkers and stores.

With the knowledge of the cargo density and temperature it is possible to calculate the space (volume) that the cargo will occupy, and then it is possible to check if there is enough space in the vessel’s cargo tanks.

4.1.1 Stress analyses

The next step is in the preparation for cargo distribution. This is done by testing the loading (on a loading computer etc.) with an eye for wanted draught, trim and most of all shear forces and bending moments. The load planning is based upon the demands that hull forces have limits at all times.

Bending moments is the force, which bends the vessel up and down in the fore-and-aft direction. The force is comparable with a flexible rod. When bending the rod up or down, it will bend up or down in the middle.

If the vessel is loaded with heavier weight in the ends than in the middle, the fore and aft part of the vessel will be pulled down while the middle section is forced up. This is called a “hogg moment”. If the vessel is loaded with a heavier weight in the middle section than at the ends, the vessel will be forced down in the middle section. This is called a “sagg moment”. So, these forces must be kept within the classification company’s limits.

Another force to consider is shear force. These forces are affected between loaded and empty parts of the vessel, also between a loaded cargo tank and an adjoining empty cargo tank. The specific vessel is supplied within the specifications, given by the classification companies, for how many empty cargo tanks the vessel is allowed to sail with.

Most of the vessels today are equipped with a cargo handling computer for cargo calculation. These computers must be approved and must have a certificate issued, which satisfies the Classification Company regarding shear forces and bending moments. The programs are supplied with curve diagrams for these forces, and remember, in all stages of a cargo operation within limitations of force.

4.1.2 Before arrival at loading port

For the loading terminal to be prepared as best as possible regarding the organization of a safe and efficient operation, the terminal needs some information about the vessel. When the vessel has provided the loading figures, and the vessel is nominated for the cargo, she receives a lot of particulars that need to be answered. Among other things this can consist of:
The vessel’s draught and trim on arrival.

Ballast on arrival. Amounts of CBT and SBT.

How the deballasting is to be done - pumped over board or deliveries to shore.

Type of cargo on previous voyage. (Usually, the three last voyages are asked for).

Amount and location of slop on arrival.

Prospective request for LOT (Load on Top). This means to load on top of the arrival slop.

To confirm that the cargo tanks are inerted on arrival, and that the inert gas plant is working properly.

Number of manifold lines and their size.

The manifold’s height above the main deck.

The manifold’s distance from rails.

The information given to the vessel from the terminal varies from port to port. If the information from the loading terminal is defective, it can be necessary to obtain the necessary information from somewhere else. Among all the reference books on board is the “Guide to Port Entry”. This book contains almost all the relevant information about most ports worldwide with international traffic. The book informs about tide, current condition, depth along side piers, pier size, number and dimension of loading/discharging arms (hoses, etc.)

With regards to information about the cargo to load, it is usually not possible to achieve accurate information before the vessel is well moored. It will now be beneficial to keep an orderly system of storing previous loading documents. The planning of a loading operation can be done in good time ahead based on the information obtained, such as:

- Available loading rate.
- Approximately density and temperature of the cargo.
- Number and dimension of loading arms (hoses). This is important to know due to connection of prospective reducers on the manifold.
- Draught along side the pier.
- Air draught limitation.
- Local circumstances like the tide, for instance regarding the moorings.

Based upon all available information, a loading plan is formed. Thorough preparations also include that personnel involved in the operation are fully informed about the plan. A good chief officer makes sure that all the involved are instructed in their duties. Such instruction is best for the personnel involved and reduces the risk of undesirable occurrences. A common principle is to gather all the personnel involved in the operation in a pre-arrival meeting. This to make a final point to each person about their duties. Such a meeting is also a good opportunity to inform the crew about the other happenings during the stay, for instance, bunkering, provisioning, etc. It is also important to inform about expected visitors from the company, oil company, inspections, Classification Company, etc.

An important part of the preparations concerns the safety on board during the stay. Besides the inevitable advantage of reduced risk for accidents, its also gives a positive impression of vessel and crew that the vessel is arriving with all the details in order. The following must be checked and in order before arriving at berth:
• The cargo tanks have positive pressure and the inert atmosphere is according to the regulation in force.
• The cargo tank’s pressure/vacuum valve is operating properly.
• The drip-tray beneath the manifold is drained and clean.
• The manifold flanges (reducers) are blind off.
• Make sure that all the scupper plugs are fitted. The main deck is, in advance, being cleaned to avoid oil film on the water surface, if rain should appear. The rainwater is to be dropped over board by an open scupper plug when necessary. Remember to replace the scupper plugs.
• Make sure that all the valves leading to the pump room from bottom lines and deck lines are shut before the operation takes place.
• The required pumps to collect oil pollution are on the main deck. These pumps are rigged ready to be used by a quick coupling connected to air, sucking hose on the main deck and a delivery hose, for instance to a slop tank (ready to use).
• The fast closing for the ventilation to the pump room is tested before arrival.
• Make sure that the radar is stopped and the vessel’s radio plant grounding is properly connected.
• Make sure that all the loose antennas from the cabin portholes are removed.
• The whole crew and personnel from shore is instructed that doors leading out on deck must be kept closed at all time.
• When entering the port the following equipment which concerns safety, in case of fire and oil pollution, should be ready and available on the main deck:
  • After the vessel is moored, a fire wire is rigged fore and aft on the outer side (if the vessel is moored with starboard side along side, the wires are to be rigged on port side). These wires are to be used by tugboats if some unforeseen circumstances should appear. The tugboats can rapidly fast the wires and pull the vessel from the berth. These wires have to be supervised constantly during the stay to make sure that the wires are hanging in right height above the water surface.
  • Safety net should be rigged underneath the accommodation ladder.
  • Next to the accommodation ladder, a capacity plan is placed, showing the vessel’s safety equipment, fire equipment, ans.
  • Next to the capacity plan, an international fire coupling is placed. This coupling is used between the vessel’s fire hydrant and the terminal’s connection. Both the above mentioned items must be placed in plain marked boxes.
  • Fire hoses rigged in the manifold area.
  • Fixed foam monitors are made ready for use and pointed towards the manifold area.
  • Absorbent booms, sheets, etc. are made ready for use in case of pollution.
  • Sawdust is ready for use.
  • A mobile 50kg’s powder extinguisher.
• A box containing personal protection, such as suit, boots, oil proof gloves, shovels, scrapes, buckets and other equipment to collect oil. All equipment in spark proof material.

• Oil detrimental chemicals - to use on board and on the water along the shipside. Local approval has to be issued before using the chemicals. On board, the chemicals must be stored in a particular locker properly marked.

As the above shows, there is a lot of work to be done in connection with a port stay. Also be aware of the value of good routines. Besides, it also has a double effect when a vessel is organized in a professional way. The cargo operation becomes safer and easier and the shore representatives get a positive impression of the vessel.

4.1.3 Procedures after arrival at the terminal

After the vessel is well moored at the terminal, the chief officer meets the terminal’s loading master, security officer and one or more independent surveyors. During a pre-meeting the operation is lined up and information is exchanged, such as:

- Number of loading arms (hoses) and which manifolds to use.
- The loading plan is reviewed. Agreement of quantity and which cargo tanks will be filled.
- Agreement for the deballasting.
- Establish start rate, full rate and topping up rate during loading.
- Agreement about how much time is needed for a stop, an emergency stop, ans.
- Agreements of shore stop or ship stop. When dead-weight limitation is in force, which stops before the cargo tanks are full, it is advantageous for the vessel to agree to shore stop.
- Before the loading commences a lot of paper work has to be done. An obligatory transition hereby exists for the serial safety points, a so-called “Ship/Shore Safety Check List”. In addition, the captain must sign a letter, which contains the vessel’s responsibility to comply with the vessel’s part of the checklist, and the consequences by not doing so.
- Once these formalities are worked out, the vessel’s representative and an independent surveyor will check the cargo tanks before commencing loading. The cargo tanks are sound/dipped and the found amount is calculated. The amount of cargo from previous voyage is called On Board Quantity (OBQ). The calculated figures are recorded in a specific report, and total OBQ, including slop, is to be drawn off from the surveyed quantity after loading.

4.1.4 Load on top (LOT)

Most of the cargo from previous voyages is to be found in the slop tank. When planning the loading operation, permission to load on top must be obtained. It is important to know if the new cargo may unite with the previous cargo without being contaminated.

On CBT-tankers, which use cargo tanks for ballast, these tanks are both crude oil washed and water washed. (See part 4, chapter 5 Ballast tanks). After ballast handling and line washing, the cargo remnants are transferred to the slop tank. Since there are still a few terminals world wide which receive slop, the slop must remain on board and be mixed with the new cargo to make use of the cargo tank's total capacity.

4.1.5 Load planning

Before a loading operation on an oil tanker can start, a detailed loading plan must be worked out. The planning should include the loading operation itself and the safety means around this plan.
A watch list is to be written, with name of the officer and crew on duty. The persons should be described with names and duties during their watch periods. A security preparation plan, in case of oil pollution, should be worked out also, which describes the preparation actions and the persons executing the different actions. All plans and watch lists are to be given to the operators in charge, and the same information is delivered to the terminal representatives ashore. Put a copy of the plan so it is available to other visitors to view (for instance the US Coast Guard).

Some particulars relating to the load planning:

- The tank atmosphere at arrival loading port. Check that O₂ content and the tank pressure is OK. The Loading master will inspect this.
- Keep well-established routines for rigging the equipment to fight fire and attempt to prevent oil pollution ans. This will reduce the risk of forgetting in a period when a thousand things happen at the same time.
- Present the ship with blind flanges on the manifold. Arrive at the port with all the valves on the loading line system closed. These can then gradually be operated as needed. A common principle is not to open more valves than necessary.
- The persons on duty should be active! Remember that the Watchman for the manifold, watch hoses and lines should also be in touch with the people on shore and the ship’s cargo control room. The Deck Watches should be aware and follow the happenings on the tank deck and moorings, the out rigged fire wire, and the gangway to shore.

4.2 DISCHARGING

4.2.1 Combination Carriers and Double Hull Tankers
The discharge plan of these ships must particularly take into account the ship's stability instructions and the need to avoid excessive free surface and consequent loss of stability.

4.2.2 Inert Gas Procedures
Ships using an inert gas system must have the system fully operational and producing good quality (i.e. low oxygen content) inert gas at the commencement of discharge.

The inert gas system must be fully operational and working satisfactorily throughout the discharge of cargo or deballasting.

Cargo discharge must not be started until:

- All relevant cargo tanks, including slop tanks, are common with the IG main.
- All other cargo tank openings, including vent valves, are securely closed.
- The inert gas main is isolated from the atmosphere and, if a cross connection is fitted, also from the cargo main.
- The inert gas plant is operating.
• The deck isolating valve is open.

A low but positive inert gas pressure after completion of discharge will permit the draining of the manifold driptray into a tank and, if required, allow manual dipping of each tank.

4.2.3 Closed Discharging
Vessels correctly operating their inert gas systems may be considered to be conducting closed discharging operations.
Discharge should normally take place on non-inerted vessels with all ullage, sounding and sighting ports closed. Air should be admitted to the tanks by the dedicated venting system. Where the design of the vessel does not allow admittance of air via the vapour system at a satisfactory rate, air may be admitted via a sighting or ullage port providing it is fitted with a permanent flame screen.
When cargo is being run between tanks during discharge operations care should be taken to ensure that vapors are vented to deck via the deck apertures protected by flame screens.

4.2.4 Pressurizing of Cargo Tanks
When high vapor pressure petroleum (e.g. natural gasoline and certain crude oils) reaches a low level in cargo tanks, the head of liquid is sometimes insufficient to keep cargo pumps primed. If an inert gas system is installed in the tanker this system can be used for pressurizing cargo tanks in order to improve pump performance.

4.2.5 Commencement of Discharge Alongside a Terminal
Shore valves must be fully open to receiving tanks before the tanker's manifold valves are opened. If there is a possibility that, owing to the elevation of the shore tanks above the level of the ship's manifold, pressure might exist in the shore line and no non-return (check) valves are fitted in the shore line, the ship must be informed and the tanker's manifold valves should not be opened until an adequate pressure has been developed by the pumps.
Discharge should start at a slow rate, and only be increased to the agreed rate once both parties are satisfied that the flow of oil to and from designated tanks is confirmed.

4.2.6 Commencement of Discharge at an Offshore Terminal
Before commencing discharge at an offshore terminal, communications between ship and shore should be tested and fully understood. The ship must not open its manifold valves or start its pumps until a clear signal has been received from the shore that the terminal is ready.
Discharge must be started slowly until the system has been tested and then gradually brought up to the maximum agreed flow rate or pressure. A close watch should be kept on the sea in the vicinity of the hoses to detect leaks. During darkness a bright light should, where safe and practicable, be shone on the water in the vicinity of the hoses.

4.2.7 Commencement of Discharge Through a Stern Discharge Line
Before commencing discharge through a stern discharge line, a dangerous area extending not less than 3 meters from the manifold valve should be clearly marked and no unauthorised personnel should be allowed within this area during the entire discharge operation.
A close watch must be maintained for any leakage and all openings, air inlets and doors to enclosed spaces should be kept tightly closed.
Fire fighting equipment must be laid out and ready for use in the vicinity of the stern discharge manifold.
4.2.8 Fluctuations in Discharge Rate
During discharge the flow of cargo should be controlled by the tanker in accordance with the agreement reached with the terminal. The discharge rate should not be substantially changed without informing the terminal.

4.2.9 Stripping and Draining of Cargo Tanks
If, during the discharge of the main bulk of cargo, a slop tank or other selected tank is used to receive the drainings of tanks being stripped, personnel should be alert to the fact that the ullage in the receiving tank will be decreasing. In these circumstances great care should be taken to avoid an overflow and proper precautions taken in respect of any vapors emitted.

4.2.10 Simultaneous Ballast and Cargo Handling
If ballasting of cargo tanks is carried out simultaneously with the discharge of cargo, vapors may be emitted from the tanks being ballasted, in which case proper precautions should be taken.

FAILURE OF THE INERT GAS SYSTEM DURING DISCHARGE
In the event of the failure of the inert gas system to deliver the required quality and quantity of inert gas, or to maintain a positive pressure in the cargo tanks and slop tanks, action must be taken immediately to prevent any air being drawn into the tanks. All cargo and/or ballast discharge must be stopped, the inert gas deck isolating valve closed, the vent valve between it and the gas pressure regulating valve (if provided) opened, and immediate action taken to repair the inert gas system.
Masters are reminded that national and local regulations may require the failure of an inert gas system to be reported to the harbor authority, terminal operator and to the port and flag state administrations.
Pyrophoric iron sulphide deposits, formed when hydrogen sulphide gas reacts with rusted surfaces in the absence of oxygen, may be present in the cargo tanks and these deposits can heat to incandescence when coming into contact with air. Therefore, in the case of tankers engaged in the carriage of crude oil, the failed inert gas system must be repaired and restarted, or an alternative source of inert gas provided, before discharge of cargo or ballast is resumed.
In the case of product carriers the formation of pyrophors is usually inhibited by tank coatings. If, therefore, it is considered totally impracticable to repair the inert gas system, discharge may be resumed with the written agreement of all interested parties, provided an external source of inert gas is provided or the following precautions are taken:

- Devices to prevent the passage of flame or flame screens (as appropriate) are in place and are checked to ensure that they are in a satisfactory condition.

- Valves on the vent mast risers are opened.

- No free fall of water or slops is permitted.

No dipping, ullaging, sampling or other equipment is 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 it should be done only after at least 30 minutes have elapsed since the injection of inert gas has ceased. All metal components of any 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.

**PIPELINE AND HOSE CLEARING**

### 4.2.11 General

The procedure for clearing the pipelines and hoses or arms between the shore valve and ship's manifold will depend on the facilities available and whether these include a slop tank or other receptacle. The relative heights of the ship and shore manifolds may also influence procedures.

Some terminals require the ship to displace with water the contents of the hoses or arms, and perhaps also the shore pipelines, on completion of cargo operations. Prior to commencing the displacement the ship and terminal should reach agreement on the procedures to be adopted.

### 4.2.12 Line Draining

On completion of loading, the ship's cargo deck lines should be drained into appropriate cargo tanks to ensure that thermal expansion of the contents of the lines cannot cause leakage or distortion. The hoses or arms and perhaps a part of the pipeline system between the shore valve and the ship's manifold are also usually drained into the ship's tanks. Sufficient ullage must be left in the final tanks to accept the drainings of the hoses or arms and ship or shore lines.

On completion of discharge the ship's cargo deck lines should be drained into an appropriate tank and then be discharged ashore or into a slop tank.

When draining is complete and before hoses or arms are disconnected, the ship's manifold valves and shore valves should be shut and the drain cocks at the vessel's manifold should be opened to drain into fixed drain tanks or portable drip trays. Cargo manifolds and arms or hoses should be securely blanked after being disconnected. The contents of portable or fixed drip trays should be transferred to a slop tank or other safe receptacle.

### 4.2.13 Clearing of Hoses and Arms

If lines, hoses or arms have to be cleared to the shore using compressed air or inert gas, the following precautions should be strictly observed in order to avoid the possible creation of a hazardous static electrical charge or mechanical damage to tanks and equipment:

- The procedure to be adopted must be agreed between ship and terminal.
- There must be adequate ullage in the reception tank.
- To ensure that the amount of compressed air or inert gas is kept to a minimum the operation must be stopped when the line has been cleared.
- The inlet to the receiving tank should be located well above any water that may be in the bottom of the tank.
- The line clearing operation must be continuously supervised by a responsible person.
4.3 TANK CLEANING AND GAS FREEING

4.3.1 Preparations
Both before and during tank cleaning and gas freeing operations, the responsible officer should be satisfied that all the appropriate precautions set out in Chapters 2 and 6 are being observed. All personnel on board should be notified that tank cleaning or gas freeing is about to begin.
If craft are alongside the tanker, their personnel should also be notified and their compliance with all appropriate safety measures should be checked.
Before starting to gas free or tank clean alongside a terminal, the following additional measures should be taken:

- The appropriate personnel ashore should be consulted to ascertain that conditions on the jetty do not present a hazard and to obtain agreement that operations can start.

4.3.2 Gas Freeing and Tank Cleaning Concurrently with Cargo Handling
As a general rule tank cleaning and gas freeing should not take place concurrently with cargo handling. If for any reason this is necessary, there should be close consultation with, and agreement by, both the terminal representative and the port authority.
Crude oil washing and cargo discharge may take place concurrently, but the terminal representative should be advised.

4.3.3 Testing of Tank Cleaning Hoses
All hoses should be tested for electrical continuity in a dry condition prior to use and in no case should the resistance exceed 6 ohms per meter length.

4.3.4 Entry into Cargo Tanks
No one should enter any cargo tank unless permission to do so has been received from the responsible officer and all appropriate precautions have been taken, including the issue of an entry permit.

4.3.5 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 gas 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 analyzer.
- 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 analyzer.
- 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.

4.4 CARGO TANK WASHING AND CLEANING

4.4.1 Tank atmospheres can be any of the following:

Inerted An atmosphere made incapable of burning by the introduction of inert gas and the resultant reduction of the overall oxygen content. For the purposes of this guide the oxygen content of the tank atmosphere should not exceed 8% by volume.

Too lean An atmosphere made incapable of burning by the deliberate reduction of the hydrocarbon content to below the lower flammable limit.

Over rich An atmosphere which is above the flammable range.

Undefined An atmosphere which may be above, below or within the flammable range.

4.4.2 Washing in a too Lean Atmosphere

The following precautions must be observed:

(a) Before washing, 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. The flushing water should be drained to the tank designed or designated to receive slops.

(b) Before washing, the tank should be ventilated to reduce the gas concentration of the atmosphere to 10% or less of the lower flammable limit. Gas tests must be made at various levels and due consideration given to the possible existence of local pockets of flammable gas. Mechanical ventilation and gas testing should continue during washing. Ventilation should, as far as possible, provide a free flow of air from one end of the tank to the other.

(c) If the tank has a venting system which is common to other tanks, the tank must be isolated to prevent an ingress of gas from other tanks.

(d) If portable washing machines are used, all hose connections should be made up and tested for electrical continuity before the washing machine is introduced into the tank. Connections should not be broken until after the machine has been removed from the tank. To drain the hose a coupling may be partially opened and then re-tightened before the machine is removed.

(e) During tank washing regular gas tests must be made at various levels. Consideration should be given to the possible effect of water on the efficiency of the gas measuring equipment. Washing should be discontinued if the gas concentration rises to 50% of the LFL. Washing may be resumed when continued ventilation has reduced the gas concentration to 20% of the LFL and has maintained it at or below that level for a short period.

(f) The tank should be kept drained during washing. Washing should be stopped to clear any build-up of wash water.

(g) Recirculated wash water should not be used for tank washing.

(h) Steam should not be injected into the tank.

(i) The same precautions relating to sounding and the introduction of other similar equipment should be taken as when washing in an undefined atmosphere. Chemical additives may be employed provided the temperature of the wash water does not exceed 60°C.

(k) Wash water may be heated. If the wash water temperature is 60°C or less, washing should be discontinued if the gas concentration reaches 50% of the LFL. If the wash water temperature is above 60°C, washing should be discontinued if the gas concentration reaches 35% of the LFL.

4.4.3 Control of Washing in an Undefined Atmosphere

In an undefined atmosphere, the vapours in the tank may be in the flammable range. The only way to guarantee that an explosion cannot occur during washing in an undefined atmosphere is to make certain that there can be no source of ignition.

The following precautions must be taken if the risk from static electricity is to be eliminated:
(a) No machine may have a throughput greater than 60M$^3$/h.

(b) The total water throughput per cargo tank should be kept as low as practicable and must in no case exceed 1180m$^3$/h.

(c) Recirculated wash water must not be used.

(d) Chemical additives must not be used.

(e) Wash water may be heated, but must not be above 60°C.

(f) Steam must never be injected into the tank.

(g) The tank should be kept drained during washing. Washing should be stopped to clear any build-up of wash water.

(h) All hose connections must be made up and tested for electrical continuity before the washing machine is introduced into the tank. Connections should not be broken until after the machine has been removed from the tank. To drain the hose a coupling may be partially opened and then retightened before the machine is removed.

(i) Sounding and the introduction of other equipment must be done through a sounding pipe if fitted. If a sounding pipe is not fitted, it is essential that any metallic components of the sounding or other equipment are bonded and securely earthed to the ship before introduction into the tank and remain so earthed until removed. This precaution should be observed during washing and for five hours thereafter. If, however, the tank is continuously mechanically ventilated after washing, this period can be reduced to one hour. During this period:

- An interface detector of metallic construction may be used if earthed to the ship by means of a clamp or bolted metal lug.

- A metal rod may be used on the end of a metal tape which is earthed to the ship.

- A metal sounding rod suspended on a fibre rope should not be used even if the end at deck level is fastened to the ship because the rope cannot be completely relied upon as an earthing path.

- Equipment made entirely of non-metallic materials may, in general, be used: e.g. a wooden sounding rod may be suspended on a rope without earthing.

- Ropes made of synthetic polymers should not be used for lowering equipment into cargo tanks.

Further information on electrostatic precautions during tank washing is given in Chapter 20.

4.4.4 Washing in an Over Rich Atmosphere
The procedures for making a tank atmosphere over rich and thereafter water washing the tank involve special measures intended to prevent the ingress of air. This method of tank washing
should only be carried out when authorized by the operator and under the supervision of a person who has received special training in these procedures. Water washing must not be started, or if in progress must be discontinued and not re-started, if the hydrocarbon content of the tank atmosphere is less than 15% by volume.

4.4.5 Portable Tank Washing Machines and Hoses
The outer casing of portable machines should be of a material which on contact with the internal structure of a cargo tank will not give rise to an incendive spark. Bonding wires should be incorporated within all water hoses. Couplings should be connected to the hose in such a way that effective bonding is ensured between them. The coupling arrangement for the hose should be such that effective bonding can be established between the tank washing machine, the hoses and the fixed tank cleaning water supply line. Hoses should be indelibly marked to allow identification. A record should be kept showing the date and the result of electrical continuity testing. Washing machines should be electrically bonded to the water hose by means of a suitable connection or external bonding wire. When suspended within a cargo tank, machines should be supported by means of a rope and not by means of the water supply hose.

4.4.6 Free Fall
It is essential to avoid the free fall of water or slops into a tank. The liquid level should always be such that the discharge inlets in the slop tank are covered to a depth of at least one meter to avoid splashing. This is not necessary when the slop and cargo tanks are fully inerted.

4.4.7 Spraying of Water
The spraying of water into a tank containing a substantial quantity of static accumulator could result in the generation of static electricity at the liquid surface, either by agitation or water settling. Tanks which contain a static accumulator oil should always be pumped o before they are washed with water unless the tank is kept in an inert condition (see Section 7).

4.4.8 Steaming of Tanks
Because of the hazard from static electricity, the introduction of steam into cargo tank should not be permitted where there is a risk of the presence of a flammable atmosphere. Should be borne in mind that a non-flammable atmosphere cannot be guaranteed in all case where steaming might be thought to be useful.

4.4.9 Removal of Sludge, Scale and Sediment
Before the removal by hand of sludge, scale and sediment, the tank atmosphere must safe for entry and an entry permit issued. Equipment to be used for further tank cleaning operations, such as the removal of sol residues or products, in tanks which have been gas freed should be so designed a constructed, and the construction materials so chosen, that no risk of ignition is introduce
4.5 GAS FREEING

4.5.1 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-emphasized 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.

4.5.2 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 sea water 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.

4.5.3 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 LFL.

4.5.4 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.

4.6 CRUDE OIL WASHING

4.6.1 General
A crude oil tanker fitted with an inert gas system and approved fixed washing equipment in its cargo tanks can use crude oil from the cargo as the washing medium. This operation may take place either in port or at sea between discharge ports. It is most frequently carried out while the tanker is discharging cargo and permits the removal of oil fractions adhering to or deposited on tank surfaces. These deposits, which would normally remain on board after discharge, are then discharged with the cargo.

As a consequence, the need to water wash the discharged tanks during the ballast voyage for the removal of residues is much reduced and, in some cases, entirely eliminated. Water rinsing will be necessary if the tank is to be used for clean ballast.

Reference should be made to the IMO publication "Crude Oil Washing Systems" and the vessel's approved Operations and Equipment Manual for further detailed guidance on the procedures involved.

4.6.2 Advance Notice
When it is required to carry out crude oil washing during cargo discharge, the master should inform the competent authority and the terminal (or vessel when ship to ship transfer is involved) at least 24 hours in advance, or in such time as is required. Crude oil washing should only proceed when their approval is received.

4.6.3 Tank Washing Machines
Only fixed tank washing machines may be used for crude oil washing.

4.6.4 Control of Tank Atmosphere
The oxygen content of the tank must not exceed 8% by volume.

4.6.5 Precautions Against Leakage from the Washing System
Before arriving in a port where it is intended to crude oil wash, the tank washing system should be pressure tested to normal working pressure and examined for leaks.

All machines which are to be used should be operated briefly to check for leaks beyond the shut-off valve. Any leaks found should be made good.

During crude oil washing, the system must be kept under constant observation so that any leak can be detected immediately and action taken to deal with it.

4.6.6 Avoidance of Oil/Water Mixtures
Mixtures of crude oil and water can produce an electrically charged mist during washing much in excess of that produced by "dry" crude oil. The use of "dry" crude oil is therefore important, and before washing begins any tank which is to be used as a source of crude oil washing fluid should be partly discharged to remove any water which has settled out during the voyage. The discharge of a layer at least one metre in depth is necessary for this purpose.

For the same reason, if the slop tank is to be used as a source of oil for washing, it should first be completely discharged ashore and refilled with "dry" crude oil.
4.6.7 Exclusion of Cargo Oil from the Engine Room

If any part of the tank washing system extends into the engine room it must be blanked-off to prevent cargo oil from entering the engine room.

If the tank wash water heater is fitted outside the engine room, it must be blanked-off during crude oil washing to prevent oil from flowing through it.

4.6.8 Control of Vapour Emissions

During crude oil washing, hydrocarbon gas is generated within the cargo tanks beyond normally existing levels. Subsequent ballasting of such cargo tanks could lead to considerable hydrocarbon gas being expelled to the atmosphere. Some port authorities prohibit such discharges.

The emission of hydrocarbon gas from ballasted tanks can be avoided in one of four ways:

(a) By the use of permanent ballast tanks of sufficient capacity to provide the minimum departure draught.

(b) By containing gas in empty cargo tanks by simultaneous ballasting and cargo discharge where the ullage spaces of the tanks being ballasted are directly connected to those of the tanks being discharged.

(c) By the gas compression method which requires that, on completion of the discharge, the tank pressure is at a minimum and all cargo tanks are made common via the inert gas line. While ballasting, the gases from the ballasted cargo tanks are transferred through the inert gas lines into all available cargo tank space and, with all vent valves, ullage ports, etc. closed, the gases are compressed within the vessel up to a safe margin below p/v valve and breaker settings. The PN valves, deck water seal and filled liquid breaker must be in good operational condition. All non-return devices must be closed to prevent the backflow of inert gas into the inert gas plant.

(d) By a suitable combination of any of these methods.

Generally, the ullage spaces of all cargo tanks are connected by the inert gas main line. If the ballasting of dirty tanks can be connected while discharge continues from other tanks, judicious adjustments of ballast and discharge rates can prevent the gas pressure rising sufficiently to cause a discharge to the atmosphere. Where the ballast rate exceeds the discharge rate it may be necessary to reduce or even temporarily stop the flow of inert gas to the tank system.

4.6.9 Supervision

The person in charge of crude oil washing operations must be suitably qualified in accordance with the requirements laid down by the flag administration of the vessel and any port regulations in force locally.
4.6.10 Cautionary Notice
A notice should be prominently displayed in the cargo and engine control rooms, on the bridge and on the notice boards of ships which have crude oil washing systems fitted. The following text is suggested

THE TANK WASHING LINES ON THIS SHIP MAY CONTAIN CRUDE OIL.
VALVES MUST NOT BE OPERATED BY UNAUTHORISED PERSONNEL

4.7 Fixed Inert Gas Systems

4.7.1 General
Hydrocarbon gas normally encountered in petroleum tankers cannot burn in an atmosphere containing less than approximately 11% oxygen by volume. Accordingly one way to provide protection against fire or explosion in the vapor space of cargo tanks is to keep the oxygen level below that figure. This is usually achieved by using a fixed piping arrangement to blow inert gas into each cargo tank in order to reduce the air content, and hence the oxygen content, and render the tank atmosphere non-flammable.

This can be explained by reference to Figure 10-1 which shows the relationship between hydrocarbon gas and oxygen in a hydrocarbon gas/air mixture. The flammable limits vary for different pure hydrocarbon gases and for mixtures derived from different petroleum liquids. For practical purposes the lower and upper flammable limits (LFL and UFL) of crude oil vaporous are taken to be 1% and 10% respectively by volume.

These values are indicated by points C and D on the line A B in Figure 10-1.

Any point on the diagram represents mixtures of hydrocarbon gas, air and inert gas, specified in terms of hydrocarbon gas and oxygen contents.

For example, hydrocarbon gas/air mixtures without any inert gas lie on the line A B, the slope of which represents the reduction in oxygen as the hydrocarbon content increases.

Points to the left of line A B represent mixtures with their oxygen content reduced by the addition of inert gas. The further left these points lie the greater the proportion of inert gas and the smaller the percentage of oxygen.

As inert gas is added to the hydrocarbon gas/air mixture, the flammable range decreases until a point, represented by E, is reached where the LFL and UFL coincide. This point corresponds to an oxygen content of approximately 11%. No hydrocarbon gas/air mixture can burn at this oxygen level. For practical purposes and to allow a safety margin, 8% is taken as the level of oxygen at which no hydrocarbon gas/air mixture can burn under any circumstances. To prevent fire or explosion in a tank containing a hydrocarbon gas/air mixture it is therefore necessary to produce and supply inert gas having an oxygen content not normally exceeding 5% and to displace the existing air in the tank until the resultant oxygen level throughout the tank does not exceed 8% by volume.
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.

When air is introduced into an inert mixture, such as that represented by point F, its composition moves along the line FA and therefore enters the shaded area of flammable mixtures. This means that all inert mixtures in the region above the line GA (critical dilution line) pass 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 when air is mixed with them. It will be noted that it is possible to move from a mixture such as that represented by F to one such as that represented by H by the introduction of additional inert gas, i.e. by purging.

4.7.2 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.
4.7.3 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.

4.7.4 Method of replacing tank atmospheres

If the entire tank atmosphere could be replaced by an equal volume of inert gas the resulting tank atmosphere would have the same oxygen level as the incoming inert gas. In practice this is not the case and a volume of inert gas equal to several tank volumes must be introduced into the tank before the desired result can be achieved.

The replacement of a tank atmosphere by inert gas can be achieved by either inerting or purging. In each of these methods one of two distinct processes, dilution or displacement, will predominate.

Dilution takes place when the incoming inert gas mixes with the original tank atmosphere to form a homogeneous mixture through the tank so that, as the process continues, the concentration of the original gas decreases progressively. It is important that the incoming inert gas has sufficient entry velocity to penetrate to the bottom of the tank. To ensure this a limit must be placed on the number of tanks which can be inerted simultaneously. Where this is not clearly stipulated in the operations manual, only one tank should be inerted or purged at a time.

Displacement depends on the fact that inert gas is slightly lighter than hydrocarbon gas so that, while the inert gas enters at the top of the tank, the heavier hydrocarbon gas escapes from the bottom through suitable piping. When using this method it is important that the inert gas has a very low velocity to enable a stable horizontal interface to be developed between the incoming and escaping gas although, in practice, some dilution inevitably takes place owing to the turbulence caused in the inert gas flow. This system generally allows several tanks to be inerted or purged simultaneously.

Whatever method is employed, and whether inerting or purging, it is vital that oxygen or gas measurements are taken at several heights and horizontal positions within the tank to check the efficiency of the operation.

A mixture of inert gas and petroleum gas when vented and mixed with air can become flammable. The normal safety precautions taken when petroleum gas is vented from a tank should therefore not be relaxed.
4.8 CARGO TANK ATMOSPHERE CONTROL

Tankers using an inert gas system should maintain their cargo tanks in a non-flammable condition at all times.

It follows that:

- Tanks should be kept in an inert condition at all times except when it is necessary for them to be gas free for inspection or work, i.e. the oxygen content should be not more than 8% by volume and the atmosphere should be maintained at a positive pressure.

- The atmosphere within the tank should make the transition from the inert condition to the gas free condition without passing through the flammable condition. In practice this means that before any tank is gas freed it should be purged with inert gas until the hydrocarbon content of the tank atmosphere is below the critical dilution line (line GA in Figure 10-1).

- When a ship is in a gas free condition before arrival at a loading port the tanks must be iner ted prior to loading.

In order to maintain cargo tanks in a non-flammable condition the inert gas plant will be required to:

- Inert empty cargo tanks.

- Be in operation during cargo discharge, deballasting, crude oil washing and tank cleaning.

- Purge tanks prior to gas freeing.

- Top-up the pressure in the cargo tanks when necessary during other stages of the voyage.

It must be emphasized that the protection provided by an inert gas system depends on the proper operation and maintenance of the entire system. Where an inert gas system is installed, it is essential that there is close co-operation between the deck and engine departments to ensure its proper maintenance and operation. It is particularly important to ensure that non-return barriers function correctly, especially the deck water seal and the nonreturn valves, so that there is no possibility of petroleum gas or liquid petroleum passing back to the machinery spaces.

To demonstrate that the inert gas plant is fully operational and in good working order, a record of inspection of the inert gas plant, including defects and their rectification, should be maintained on board.

4.8.1 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. If the 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.
4.8.2 Preparation for Tank Entry
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% LFL.

If the presence of a toxic gas such as benzene or hydrogen sulphide is suspected, gas freeing should be continued until tests indicate that its concentration is below its TLV.

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.

When a gas free tank is re-connected to the inert gas main it should immediately be reinerted.

4.9 PRECAUTIONS TO BE TAKEN TO AVOID HEALTH HAZARDS

4.9.1 Inert Gas on Deck
Certain wind conditions may bring vented gases back down onto the deck, even from specially designed vent outlets. Also, if gases are vented at low level and the cargo hatches, ullage ports or other tank vents are used as outlets, the surrounding areas can contain levels of gases in harmful concentrations, and may be oxygen deficient. In these conditions all nonessential work should cease and only essential personnel should remain on deck, taking all appropriate precautions.

In addition, when the last cargo carried was a sour crude, tests should be made for hydrogen sulphide. If a level in excess of 10 ppm is detected, no personnel should be allowed to work on deck unless wearing suitable respiratory protection.

4.10 COMBINATION CARRIERS

4.10.1 General
Combination carriers carrying oil must be treated as tankers and all precautions applicable to tankers observed.

The basic principles of inerting can be applied in exactly the same way for a combination carrier as for a tanker. However, differences in design and operation give rise to certain particular considerations for combination carriers, which are outlined in the following sections.
4.10.2 Slack Holds
It is particularly important for combination carriers to maintain their holds in an inert condition. These holds may extend to the full width of the ship and, even at small angles of roll, agitation of clean or dirty ballast in a slack hold (i.e. one in which the liquid level is not within the coaming) may result in the generation of static electricity. This agitation is sometimes referred to as sloshing and can occur whenever the liquid level of the hold is not pressed up into the hatch coaming. Slack holds should be avoided whenever possible.

4.10.3 Leakage
To ensure that leakage of gas, particularly through the hatch centre-line joints, is eliminated or minimized, it is essential that the hatch covers are inspected frequently to determine the condition of their seals, their alignment etc. When the hatch covers have been opened, particularly after the ship has been carrying a dry bulk cargo, the seals and trackways should be inspected and cleaned to remove any foreign matter.

4.10.4 Ballast and Void Spaces
The cargo holds of combination carriers are adjacent to ballast and void spaces. Leakages in pipelines or ducts in these spaces, or a fracture in the boundary plating, may cause oil, inert gas or hydrocarbon gas to leak into the ballast and void spaces. Consequently gas pockets may form which, because of the complex structure of these spaces, could be difficult to disperse. Personnel should be alerted to this hazard.

4.10.5 Inert Gas Distribution System
Because of the special construction of combination carriers, the vent line from the cargo hatchway coaming is situated very close to the level of the cargo surface. Also, in many cases the inert gas main line passing along the main deck may be below the oil level in the hold. During rough weather oil or water may enter these lines and thus prevent an adequate supply of inert gas during tank cleaning or discharge. Vent lines should therefore have drains fitted at their lowest point and these should always be checked before any operation takes place within the cargo hold (see Section 12.6.2).

4.10.6 Slop Tanks
If slops are retained on board because of the lack of reception facilities, the slop tank or tanks should be maintained in an inert condition and at a minimum pressure of 100mm water gauge at all times. These tanks should be checked at intervals of not more than 2 days to ensure that the oxygen level does not exceed 8% by volume. If any oxygen level in excess of this figure is detected, the tanks should be re-inerted until the oxygen level is less than 8%.

Except when the slop tanks are being purged or re-inerted, they should be isolated from the inert gas main.

Additionally, all cargo lines to and from the slop tanks should be isolated by means of blanks.
4.11 DOUBLE HULL OPERATIONS

4.11.1 Stability considerations
Single hull oil tankers usually have such a high metacentric height in all conditions of loading and ballasting that they can be considered as being inherently stable. Whilst tanker personnel have always had to take account of longitudinal bending moments and vertical shear forces, the actual stability of the ship has seldom been a prime concern. However the introduction of double hulls into tanker design is likely to change that situation.

The main problem likely to be encountered is the effect on the transverse metacentric height of liquid free surface in the cargo and double bottom tanks.

Depending upon the design, type and number of these tanks, the free surface effect could result in the transverse metacentric height being significantly reduced. The situation will be most severe in the case of wide cargo tanks with no centreline bulkhead and the so called "U" ballast tanks which have no centreline bulkhead.

The most critical stages of any operation will be whilst filling the double bottom ballast tanks during discharge of cargo, and emptying the tanks during loading of cargo. If sufficient cargo tanks and double bottom tanks are slack simultaneously, the overall free surface effect could well be sufficient to reduce the transverse metacentric height to a point at which the transverse stability of the ship may be threatened. This could result in the ship suddenly developing a severe list. Large free surface area is especially likely to threaten stability at greater soundings (innages) with associated high vertical centre of gravity.

It is imperative that tanker and terminal personnel involved in cargo and ballast operations are aware of this potential problem, and that all cargo and ballast operations are conducted strictly in accordance with the ship's loading manual.

Where they are fitted, interlock devices to prevent too many cargo and ballast tanks from being operated simultaneously, thereby causing an excessive free surface effect, should always be maintained in full operational order, and should never be over-ridden.

Ships which operate with limited metacentric height should be equipped with a loading computer which calculates metacentric height.

It is imperative that masters and officers be aware that partially loading a cargo tank with heavy weather ballast may present a potential problem. The combination of free surface and the flat tank bottom can result in the generation of wave energy of sufficient power to severely damage internal structure and pipelines.

4.11.2 Routine monitoring of double hull spaces
Double hull spaces should be regularly monitored in order to check the integrity of the inner shell plating. This can be accomplished by monitoring the ballast tank atmosphere for hydrocarbon gas, and by regular sounding/ullaging of ballast tanks. The sampling referred to in this section is for leak detection purposes only, and should not be used as the criteria for tank entry.
The atmosphere in each double hull tank and double bottom tank should be monitored for hydrocarbon content:

- Regularly during the loaded passage.
- Prior to ballasting the tank following a period of heavy weather.
- After any unusual event or occurrence eg. unexpected lists, unforeseen operational problems.

The atmosphere monitoring programme should ensure that each tank is monitored at least once per week during the loaded passage. However, where ships are engaged on short haul voyages which make this impractical, visual inspection of the tanks or the ballast water is considered to be a suitable alternative measure.

The hydrocarbon measurements should be taken with a portable gas detector at designated sampling points using installed fixed lines or a portable sampling hose, or with a fixed gas detection system where one is installed.

Where fixed gas detection systems are installed, operators should develop procedures to ensure that tank atmospheres are monitored on a regular basis. They should ensure that full operating, maintenance and fault detection instructions are readily available to ship's personnel, and that they are familiar with the use of the equipment.

Information as to the point of origin of each fixed sampling line should be readily available to ship's personnel.

Procedures should be developed for the regular clearing of all fixed sampling lines.

The ship should be provided with information relating to any restrictions on lowering a sampling hose into the tank which might be imposed as a result of normal operating trim or list.

During the loaded passage, ballast tanks should be sounded on a frequent and regular basis as a back up method of detecting any oil leakage into them.

After ballasting, tanks should be checked visually to ascertain if any oil is present. A similar procedure should be carried out prior to discharge of ballast.

During the ballast voyage, the ullage of each ballast tank should be checked at frequent and regular intervals. Consideration should also be given to the feasibility of routine monitoring to detect water ingress to the cargo tanks.

4.11.3 Tank entry procedures for double hull spaces

All tank entry must be strictly controlled, and it is strongly recommended that this control is exercised in accordance with the Tank Entry Permit procedures referred to in Chapter 1 1. It must however be appreciated that the compartmentalised structure in double hull and double bottom tanks makes them more difficult to gas free than conventional tanks and particular care should be taken to monitor the tank atmosphere.
Although entry into double hull or double bottom tanks should be kept to a minimum, tank entry will on occasion be required for such purposes as tank inspections and maintenance of ballast tank systems, gauging systems etc. In such cases, the recommendations in this section should be strictly enforced.

Measurements of hydrocarbon, oxygen and toxic gas (as appropriate) must be taken at every sampling point and in each case must meet the criteria specified in section 11.3.

The tank must be kept continuously ventilated throughout the period that people are inside it and during any breaks in the entry. If the ventilation is suspended for any significant period, the atmosphere must be re-verified as above and a new entry permit issued.

Once the tank atmosphere meets the entry criteria at each sampling point, actual entry by personnel should be undertaken in two stages. The first stage should be for the purpose of atmosphere verification and a general safety review.

In addition to the problems associated with gas freeing, the design and structure may add additional hazards to the entry process and therefore the following additional precautions should be considered during the initial entry. A strict radio reporting procedure should be established between those entering the tank and a monitor on deck.

One person should be assigned responsibility for atmosphere monitoring and communications. Personnel making the entry should be equipped with an emergency escape breathing set, a personal gas detector capable of monitoring at least hydrocarbon and oxygen, a portable radio, an emergency light source, a retrieval harness and an alternative means of attracting attention, eg. a whistle.

Only after this initial stage has verified that the atmosphere throughout the tanks is safe for the intended task should entry for other purposes be permitted. All such entry operations should be conducted in accordance with the procedures detailed in Chapter 11.

In order for people entering the tank to ascertain their position within the tank, and to facilitate position reporting, each tank bay should be identified by a simple number and/or letter system. This should be clearly marked in each bay and maintained in a visible condition throughout the life of the ship.

The tank entry route and the extent of penetration should be planned in advance. Any deviation from this plan should be agreed in advance with the person monitoring those inside the tank.

Consideration should be given to the laying out of hand lines to provide both an easy identification of the exit route and an aid to any rescue team.

4.11.4 Ventilation procedures

The complexity of the structure in double hull and double bottom tanks makes them more difficult to gas free than conventional ballast tanks. It is strongly recommended that the operator develop guidelines and procedures relating to the ventilation of each tank.

Whenever possible, these guidelines and procedures should be developed in conjunction with the shipbuilder and should be based on actual tests/experiments as well as on calculation. They should give details of the configuration of each tank, the method of ventilation and the equipment to be used. Details should also include the time required for
each method of ventilation to gas free the tank for entry. This should be the time to remove all contaminants rather than a simple volume/rate calculation.

Where portable fans are used for ventilation purposes, the above information should be provided for a range of drive pressures and different numbers of fans.

Where tanks are identical in structure and size, and where the method of venting is identical, the data can be obtained from tests on a representative tank. Otherwise the tests referred to above should be carried out for each tank.

4.11.5 Action to be taken in the event of cargo leakage

If a hydrocarbon leak is discovered the first step should be to check the atmosphere in the tank to establish the hydrocarbon level. It should be noted that the atmosphere in the tank could be above the UFL, within the flammable range, or below the LFL. Regardless of the number of samples taken, any or all of these conditions may exist in different locations within the tank, due to the complexity of the structure. It is thus essential that gas readings are taken at different levels at as many points as possible in order to establish the profile of the tank atmosphere.

If hydrocarbon gas is detected in a tank, there are a number of options which can be considered to maintain the tank atmosphere in a safe condition:

- Continuous ventilation of the tank.
- Inerting the tank.
- Filling, or partially filling the tank with ballast.
- Securing the tank with flame screens in place at the vents.
- A combination of the foregoing.

The option chosen will depend upon a number of factors, not least the degree of confidence in having established the hydrocarbon content of the atmosphere, bearing in mind the potential problems identified above.

It is strongly recommended that operators develop guidelines, taking into account the tank structure and any limitations of the available atmosphere monitoring system, which will assist ship's personnel to select the appropriate method of rendering the atmosphere safe.

Filling or partially filling the tank with ballast in order to render the atmosphere safe and/or stop any further leakage of cargo into the tank must take into account prevailing stress, trim, stability and loadline factors. It must also be borne in mind that the ballast may be classed as dirty ballast and may have to be processed in accordance with the MARPOL.

If the tank is ventilated or inerted in lieu of filling, it should be regularly sounded to ascertain the rate of liquid build up and thus of leakage.

If the quantity of cargo leaking into the space is determined to be pumpable, it should be transferred to another cargo tank via the emergency ballast/cargo spool piece connection, or
other emergency transfer method, in order to minimize contamination of the space and to facilitate subsequent cleaning and gas freeing operations. Ships should have written procedures available on board which indicate the actions to be taken and the operations necessary for the safe transfer of the cargo.

So far as is possible entry into the tank should be prohibited until it is safe for entry and there is no further possibility of oil ingress. However, if it is deemed essential to enter the tank for any reason, such entry must be carried out in accordance with Section 11.4.4. The entry, which must be carefully planned and controlled, should be made by people trained and experienced in the use of self-contained breathing apparatus, who should have two independent sources of air available to them.

4.11.6 Inerting double hull spaces
If the decision is taken to inert a leaking double hull tank, the operation should be carried out in accordance with the guidelines contained in this section.

The complexity of the structure in double hull and double bottom tanks makes them more difficult to inert than conventional tanks. It is strongly recommended that the operator use these guidelines as a basis for developing procedures relating to the inerting of such tanks.

Whenever possible these procedures should be developed in conjunction with the shipbuilder and should be based on actual tests/experiments as well as on calculation. They should give details for each tank

- The procedures to be followed.
- The equipment to be used and its configuration.
- The time required to reduce the oxygen level in the tank to less than 8% by volume.

Where tanks are identical in structure and size, and where the method of inerting is identical, the data can be obtained from tests on a representative tank. Otherwise the tests referred to above should be carried out for each tank.

The introduction of inert gas into a tank may give rise to electrostatic charging. The compartmentalised structure of the tanks means that this charge is unlikely to reach incendive levels. However, because there may be a flammable atmosphere in certain areas within the tank it is essential that all electrostatic precautions are complied with throughout the inerting process and for 30 minutes thereafter.

Flexible hoses used for inerting double hull tanks should be clearly identified, be dedicated solely to this use, and stowed safely and correctly. The hose string should be electrically continuous, and this should be verified prior to putting hoses into service. It should be confirmed that the string is properly earthed before inerting commences.

In order to minimise the transfer of hydrocarbon vapour from cargo tanks all cargo tank inert gas supply valves, where fitted, should be temporarily closed. Prior to connecting the hoses the inert gas line should be purged with inert gas. The hoses should not be connected until required.
Once the tank has been inerted, consideration should be given to the benefits of keeping it permanently connected to the inert gas system - constant pressure monitoring, over pressure protection via the deck water breaker, ease of topping up - against any potential problems of vapour transfer, vulnerability of the hose to heavy seas etc. If the hoses remain connected then all the cargo tank inert gas inlet valves must be re-opened. If the hoses are disconnected the inert gas system must be returned to its original status.

If cargo is to be transferred from a space which has been inerted, it is important to ensure that further inerting is carried out during the operation in order to avoid the introduction of oxygen into the tank.

Once inerted the tank should be kept topped up as necessary to ensure that a positive pressure is maintained and the oxygen content does not exceed 8% by volume.

The exhaust vapour from the tank during inerting should be ventilated through an opening at least 2 metres above the deck. Portable stand pipes should be used where necessary.

The progress of inerting can be monitored by measuring the oxygen content of the exhaust vapour. However, atmosphere measurements to determine when the tank is fully inert, and subsequent monitoring measurements, must be taken at all designated sampling points with the inert gas supply secured.

4.11.7 **Gas freeing and tank entry after inerting**

The complex internal structure of the double hull tanks means that, before the entry of personnel can be considered, particular care must be taken when gas freeing the tanks after they have been inerted, in order to ensure that there are no pockets of inert gas or hydrocarbon gas anywhere within the tank.

Where the tank ventilation system may have been modified it must be returned to its original status before commencing any operations.

A method of removing all inert gas vapors from the tanks is to fill the tank with ballast and then empty it, but this should not be relied on to produce a gas free atmosphere. Every effort should be made, taking account of stress, trim and loadline factors, to carry out this operation as the initial stage of the gas freeing operation. However it must always be borne in mind that this ballast may be dirty ballast which must be handled in accordance with the MARPOL regulations. When ballasting the tank it should not be allowed to overflow on to the deck.

(Note: Although filling the tank with water is an efficient method of gas freeing, consideration should be given to the fact that the operation may result in spreading oil onto the tank structure, thereby making the subsequent cleaning operation more difficult.)

Prior to any venting operation, in order to ensure that the atmosphere in the tank will not enter the flammable range, the tank should be purged with inert gas to reduce the average hydrocarbon content to less than 2% by volume. Readings should be taken at all sampling points.

Because of the additional hazard posed by the possible presence of inert gas the initial entry for atmosphere verification must be carefully planned in advance and should be the subject of
its own specific entry permit. Those making the entry should be equipped with emergency escape respiratory protection or self-contained breathing apparatus as appropriate, and personal gas detectors. They should proceed through the tank compartments in accordance with the pre-planned sequence, verifying and reporting the atmosphere in each compartment prior to proceeding to the next compartment. Only when the entire tank has been systematically examined and verified to be free of inert gas should general entry be permitted. The cargo tank from which the leak originated must also be gas freed prior to entry into the double hull space.
5. ENVIRONMENT AND POLLUTION

5.1 HISTORY
Pollution is not a problem recently discovered. When people settled down in small towns and gathered in communities they experienced, as time went by, the difficulties in getting rid of garbage and so on. Civilisations dumped all sorts of waist; garbage, dead animals and so on, in open ditches just outside the small towns. This can be directly connected to large epidemics and disasters, which have arisen during different époques throughout history.

Around year 1800, the first attempts were made to make simple constructions of drain arrangements and some kind of garbage removal arrangements. During this period of time the rate of illness and disease showed to be higher in the crowded small towns compared to the countryside. When the Industrial Revolution ended - large crowds of people gathered in proportionately small areas. The local environment was extremely loaded because of this. The development of new substances and materials increased rapidly - and lack of knowledge concerning the effect and damages to the environment due to these new substances and so forth - led to free flow of the new substances both into the sea and the air.

In some cases, both cause and result of these uncontrolled outlets almost immediately appeared. Even today, the reasons for these damaging effects on the environment are questioned. In later years, people really have become aware of the environmental effects this pollution causes. A media focus on oil pollution disasters, industrial leakage, and so on, has contributed to the development of very strict regulations and demands to preserve security that protects us from environmental pollution. However, there is still a long way to go.

5.2 EFFECTS ON ECOLOGY

5.2.1 Pollution in general and its effect on Ecology
Note that pollution is usually related to human activity. Phenomena, such as radiation due to natural radioactivity in the earth, volcano eruptions and the like, are not usually considered as pollution. They exist, however, in areas where the environment is burdened. This is nature’s own way to balance and renew itself.

Any pollution has a main source and a receiver. The main receivers are air, sea, and soil. The most effective way of spreading pollution is through air. But eventually the pollution always falls to the ground and into the sea. The earth is most resistant to pollution as a receiver, but the problems appear because this pollution almost without restrictions has free flow to pollute sea and waters. Compare the human body with its own immune system to the environmental system (Eco-system), and you will find that all basic “building blocks” are linked together in some way or another with the same influence and with the same purpose. Every part is equally important in obtaining the ability to function as a whole unit.
**Definition of pollution:** *Substances and materials spread through air - sea - and soil which cause damage and malfunction due to human activity.*

Many factors contribute to pollution, such as the chemical, physiological or biological characteristics. Life on earth is dependent on solar energy. Plants turn solar energy, water and carbon into plant tissues. This is called the first trophic level. The herbivores (vegetable-only eating animals) cannot exploit solar light directly in their growth or tissue change. Herbivores use the plants to produce tissue. This is called the second trophic level. The energy loss caused by transmission from the first level to the second level is calculated to be at approximately 90%. An even greater loss appears at the next level, which is the third trophic level. This level includes the humans and the animals, which survive by eating animal meat. The demolishing link in this process is the carrion eaters and small organisms, which demolish dead plants and animal materials into simple organic and inorganic compounds, which the plants need to grow.

An Ecology System appears as a result of developing and adapting to each other as a species in nature throughout millions of years. Accurate balance and stability is obtained and smoothly functioning. This system is an everlasting process and is continuous throughout time and space. An Ecology System can endure huge changes and variations in nature, but faced with artificial factors and synthetic substances spread by human actions, important parts (areas) in this process can be demolished. The reason is simply that no natural mechanism exists to keep the process active and in balance. In numerous cases, these unwanted non-natural substances are spread throughout the nature process-creating disharmony and malfunctions both geographically and ecologically.

**5.3 Heavy Metals and its Influence in Nature:**

Heavy metals are basic elements. These elements exist in some relation or another in nature, and further on in raw materials used by Industry. Some of the most polluting heavy metals are lead, quicksilver, cadmium, nickel and vanadium. Heavy metals are supplied to water, partly by natural flow, through human activity, through the atmosphere, directly to water and spreading on the ground. These heavy metals affect not only single organisms, but also the Ecology System using their ability to function with the other organisms to obtain and keep harmony and balance. Therefore pollution of heavy metals can influence and lead to direct malfunctioning and cause changes in the composition of a species. This creates disharmony in the Eco-system.

Natural, clean and nutrient-rich water demonstrates a well-adjusted and balanced Ecology System.

**5.4 Pollution of Air & Sea and the Influence of Ship Trade**

**5.4.1 View of the most important air pollution:**

Burning sulphurous fossil fuel forms sulphur-dioxides and compounds of this gas. The gas responds to air and transforms into sulphur acid.

Nitrogen oxides are also formed by combustion of fossil fuel, and release nitrogen mono oxides, which again transforms into nitric acid and nitrogen oxides.

Carbon mono oxides formed by uncompleted consumption of organic material can further react to air and transform into carbon dioxide.
Further, a number of gases are released with the gas freeing of cargo tanks and cooling plant. These are CFC – gases (chlorous fluor carbons). Carbon dioxide and CFC - gases function as a glass roof in a hothouse, the heat radiation from the sun is easily received and is harder to let go. This is the hothouse effect in a nutshell.

Sulphur and nitrogen oxides in outlets (pollution) cause huge destruction of soil and sea. The consequences of this are recognised in areas where the forest is dead and fishing lakes are empty.

Below is a bird, which represents just one of the many members of nature, well worth fighting for. Protect and preserve all parts of our Ecology System.

Below are some figures, which show the outlet/pollution from internal combustion engines in the Norwegian coasting trade.

In accordance to the investigations performed by the Governmental Pollution Inspection and representative figures were presented in 1985:

<table>
<thead>
<tr>
<th>Air pollution</th>
<th>Chemical names</th>
<th>Amount in 1000 tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen oxides</td>
<td>NO&lt;sub&gt;x&lt;/sub&gt;</td>
<td>85,5</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>CO</td>
<td>11,75</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>SO&lt;sub&gt;2&lt;/sub&gt;</td>
<td>12,57</td>
</tr>
<tr>
<td>Hydro carbons</td>
<td>HC</td>
<td>7,59</td>
</tr>
<tr>
<td>Various particles</td>
<td></td>
<td>1,35</td>
</tr>
</tbody>
</table>

The figures in this investigation represent only Norway and its coasting trade.

The following shows the consumption of fuel in domestic waters:

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marine Fuel</td>
<td>514 000</td>
</tr>
<tr>
<td>Heavy Fuel</td>
<td>163 000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>677 000</strong></td>
</tr>
</tbody>
</table>

The average sulphur content in different bunker types:

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>kg/mt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline</td>
<td>0,1</td>
</tr>
<tr>
<td>Marine Fuel</td>
<td>5,4</td>
</tr>
<tr>
<td>Heavy Fuel</td>
<td>43,7</td>
</tr>
<tr>
<td>Heavy Fuel in the fishing trade</td>
<td>44,0</td>
</tr>
</tbody>
</table>
The outlet of NOx from the coasting trade represents 45% of the outlet from the mobile sources and 38% of the total outlets/pollution in Norway.

What can be done to reduce the outlet from machines?
Through International Conventions, Norway made a commitment to reduce the outlets of nitrogen oxides by 30% within the year 1998. The Norwegian domestic trade represents approximately 40% of our total outlet. In order to reduce outlet along the Norwegian coastline, efforts in following areas were made:
- Engine technical methods, which concern construction improvements of engines and the engine equipment.
- Fuel technical methods as a use of alternative fuel and higher graded demands to the compounds of the fuel.
- Purifying technical methods as catalyzer and absorbents.
- Other technical methods as better shaped hulls and alternative propulsion systems.

5.5 POSITIVE ENVIRONMENTAL PROPULSION
In all these fields with intense investigation, new solutions in future engines and maximisation of already existing engine types is put in priority.
Concerning economical views, the investigation has shown increase in costs calculated to be 0.1% - 0.9% regarding the cargo trade, when the actual reducing actions are executed.

5.6 WATER POLLUTION:
The total pollution from the fleet world-wide is enormous and represents one of the greatest threats to the environment today. The world’s great oceans are continuously exposed to pollution. This causes tragic consequences to animals, fish and all life at sea. The consequences for mankind will be just as tragic, unless this development is reversed. The Ocean has, is and will always be an important food supply and reservoir for human life. If life at sea comes to an end, this will of course lead to the increase in lack of food and then starvation for millions of people. Various species are threatened of extension as a result of the pollution.

The most “significant” oil disasters caused by oil tankers that caused damages and destruction of coastlines and the oceans are: “Tory Canyon” (Southern England 1967), “Amoco Cadiz” (Normandy 1978) and the “Exxon Valdez” (Alaska 1989). These disasters influenced the public opinion and led to new laws and regulations. The last mentioned accident was the direct event leading to new strict American regulations, OPA.
5.7 OPA90

5.7.1 The American “Oil Pollution Act of 1990”.
In USA, the accidents involving “The Exxon Valdez” and “Mega Borg” were in focus and were well covered by the media and press, which influenced public opinion. This resulted in the OPA90. The media distributed pictures of the rich animal life and the magnificent coastline in Alaska covered with oil and showing the suffering of dying seals and seabirds. This presentation made a strong impression, which made the U.S. Congress realise that the existing International Conventions had to be reviewed and bettered, in order to protect and take care of the American interests. American lawyers developed the OPA90 and the Congress supported the proposed Act.

The Main Items In OPA90:
1. The threat of unlimited responsibility.
2. Demand of double hull.
3. Direct access to the means in P & I - Companies, in case of indemnity due to accidents.
4. Higher graded demands meant for the crew regarding narcotics and alcohol testing.
5. Use of pilot in sensitive waters.

Entering American waters OPA requires drill (training) according to OPA90 regulations. The drill (training) should be logged and reported due to the ship owners/operators policy. OPA90 regulations are in force for all kind of ships.

5.8 MARPOL 73/78
The IMO Convention to prevent pollution from ships of 1973, with The Amendment Protocol of 1978 - came in force October 2nd, 1983. The Convention is named MARPOL 73/78 and is introduced in the Norwegian Shipping Control Regulations, section 21 (page 757 and in 1996 edition). This is the most important pollution agreement ever adapted and it has been of great significance contributing to pollution prevention regulations from ships.

MARPOL 73/78 consists of two parts

MARPOL-73, which is The International Convention about preventing ship-pollution. (Marine Pollution 73). TSPP-78, which is a 1978 Protocol to MARPOL -73 (Tanker Safety and Pollution Prevention 1978). The MARPOL Convention is extremely important to be familiar with. The Convention consists of 20 articles, 2 Protocols and 5 Enclosures: The 5 Enclosures are as follows:
Enclosure I - Oils
Enclosure II - Chemicals
Enclosure III - Damaging elements in wrapped form, barrels, tanks, containers and so on.
Enclosure IV - Sewer
Enclosure V - Garbage

MARPOL 73/78 - Enclosure I (Oils). The following information referred to is from MARPOL 73/78, enclosure I:

5.8.1 Discharging criteria
The amount of oil pumped from an oil tanker on a ballast voyage in open sea, is set to be 1/30 000 of the loading capacity for all “new ships” (ships contracted later than 31.12 1975 or delivered later than 31.12 1979).
Ships older than these can pump as much as 1/15 000 of the loading capacity.
Nevertheless - no rule allows discharging more than 30 litres pr. nautical mile during the voyage.
Several exceptions exist other than the before mentioned dates, but it is too extensive to view in this text. In the MARPOL regulations 73/78, which should be on board all ships, you can find a complete definition of what “new” and “old” ships are.
As mentioned before a “new” ship of 200 000 dwt could legally discharge a total of (200 000 : 30 000) = 6,67 tons of oil during a ballast voyage- if a maximum limit 30 litres pr nautical mile is in compliance.

5.8.2 Special Areas
In respect for the maritime environment, there are some areas regarding Prohibition Law for Oil Pollution.
These areas include among others, the Eastern Sea, the Mediterranean, the Black Sea, the Persian Gulf and the Red Sea and have the definition as follows:
“The Baltic Sea” area means the Baltic Sea proper with Gulf of Bothnia, the Gulf of Finland and the entrance to the Baltic Sea bounded by the parallel of the Skaw in the Skagerrak at N57° 44,8’.
“The Mediterranean Sea” means the Mediterranean Sea proper including the gulf s and seas therein with the boundary between the Mediterranean and the Black Sea constituted by the N41° parallel and bounded to the west by the Straits of Gibraltar at the meridian of W5° 36’.
“The Black Sea” area means the Black Sea proper with the boundary between the Mediterranean and the Black Sea constituted by the parallel N41°.
“The Gulfs” area means the sea area located north west of the rhombi line between Ras al Hadd (N22° 30’, E059° 48’) and Ras al Fasteh (N25° 04’, E061’).
“The Red Sea” area means the Red Sea proper including the Gulfs of Suez and Aqaba bounded at the south by the rhombi line between Ras si Ane (N12° 08,5’, E043° 19,6’) and Husn Murad (N12° 40,4’, E043° 30,2’).
The definition of clean water means a content of maximum 15 ppm (parts pr. million) of a mixture consisting of water/oil. This “clean water” can be pumped over board - even in these so-called special areas.

Oil tankers should be equipped to load a new cargo on top of the saved oil deposits after tank washing and so forth. The system is known as LOT, Load On Top. See section “Load on Top”, part 5, chapter 1, page 7.

5.9 AIR POLLUTION

IMO agrees to the commitment of air pollution regulations for ships, but not the stringent demands of the rules. Norway, for instance, has the attitude that the presented environment regulations allow for too large sulphur outlets. After seven years of negotiations, IMO probably will adapt regulations concerning pollution from ships in the autumn 1997. The dispute will concentrate on how restricted these regulations will be. This will mainly concern the introduction of upper limits in the sulphur content in bunkers. Sulphur contributes to acid rain. A limit of 5 % has been proposed and Norway has proposed a limit of 3,5 %. An analysis done by DnV proves that bunkers for sale world-wide contain hardly more than 4,2 % sulphur. Average level is 2,7 % sulphur. Norwegian dealers believe realistic limits to be around 4%.

During the negotiations the Baltic countries suggested that the Baltic should be a special area and should have even stronger demands and regulations to sulphur pollution than these presented by IMO regulations. The same proposition will be requested concerning the Northern Sea area. Here, the sulphur limits in air is suggested set to 1,5 %. The ship owners will then have the opportunity to select for themselves what type of oil to use that contains low sulphur values or rinse purifiers for the outlet of sulphur. The NOx pollution will be evaluated in this conference as well. Even if IMO in autumn should vote for enforcing pollution regulations, it will still be an open question when these regulations will be set in force. The term for this to happen is one of the disagreements yet to be resolved. Keep yourself updated in this field concerning air pollution and the regulations in force in the nearest future!

5.10 TANK WASHING WITH CRUDE OIL

All new crude oil tankers (20 000 dwt or more) and already existing ships (ships delivered before 1.6. 1982 with 40 000 dwt or more) have to be supplied with crude oil washing equipment, described as COW (crude oil washing). Existing ships between 20 000 dwt and 40 000 dwt do not need to have this washing equipment, but should have inert gas equipment for use in cargo tanks during operations. These demands are noted in the MARPOL protocol of 1978 to MARPOL 73/78 and are useful in reducing oil pollution at sea.

The National Governments have the obligation to put this in force and check that the regulations presented by IMO are in compliance. The Norwegian Maritime Directorate will perform inspection on the Norwegian trading fleet to control that these regulations are executed. When it comes to COW, classification companies are elected to evaluate the documentation and reports after inspection and testing of the equipment on board. See COW under part 10 in the compendium.

5.11 ODME

On board all ships carrying oil there are demands for the installation of Oil Detection Monitoring Equipment that will survey all pumping of ballast and slop water over board. The equipment is simply described:
An analysis instrument, which analyses the content of oil in the ballast water before pumping it over board.
A control unit that calculates the received information and records this on a printer.
A sampling pipe from the high over board line.
A flow meter on the high over board line.

To operate the ODME some information has to be manually programmed. This is the ship’s speed, flow rate, year, month, day and time. Study this manual for the specific ship and note that the manual must to be available at all times.

5.12 BALLAST HANDLING

Ships constructed for SBT (segregated ballast tanks) have the advantage of already minimised oil pollution. Ships without SBT have CBT (clean ballast tanks) where the cargo tanks are used both for departure and arrival ballast. IMO’s regulations on the tanks used for departure and arrival ballast state that the tanks must be crude oil washed. (COW).

Before arrival at discharging port, a discharging plan including crude oil washing should be worked out and it should also contain departure condition that shows the loaded departure ballast. The amount, the quantity and where the departure ballast is placed are viewed in part 10 in the compendium. This departure ballast is called dirty ballast.

After departure and in waters allowing water washing of tanks used for arrival ballast, this washing operation should be executed according to regulations in force. Arrival ballast tanks must be crude oil washed beforehand according to the regulations in force. This procedure is done at the last discharging port. The water washing is performed using the specialised washing system on board meant for crude oil washing - the only difference is that the medium now is water.

Set pressure on the line system with water from the sea, and via crude oil washing machines, arrival ballast tanks are water washed. Supplied water is stripped from the actual tank and into the primary slop tank. Via the balance line, the liquid is transferred over to the secondary slop tank, and further the separated water is pumped over board via ODME.

To finish water washing of arrival ballast tanks lines and pumps are thoroughly washed. Here the same washing procedure from primary to secondary slop tank is performed and pumped over board via ODME. Now it is time to change ballast. In other words, clean ballast should be pumped in arrival ballast tanks, while dirty ballast should be pumped out from departure ballast tanks. The dirty ballast is pumped over board via ODME.

The last oil deposits are stripped into the primary slop tank and after a settling time (when oil and water separates completely), the clean water is pumped over board via ODME. At last the secondary slop tank is pumped into the primary slop tank. This way the ship arrives at the loading port with slop in one of the slop tanks. This saved slop contains the oil deposits from stripping and water washing and the load on top. This is available if it is requested from the charter.

This is specified in the charter party for the present voyage. Note: The line system has to be properly cleaned before arriving at the loading port, where the clean ballast is pumped over board.

When the ballast changing, line washing and slop handling is completed, the ship contains only the arrival ballast. The arrival ballast is the so-called “clan water”, which is a mixture of water/oil containing a maximum of 15 ppm. This arrival ballast is pumped over board via ODME.
5.13 THE OIL RECORD BOOK-

This is an extremely important book and must be recorded with accuracy, in order to comply with the regulations in force. All ships should have one oil record book or more in order to record operations, which involve pumping, transferring, ballast handling, bunkers, slop handling, any kind of cargo handling what so ever. All items mentioned must be recorded in the oil record book.

The oil record book must be available at all times to show authorities when arriving at any ports. Remember to keep this book updated and in necessary order at all times.

Be environmentally conscious in all aspects on board.
6 FIRE-FIGHTING IN GENERAL

There are two conventions in particular that deals with safety at sea. One is the “International Convention on Load Line, 1996, that was adopted at an IMO conference in 1996. The other is the “International Convention for the Safety of Life at Sea” as Amended/SOLAS 1974. This international convention was signed in London on the 1st November 1974. 68 states were at this conference, where the purpose was to come to a decision, as quickly as possible. Both conventions are valid in Norway and are included in the required inspection of ships. The Safety convention and all rules are in the “SOLAS 1974” with supplement 1 and 2 were translated to Norwegian. It is this convention that establishes fire-fighting arrangements etc., with which we have to comply.

The Safety convention is a comprehensive convention that intervenes in many areas regarding safety of human life at sea. It starts with the construction of the ship to maintain as high level of safety as possible due to divisions, stability of the machinery and electrical installations. There are detailed rules for fire, protection, fire discovery and fire extinguishing and of life saving equipment.

In addition to “SOLAS 1974”, national authority and classification companies will include further requirements of equipment and arrangements.

There are regulations to consider, international as well as national. We will, in particular, study what involves oil tanker and gas tankers in this part of the compendium.
6.1 MANAGEMENT TASKS & TACTICS - FIRE EMERGENCY PREPAREDNESS

Fire Emergency preparedness onboard is comprised of the following:
- Sufficient and adequate equipment.
- Organisation and management.
- Training and practice.

Organisation and management are essential factors, which deserves a great deal of attention. The leader of the fire fighting must, in any case, consider the situation and depending on a number of circumstances, execute adequate initiatives. The leader of the fire fighting should be able to take care of his/her responsibilities in the best possible way. Essential to this, training and practice must be fulfilled.

Fire onboard - Management’s duty: A fire burst onboard represents a threatening and critical situation. To prevent disaster, a quick and determined effort from the whole crew on board is needed.

For most of the people, fire is an unfamiliar event and it is therefore natural that such a threatening occurrence can lead to unpremeditated actions and panicky contributions to the situation.

When this happens, it is the management’s first duty to, as soon as possible, activate the different teams in accordance with the fire instruction plan. Fire resistance arrangements onboard the specific vessel should be utilised to the fullest extent.

If a fire should occur, the management will be confronted with a lot of problems that all seem to be equal in importance. It is important to prioritise when dispersing the tasks. This means that those tasks that seem to be most important must be delegated to the most competent unit or team in the emergency squad. The squad will have to do their best to solve the problems in a satisfactory way. In many cases, the first decisions must be made based on few and uncertain pieces of information about the situation. Any hesitation from the management about which approach to use, will promote the feeling of fear and insecurity among the crew.

Since the crew has been trained in relevant practical skills, the management must also be prepared and trained for the problems they are expected to solve. The ship’s fire instructions
must be considered as a tool. The benefit and effect that this tool will give depends on how
the management decides to utilise it.
There is nothing that can really replace the valuable experiences you will get by managing
extinguishing operations in real fire situations onboard. As this, of course, is practically
impossible to accomplish as part of a training programme, other methods have to be tried out.
Typically the standby crew (e.g. fire brigade, first aid teams, civil defence) will need to make
quick decisions and judgements of the situation. This type of responsibility requires special
training. Imagine a situation and try to picture the conditions and based on that try to find out
how you can, as best as possible, use the resources you have available. This is one way to
manage a situation. However, you have to be aware that in a real situation, the approach to
the problem can not be changed to fit your own perception.
By using similar methods onboard, consider imagined fire situations and at leisure find out
how to handle the situations, so that the management of the ship can prepare their fire
fighting duties. Even though you have worked through a lot of imagined situations, and one
day there is a fire, there will never be a situation similar in detail to one of the imagined
situations. On the other hand there will most likely be a situation similar to something you
had been through before. In any case you will be better prepared, at least mentally, to
manage the situation.

6.1.1 Plans of Action
The more people know the main guidelines for fire fighting situations onboard each particular
ship, the better the chance for a successful response. Therefore it is of urgent importance that
the management group (The Captain, The Chief Engineer and The Chief Officer) is fully
aware of the existing plans. When considering these imagined situations where you find the
best solutions, several point of views will improve the plans.
The management group together should work out the plans for the actions for different kinds
of fire situations. Therefore, the managers will be informed about the plans, which will make
it easier for them to manage accordingly.
In hectic situations, as a fire, it will be easier to change an existing plan rather than making a
new plan from scratch. The plan will be easier to execute, if more people know about its
contents.
If training is arranged according to appointed plans, the crew will get familiar with the plans
in addition to variations in training. Realistic and well-planned training exercises are good
practice, as well as, it is interesting and instructive. Successful fire fighting is a result of
good planning, good leadership and a well-trained standby crew.
6.1.2 Tactics

By tactics we really mean line of action. It is a calculated way to act out a plan of action where we want to use the crew available, in such a way that maximises the effect achieved. The intention with tactics is to reach the goal you have set. You have to be aware of what you want, what is the result you aim for. In a fire situation, it should be easy to conclude that you want to extinguish the fire, as soon as possible, with as little mess as possible, without any risks to the fire fighters.

6.1.3 Select an Action

When planning a line of action, choose tactics, try to clarify the situation first (reconnoitre). The more details you know about the situation, the easier it is to evaluate the situation. In a critical situation, decisions have to be made quickly. The next step in the planning process will be the evaluation of the situation. Based on the information known, you have to try to determine how the fire will grow. Here it is important to prioritise, as there could be parts of the fire that has to be stopped no matter what. Meanwhile, other things have to be held off, as long as possible. There are may be some parts that can be temporarily disregarded. With the evaluation of the situation as a basis the disposals of resources are being made. The extents of the contribution depends on how important the effort is, how demanding the work to be done is, and how quickly it has to be effectuated. You should always be prepared to change tactics if unforeseen difficulties occur. Well-prepared tactics considers all known factors whether there are only a few, or many and detailed at any stage.

6.1.4 Conditions for actions

One condition for actions is that you have resources available. The following estimate can be put up to show the connections in an action of extinguishing onboard:

Personnel + Officers = Crew.
Equipment + technical arrangements = Material/Force.
Training + Practice = Techn./resources.
Reconnoitre + Evaluate situation + disposal = Tactics/action.
Instructions + communications = Management/effect.

A crew organised in fire protection and with sufficient and adequate equipment forms the force. To be able to perform their duties, the force has to master the necessary skills.
Technique is to use the equipment in such a way that a maximum effect is achieved. Extinguishing technique covers the correct use and handling of the particular parts of the extinguisher equipment and the fire technical installations. This also includes practical skills, methods of practice and routines, knowledge of how the particular equipment works, effect, capacity and limitations.

6.1.5 Extinguishing Tactics

Extinguishing tactics make use of resources available so that maximum effect in an action is achieved. It also makes a sufficient effort at the right place at the critical moment. Offensive tactics is a well-known expression, it means that you will use all resources in the fight to win back the terrain and to get the situation under control. Defense tactics are when you use the whole force to last as long as possible to prevent being forced to back out, avoid loss of terrain, try to hold the position, as long as possible, while waiting for backup. In the following, you will find some situations listed where you will have to consider the influence these situations have on the actions to be taken.

6.1.6 The site of the fire

It might be difficult to get access to the site of the fire, as well as it might be unjustifiable to send people in there. Alternative extinguishing methods might cause large damage to the environment. The risk of loosing lives should be considered more important than avoiding a large loss of materials.

6.1.7 The extent of the fire

The extent of the fire can be so large that the possibilities for extinguishing with available equipment are small. An extinguishing effort with the capacity available might reduce the opportunity to successful back out.

6.1.8 Force available

A well-trained force, which is familiar with the use of the equipment and the facilities, will be an advantage in a difficult situation.

6.1.9 Mobility

A well-trained force, which can quickly attack the fire, has a greater chance for success. Communication

It is very important to have a good communication because it will make it easier to manage the operation. The force can easily be re-directed and there is a quicker determination of how the situation is developing.

6.1.10 What is on fire?

There may be combustibles in the fire zone that can produce poisonous gases when heated. Fire fighters must be well protected.

We will further mention other situations, such as where and in which directions the fire can spread, changing the ship’s course to achieve the best possible conditions, the fire-technical
arrangements intact, element of risk in the fire zone, e.g. oil tanks, transportable gas holders, chemicals etc.

6.2 FIRE PREPAREDNESS

Fire preparedness is the capability the crew has to fight a fire with the help of the equipment available on board. To manage a fire situation, preparedness promotional efforts are done. Fire preparedness is the result of a number of arrangements and different efforts, for example fire protection organization, strategic placing of equipment, instructions, maintenance of equipment, training, exercise. Remember the preparedness is not stronger than the weakest link.

Practical (technical) exercises are meant as a test to see if the crew has the necessary skills. The exercises are also designed to train in the skill of being prepared. Tactical exercises will reveal the management’s capability to evaluate situations and delegate the right effort at the right time. The practical and technical skills together will contribute to an effective force. It is therefore very important that realistic and varying exercises are exercised on board. The technical will cover the quality of the “tool” at disposal, while the tactical will cover what capability one has to utilize the strength at his disposal.

6.2.1 Alarm instructions

Central part of fire preparedness on board is the safety plan’s part on the fire fighting organization. The ship’s alarm instructions provide the emergency plan if there is a need for a united and systematic effort of the crew. Main features in the emergency plan should include special distribution of the crew, duties when fire fighting, plus another special distribution, if preparations for abandon the ship become a reality. All emergency plans organize the crew into practical teams or units, plus instruct of the duties that everyone has when the organization is active. Emphasize the importance of knowing the alarm instructions well, on board your specific ship. There can also be other situations that can be covered by the preparedness organization, for example man-over-board, tank accident, and personal injury and helicopter preparedness.

6.2.2 Layout of the instructions

The layout of instructions for the individual team in the fire preparedness organization offers the same challenge as splitting up the crew into teams. At the outburst of fire, there are a number of duties to execute regardless of the site and situation of the fire’s location. For example: starting of auxiliary engine, starting the pump, set pressure on the fire lines, stop the fans, close ventilation to the fire area, switch off the electrical plant in the fire area, prepare for maneuvering, change course and speed, clarifying the extinguishing equipment etc.

The purpose of the instruction is to allow the first effort’s execution without waiting for special orders.

In connection with the distribution and the instructions for the individual units in the fire protection organization, there are a number of other instructions that needs attention:

1. - Instructions for the navigator on duty.
2. - Instructions for the engineer on duty.
3. - Instructions for the extinguishing leader.
4. - Instructions in utilizing the main extinguishing plant.
5. - Instructions for the officer on duty in port.
6. - Instructions for helicopter landing.
7. - Instructions for the person who detects fire.

All instructions must overlap one another so that all conditions are covered. The purpose with the instructions is to eliminate doubts of who does what. At the same time secure that what is being done is rational and in right time.

One can compare the fire protection organization to machinery with many wheels that all must overlap one another in such a way that the machinery is functioning. The instructions are the force that will run the machinery.

The symbol for teamwork characterizes a well drilled fire crew.

The individual links in the fire protection organization approach by the instructions on board. This is regarded to the captain, extinguishing leader, extinguishing team, technical team, engine room team, instruction for engineer on duty, bridge instruction, instruction for navigator on duty, radio station, security team, first aid team, life boat team, evacuation team, instruction for officer on duty in port.

In addition to instructions for the individual fire protection organization, there are also instructions for special situations. It is important for all those who will operate a CO₂ plant that they follow the instructions clearly and categorically, because before triggering of the plant can take place, it must be ascertained that no one is in the area that the plant covers. Get to know the fire alarm on board and follow your instructions when this sounds, and get to know the CO₂ alarm and follow the instructions. If the CO₂ alarm sounds, one should act as though the fire alarm has sounded, even before the fire alarm.
We will pay particular attention to the advice upon fire discovery, which gives all of the crew practical advice and directions of how to react if you are the person discovering the fire.

The principal points, in such an instruction, are:

- Immediately shout of alarm in order to call on more people.
- First try to extinguish the fire, provided this is possible and without risk.
- Close doors and try to prevent, as much as possible, an influx of air to the area.
- Try to inspect rooms nearby the fire area where personnel might be, that could be overwhelmed by smoke, or in bed.
- Realise the element of risk, such as toxic gas, explosions etc., and where escape equipment is possibly placed.
- Upon alarm the significance of all to show up at their post, as quickly as possible, to state if someone is missing. This will avoid time loss resulting from unnecessary searches. Be very strict in having all present at their post. Those who don’t show up are basically missing.
- If fire bursts out in port, immediately try to call the local fire department.
- Organise in the normal procedure to put fight the fire when there is fire in port.

Alarm instruction layout, crew distribution, layout and content of the special instructions will vary by the type and size of the ship, the number of crew members, extent of equipment, plus other relevant conditions. Common for all alarm instructions is the desire to, as much as possible, have a flexible preparedness plan that gives the possibility for all to contribute his best in the management of a number of different situations.

Some important guidelines:
- The entire force on board is available and able to be on the spot rapidly.
- Because of continuous duty, fire is detected at an early stage.
- Equipment and facilities are nearby.
- The area is restricted.
- Alter the course in favour of the fire fighting.
- The amount of equipment is limited.
- Mobilise maximum force immediately.
- The crew/force is naturally experienced with the surroundings.
- Simple checks if someone goes missing.
- The most flammable areas are covered by fixed fire fighting equipment.
- The retreat possibilities are very restricted.

When onboard during fire, it is similar to being “on the roof of the burning building”. The escape routes are limited and few. Because of the extraordinary conditions on board, limited
retreat possibilities and the great chance of blocking off the rescue units in a fire situation, it is natural that retreat route security and clarification of these routes has high priority. As the conditions on board are extremely special compared to ashore, the manager must treat the retreat as a very important point in his procedural duty. Further the manager must observe the four following main tasks:

1. - Rescuing life.
2. - Extinguishing fire.
3. - Restriction of fire.
4. - Executing the retreat.

### 6.2.3 Rescuing of life

In most cases, it is not direct contact with the fire that causes the loss of life. In a fire, smoke and the damaging gases that develop cause most deaths. As soon as someone is determined missing, the manager must be informed so a search can be carried out. Notice that this search involves risk for the rescue crew, plus it directly delays the extinguishing activity because of impaired capacity and conditions that may have vital importance to the outcome. It effects fire fighting and the security work drastically when a delay is caused by the search for personnel who not are in any danger. It is therefore an unalterable requirement that all the crew show up at their posts according to instruction, as quickly as possible, and that missing personnel are immediately revealed.

### 6.2.4 Extinguishing of fire

The faster the extinguishing activity is effectuated, the greater the chance of a successful result. In choosing an extinguishing method, quencher remedy and capacity, the goal must be total elimination. One must also consider the amount of damage the extinguishing agent will cause to the area. However, put out the fire before causing any larger damage. In some parts of the vessel, one can choose between permanently installed extinguishing equipment and manual efforts. On parts of the ship, a manual effort is the only alternative. Permanent equipment should be used in an area where the fire risk is large and has a large risk of spreading. Any manual combating involves a large risk for the extinguishing force. The decision about what to utilize in a specific situation must be well substantiated.

### 6.2.5 Securing the retreat

Due to the limited possibilities on board, it is natural upon securing the retreat will involve clarifying if is necessary to abandon the vessel. The fire may block the access to rescue units. In addition, it is very important that the psychological effect will influence all of the crew in the knowledge that the retreat is prepared and protected in case of ending the fire fighting.
6.3 FIRE FIGHTING PLANTS & FIRE FIGHTING REMEDY

6.3.1 Manual call point plant

Fire type, discovery and alarm equipment should be installed on vessels that are regulated by SOLAS. Approval type for these plants takes place according to a determined procedure by posting the plant’s documentation. This documentation should contain user instructions, procedures for routine testing on board, fault location procedures, power supply information, connection of detector loop, alarm organs, fan failure, door magnet, assembly work, function description, accordingly all requirements in accordance to the documentation claim. The plant is tested to determine if it fulfills the regulations required. The manual call point plant should at all times be according to the regulations in force. Some of the criteria follow:

- It should give optical and acoustic alarm at fire.
- It should indicate where fire breaks out.
- It allows for fault warning.
- The central unit automatically goes over to reserve power to supply upon voltage failure.
- Positive indication on the panel by interruption of functions.

Otherwise according to the approval companies, it is important to notice that the plant should have two independent power sources. If one “falls out” the other will operate the plant with full power. However, please refer to the regulations regarding complete approval.

6.3.2 Fire control draft

The fire control draft or as called on board; the “safety plan” illustrates the safety installations and equipment on board. The draft shows the vessel side wise and a sketch of each deck top wise. It indicates zones with isolated bulkheads and fire doors, manual call point plants with detectors, alarm buttons and alarm bells, the fixed main extinguishing plant and where on board these can be remote controlled. Valves to stop engines, machinery, and from where one can remote operate these are also indicated. It indicates where the ventilation plant with fans, ducts and damper is and from where one can stop the plant. All portable extinguishing equipment, protection equipment and utility equipment appear on the draft, and where on the vessel the equipment is kept. It also displays all decks, rooms, and all emergency exits. Symbols for marking equipment are utilised to make the draft well arranged. Also, on the draft is a list with an explanation of the different symbol. Colouring is often utilised to keep the symbols apart. This draft is available for all on board. To effectively utilise the different fire technical installations, thorough knowledge of the individual plants is required, plus how to use them.

The gangway during the port stay should keep a copy of the safety plan. If anything occurs during the stay and local help is required, the local fire department can quickly approach the plan, and from an early stage, have knowledge of the preparedness plan. All are advised to thoroughly study the “safety plan” in detail.
6.3.3 Fire pumps

A fire pump in the engine room is connected to the fire pipeline network. In addition, there is a separate fixed emergency fire pump installed in a distance from the engine room. One can either operate the emergency fire pump by its own diesel engine; it can be hydraulically driven or electrically driven by power from the emergency power unit. Oil, for at least 12 hours of running power, is kept nearby the emergency pump, in addition to oil for the fuel tank itself in case it a should be filled at any time. Fire pumps, which are able to produce more pressure than the pipeline network is designed for, are at all times equipped with a safety valve. All centrifugal pumps, for instance, are supplied with non-return valves.

6.3.4 Fire pipeline network

The fire pipeline network branches all over the vessel and has a number of hydrants - hose connections with valves. The pipeline network is divided into sections with a cross over, arranged in a way that if damage occurs on a part of the system, the damaged part is shut off without shutting off the entire pipeline network. Properly study the pipeline network on board to understand how the network is divided, plus where the shut-off valves are placed. If parts of the network are damaged, it is possible to bypass the damaged part by help of hoses from hydrant to hydrant. Hydrants are placed such that two water jets at the same time can reach any part of the vessel, one jet from a hose length, the other from two hose lengths. On the main line of the tank area there should be one shut-off valve for each 40 metres. This is, of course, fitted to the size and type of the vessel.

6.3.5 Foam in general

A system consisting of gas or air bubbles bound in a water coating (membrane), is called foam. Constant foam is when the wall/membrane consists of a constant material, such as
pumice stone, gas concrete and foam rubber are examples of constant foam. When the wall has a coating, we are talking about floating foam, such as soapsuds. Different types of floating foams are used for fire extinguishing.

6.3.6 Producing foam

In order to produce foam that will extinguish fire, you need: water, a frothing material that dissolves in water in anatomised condition, and a non-flammable gas mixed with a solvent. The foam is shaped when gas/air is mixed into the foam/frothing liquid and into the water by help of mechanical equipment. The result is mechanic foam.

6.3.7 Mechanical foam

Different types of foam pumps, foam sprinklers and foam pipes are used. The foam liquid is dissolved (or emulsified) in the water. After this, the air is mixed in by mechanical means. Normal equipment produces bubbles, which have a diameter of 0,1mm to 1,5mm.

6.3.8 Extinguish effect

Foam has a suffocating effect and acts as a cooling extinguishing agent. The suffocating or the cooling effect can be more or less the dominating effect, but depends on what material is burning and what sort of foam is used. By extinguishing a burning liquid with a surface temperature higher than +100° C, the cooling effect is the dominating force. This is caused by evaporation of the liquid that penetrates into the surface’s layer of the burning material as the foam collapses.
By extinguishing fire when the temperature in the surface is below +100°C, the extinguishing effect is connected with the heat-insulating foam and, above all, a differentiation effect. When the foam cover has spread outward across the liquid’s surface, the heat rays from other, still burning parts of the liquid surface, is not able to penetrate through the area covered with foam. Therefore, combustible gases are no longer formed, evaporation ceases and the fire dies out.

6.3.9 Foam plant

Foam is chosen as the main extinguishing agent for the tank area. A foam plant consists of a foam central unit with a foam tank, foam pump that is also connected to an emergency generator, distribution manifold, foam jets, automatic valves, and a pipe system connected to fixed monitors on the tank deck. The capacity of the plant should be big enough that the whole tank area could be covered with foam. If the vessel has an inert gas plant, the foam capacity must have a volume that can deliver foam for a minimum of 20 minutes. The demand is at a minimum of 30 minutes if the ship is not equipped with inert gas plant.

The main foam line from the foam central unit to the monitors should contain shut-off valves within determined requirements, in order to bind the line in case of damage. The foam line going to each monitor has a delivery valve installed to supply foam. The valve can also be used to regulate the amount of foam supplied in order to achieve the right mixture condition between foam and water.

A foam jet pipe is attached to the monitors. Study the plant installed on your vessel, and understand how this plan is operated. This equipment (the foam plant) is obligatory for oil tankers.

Mobile foam equipment is also available on many vessels. This consists of a fire hose with a foam nozzle unit, small foam containers (20 litre), a foam ejector, a small hose for the transmission of foam from a foam container to a foam hose pipe, and protection equipment. This equipment is prepared for use with fire hoses and a foam nozzle unit connected to the fire line. A foam ejector with a tap for supplying foam liquid is installed between the fire hose and foam nozzle unit. Water pressure is established, foam liquid is sucked (ejector function) from the foam container via hose connection between the foam container and ejector.
6.4 CO₂ - PLANT

The engine room and pump room are protected with a bar plant that utilises CO₂ as an extinguishing agent. CO₂ (carbon dioxide) is a colourless, non toxic, scentless, corrosion free, non-electrical leading gas with qualities that extinguish fire quickly and effectively with a recommended gas concentration, which does not damage electronic equipment and requires no clearing/cleaning after use.

CO₂ plants are delivered either as a “Total Flooding System”, where the entire room is filled with gas, or as “Object Protection”, where a part of the room is filled with gas. The room on vessels with “Total Flooding System” is filled with a CO₂ -content corresponding to 40 % by volume, that is 0.72 kg/m³ with gas.

CO₂ plants consist of CO₂ cylinders with valves, a cylinder rack, releasing mechanism, accumulating manifold, pipe system and jet.

6.4.1 Extinguishing effect

CO₂ has a suffocating extinguishing effect in that the oxygen content in the air is reduced to the point where combustion become impossible. Familiarise yourself with your vessel’s plant.

6.4.2 Choosing extinguishing agents

If an active extinguishing method is chosen, the extinguishing agent must be properly suited for the actual situation. The extinguishing agent should:
- extinguish the fire, as quickly as possible.
- not cause the fire object any additional damage.
- not harm the environment.
- not cause damage to the user.
- not demand risky operation.
- give protection to the user.
6.5 WATER

Water must be in direct contact with the fire to gain an extinguishing effect. The effect emerges when water changes to vapour. Water takes heat from the fire via evaporation; the vapour displaces air and consequently the oxygen. Since water does not evaporate, it can add to the object’s damage. To obtain maximal evaporation, the water must have as large surface as possible when hitting the heat zone. A scattered jet obtains this, the water comes in shape of drops, the smaller the drop, the larger the surface. Drops with 1 mm diameter have a surface of 0.126 cm$^2$, the same water amount in drops of 0.1 mm in diameter have a 1.26 cm$^2$ surface. Th smaller the drops are, the shorter the air throw is needed. With a drop size of 0.2 - 0.3 mm, the most practical proportion between air throw and surface is obtained. By throwing, as much as possible, atomised water into the warmest part of the fire zone, the largest effect is obtained.

6.5.1 Powder

To have any effect, the powder must be lead down to the fire object. To obtain an extinguishing effect, one must reach a position from where the powder can reach the fire itself. The powder works partly by suffocating and partly by poisoning the flame, it also has a little bit of a cooling effect. Danger of re-ignition is therefore large until the temperature is brought down below the self-ignition temperature.

The powder has no direct damaging effect on the object. In sensitivity instruments and in electronic equipment, powder has a disturbing effect on the functions.

6.5.2 Carbonic acid

Carbonic acid is utilised either as a “total flooding” agent where the whole area on fire is filled with CO$_2$ in large concentration, or is used as a spot extinguishing agent. The gas has little cooling effect, so that re-ignition is a danger. One must utilise total flooding, as early as possible. Evacuation of the area is necessary, and before releasing the plant, one must check that no one is missing. The gas has no damage on the environment. In utilising spot extinguishers, the thermal effect may cause damage to sensitivity instruments.

6.5.3 Foam

Foam has both a cooling and suffocating effect. A light foam contains less water than heavy foam, and thereby less damage is caused by the extinguishing agent One can utilise light foam to cover larger areas and thereby suffocate the fire. One can also utilise foam as secondary remedy to prevent re-ignition, or prevent ignition from oil leakage, etc. When selecting an extinguishing agent, one must consider the type of fire:

- only a glow, or glow and flames, (fire in solid material), where the fire core has high temperature.
- only flames (fire in liquids) where gas vaporised from the surface is on fire, relatively low temperature in the liquid itself.
- fire in alive, electrical components (glow/flame fire in isolation materials, painting, lubricating oil etc.).
The main rule when choosing an extinguishing agent is:
- glow fire and glow/flame fire is extinguished by cooling (damp extinguishing remedy).
- one extinguishes a flame fire by suffocating.
- one extinguishes an electrical fire with a dry extinguishing remedy.

One must also consider the surroundings (as little extinguishing damage as possible), special circumstances (alive plants), danger of re-ignition (need of cooling), special material (chemicals, explosives, dangerous goods, swelling), protection of the fire squad (protect the users).

One must also evaluate the practicality of utilising a combination of mutual extinguishing remedies. For example, at first extinguish the flames with powder, thereby cooling with water, and possibly cover with foam to prevent spontaneous ignition.

### 6.5.4 Transportable fire extinguishing apparatus

There are a number of transportable fire extinguishing apparatus (hand-extinguishing apparatus) placed in different places onboard. The placement and type of apparatus is in accordance to the regulations based on the specific vessel. These apparatus are marked by symbols on the vessel’s “safety plan”. Knowledge of placement and use is introduced in the fire exercises onboard.

### 6.5.5 Water

Normally there are 10 litre apparatus placed in different locations onboard. 10 litres is a very limited amount, and has a period of use lasting approximately 60 seconds. Some types have a united jet, while others alternate between united and spread jets.
6.5.6 Powder
There are mostly 12 kg powder apparatus onboard, except where something else has been determined, for example 25 kg, 50 kg or 6 kg. This is clearly found in the “safety plan” onboard. A 12 kg powder apparatus has a period of use lasting approximately 20 seconds; a 50 kg apparatus has a period of use of approximately 60 seconds. The apparatus has good air throw, and will provide the user good protection. To utilise powder extinguishing equipment at full effect, a well-drilled technique is demanded. Add this to the training exercises onboard.

6.5.7 Carbonic acid
There are carbonic acid apparatus of 6 kg stationed on board. These apparatus have a very limited capacity and no air throw. The protection for the user is poor. The period of use is approximately 20 seconds. These apparatus are suited for spot extinguishing of relatively small fires.

One should have high goals regarding knowledge in utilising, of function and capacity of the fire extinguishing apparatus on board your vessel.

6.6 PERSONAL SAFETY EQUIPMENT

6.6.1 Fire fighter equipment
The requirement onboard oil tankers, as well as onboard gas tankers less than 5000 m³, are 4 sets of fire fighter equipment. Onboard gas tankers more than 5000 m³, a minimum of 5 sets of fire fighter equipment is required. Each set consists of:
• One breathing apparatus (BA) with an air capacity of minimum 1200 litres.
• Protection suit including boots and gloves.
• Fire resistance safety line with belt.
• Safety lamp.
• Fireman’s axe.
The equipment is specified in SOLAS, chapter 11-2, rule 17. National, and classification companies requirements may come in addition. This is of course considered for each vessel and the equipment is at all times in accordance to existing requirement and rules.

The breathing apparatus

The breathing apparatus onboard must be of an accepted type, and must fulfil the requirements in accordance to the regulations. Frequent training exercises on board will familiarise you with the apparatus and use of a breathing apparatus.

The requirement for in the air content in bottles is minimum 1200 litre clean air. Spare bottles are required for each apparatus, so that each apparatus has a period of use of 2 hours minimum. If a consumption of 60 litre air pr. minute (equivalent to hard work) is assumed, one obtains, as follows:

- Min. 1200 litre: 60 litre pr. minute = 20 minutes pr. bottle.
- 2 hours (120 min. : 20 min.) = 6 bottles
- Totally (1200 litre x 6 bottles) = 7200 litre air pr. apparatus.

A compressor is also required to fill up the breathing bottles after use. The period of use for the apparatus is dependent upon the consumption of air pr. time unit, for light or heavy work and the bottle size.

6.6.2 Example

An air bottle of 7 litres and a pressure of 200 bar give (7 x 200) = 1400 litres clean air. Assume that heavy work is to be carried out with a consumption of 60 litres pr. minute. Disposal time will then be (7 x 200): 60 = 23.3 minutes. The apparatus has an audio signal that alerts the user that it’s time for to abandon the area. This audio signal is released at approximately 40 bars, and leaves us with (40x7) = 280 litres air for retreat. The time for retreat is (280 : 60) = 4.66 minutes. We then have 4.5 minutes to abandon the area.

It is recommended to train in the use of the apparatus in order to learn the special breathing technique for such an apparatus. The definition of breathing technique is a rational way of utilising the air to obtain a maximum safe user time.

The user is dependent upon the state of the apparatus when residing in smoke or gas filled rooms. Before entering such rooms, the user himself must control the apparatus. After strapping the bottle on his back, a special routine must be followed regardless of the duration and regardless of others. The procedure varies with each apparatus. It is of great importance to knowledge of the apparatus onboard your vessel. The control will mainly be, as follows:

**Bottle pressure:** Open the bottle valve 2-3 shifts and read the manometer pressure. Then put on the mask, the panorama mask is put on with all straps extended. Set the chin in the mask and lead the straps behind the head. Tighten the lower strap, then the upper straps and finally the top strap.

**Retreat signal:** Shut the bottle valve and breath carefully until the retreat signal appears. The manometer indicates approximately 40 bars when the signal appears. If there is a change over valve on the apparatus, ensure that this is in the right position. The change over valve is activated when the retreat signal appears and has an opening effect for spare air to release.

**Mask’s seal ability:** Suck the mask empty of air. The mask will then be pressed against the face, if not, tighten the head straps. If it is airtight, open for air again.
**Pneumonic automatic:** The bottle valve is set fully open, breathe a few times to make sure that the pneumonic automatic unit is working.

**Flushing button:** The button on the pneumonic automatic unit is activated and air will flow into the mask. Sometimes extra air in the mask is needed.

**Bottle pressure:** Control again the pressure manometer to make sure that the bottle is full. Place the manometer back in the clip.

All tests must be repeated for each exercise, or change of bottle, to make sure of satisfactory operation at all times.

6.6.3 Fire stations

The fire stations are marked on the safety plan, and also the content of all required equipment at the stations. In addition to mentioned fire fighting equipment, the content must include personal protective equipment, fire hoses, jet nozzles that can switched from jet to fog dispersement, keys to hose coupling and an extra fire axe. Other equipment included is an electrical drill with 5/8” drill steel together with an extension cord. It is smart to obtain a smaller drill steel to drill a pilot hole, if this is a matter of necessity. A portable oxyacetylene torch that renders it possible to make a quick carving of a manhole or other openings to ease access is also included. This equipment is marked on the safety plan, where it is placed onboard and at the right number according to type and size of vessel.

Everyone is encouraged to know the seriousness of exercises onboard, being prepared in a realistic and objective way can be, as a matter of fact, very interesting and informative. Anxiety is relieved because confidence leads to safety.

6.6.4 International shore connection

SOLAS chapter II-2, rule 19, deals with the international “land coupling” that is required onboard all vessels in accordance to this rule’s specification. The existence of this is shown in the safety plan. It must be readily available during harbour stay. It is used as connection between the vessel and harbours equipment, in case of fire during the stay. Familiarise yourself with the escape and protection equipment onboard the gas tanker/chemical tanker, masks with filter for all onboard, appropriate protection equipment placed for easy availability. This protection equipment contains large aprons, special gloves with long cuffs, appropriate footwear, coveralls made of chemical resistant material, tightened glasses or face shields. Clothes and equipment must protect all body parts.

An escape apparatus with oxygen mask that makes the carrier independent of the oxygen in the air at a minimum of 15 minutes must be available on all vessels. This is only for use of escape. Specifications state how much of this equipment exists onboard. The safety plan informs where it is located.

6.6.5 Boarding tanks

Before boarding tanks and closed spaces, one must take measurements, make sure that dangerous gas is non-existent and that the oxygen content is satisfactory. After tank ventilation, take great care in the measuring and the certainty of the atmosphere before
entering. Ensure that the pump room is well ventilated by running the fans for awhile before entering. There is monitor supervision of the pump room atmosphere onboard many vessels today. This takes place by automatically testing the pump room atmosphere at different sampling points. Then it is analysed and indicated on the control room monitor. This is also equipment you need to be familiar with.

6.6.6 Personnel inside tanks

When entering tanks, it is very important to prepare equipment and make it easily available in case of emergency. Preparation includes a complete set of fire fighting equipment (also an extra fresh air mask in case it is needed for a rescue action), lines, communication, and crew on deck for supervising. The knowledge of the number and names of crew in the tank at all times is very important in order to be as prepared as possible for any rescue action.

6.7 HEALTH HAZARDS

6.7.1 In general

What is health? In short, it is when the physical is in balance with the non-physical, and the harmonisation here has a natural function. The result is good health. To maintain this, knowledge about harmonisation is the vital factor in health. Health is different for each one of us based on individual tendencies and external/internal influences that mark (or chooses to mark) our life.

Most crewmembers that sign on a vessel have been through a medical check in order to have a regular status of his/her health condition. Life at sea is a special work place, it is important that the general health condition at all times is good. What can be done to maintain a good general health condition on board?

The answer is built into the safety and protection of personnel on board. You can also take care of one another in a good manor by being aware of the risks that may have direct and external effect on health, regarding the special cargoes carried onboard your vessel. Primarily, you can take good care of your own machine, the body, by paying attention to the “fuel”, which contains the nutrients the body needs. It is very important that the “chef” onboard has basic knowledge about anatomy/physiology, in order to assemble the right raw material into the right article of food, in the form of nutrient rich meals. Together with good cleanliness and comfortable surroundings in the galley, the best basis is given. If the meals are “spiced-up” with a nice atmosphere, in addition to existence of an inter-human working environment and well-being, the result is solidarity, well-being at work, increased efficiency, less sickness absence and saved costs.

A positive mental attitude toward life is also important and, at the same time, improves or maintains health. This is an important factor of the human’s total health. For example, one can turn a “I will not, cannot” behaviour pattern into a “I can, I will” attitude. This will increase co-operation between the people onboard. With an attitude change based on positive thinking, the result is noticeable onboard, due to well being, solidarity, better performance, and a healthier atmosphere for the whole crew. The human resource is the only resource.
6.7.2 The body

The doctrine of how the body is built is called anatomy. The doctrine of the body’s function is called physiology. This will be roughly illustrated to achieve a synopsis of how the “machine” functions.

6.7.3 The cell

This is the smallest, independent unit of the body and the basis for all living organisms. All the processes in the body are caused by the chemical reactions that take place in the cells. Cells in different tissue and organisms co-operate in their duties. The cell has a water content of approximately 70% in addition to proteins, carbohydrates, fat and inorganic material. All the cells have the same basic structure and a number of mutually basic qualities. Simultaneously each part of the cell has its function. We all utilise nutrients both to achieve energy and as “building stones”. In new cell components, glucose (grape sugar) is the most important energy source. It is important to have a nutrient rich and varying diet.

6.7.4 Tissue

Cells that look alike remain lying to form tissue. All surfaces of the body are covered with epithelial tissue (type of tissue that mainly covers all surfaces, the cavity and channels of the body). Connective tissue and support tissue forms the tissue network in the body and keeps tissue and organs together. There is an innumerable of tissues, for example osseous tissue, muscular tissue and nerve tissue. The cell co-operation is controlled by chemical signals. These signals consist of two types, nerve signals and hormone signals. These two systems co-operate for an appropriate reaction. This is fully necessary for our survival. The hormone system controls the activity of many internal organs, the nerve system controls muscles and glands.

Several organ systems co-operate to keep the composition of tissue fluid constant. The blood renews this tissue fluid. The blood must circulate the whole time. The duty of the lymph artery is to drain excess tissue fluid.

6.7.5 The digestive organs

These demolish and absorb nutrient material. It is very important that the nutrient content satisfies the body’s need.

The respiratory organs

These absorb oxygen and partly carbon dioxide. Respiration is an exchange of gases between the blood arteries and the air in the lungs. The blood absorbs oxygen into the body’s cells and partly the excess carbon dioxide that arises. The respiratory organs consist of the bronchia and the lungs. Gas exchange between blood and air takes place in the lungs.

6.7.6 The urinary organs

These regulate the composition of the tissue fluid. The urinary organs consist of the kidneys, urinary tract, bladder and the urethra. The kidneys’ most distinct duty is to separate water...
from waste. The resultant urine is processed in the urinary tract and bladder then empties via the urethra.

6.7.7 The blood circulation

The blood circulation carries materials between the organs in the body. The tissue fluid is constantly renewed from the blood in the capillaries. The heart is a pump that makes blood circulate. “Heart valves” help the blood run in the right direction. The heart musculature sends blood through the coronary artery (the heart’s arteries). The heart is the most persevering muscle in the body. The blood flows from high pressure to lower pressure. The pulse is thereby a regulator in the blood. The blood pressure is the pressure inside the artery, which is part of the blood circulation. The blood acts, as a sort of, transportation system. Blood sends tissue circulating through the artery system. This contains blood cells floating in a protein rich fluid - blood plasma - with two main types of cells, red and white. The red cells are important for transportation of oxygen from the lungs to the different body tissues, while the white, in different ways, participates in the body’s defence against disease. It is important to remember that one cannot mix different blood types. Blood cells are formed in the bone marrow.

6.7.8 The human organism and the surrounding world

Our senses tell us about the surroundings. The main senses are sight, hearing, touch, smell and taste. There are also important senses in the muscles, the joints and the equilibrium organ in the inner ear. Each sensory organ has its best reaction to a certain type of stimulation, but has a different reaction to long lasting stimulation.

6.7.9 The skin

The skin forms an essential boundary to the surroundings, and is the body’s largest “breathing organ”. The skin consists of different tissue with different qualities and covers the body surface, like an almost impenetrable protective film. The skin is an important sensory organ with large adaptability.

6.7.10 The immune system

This system protects the body and consists of several parts. There is no possibility of living a normal life without this defence, as its duty is to render harmless infective agents or other strange material. In addition to combating infection from outside, this defence system also fights against any internal cell changes.

6.7.11 The Body’s Motion Apparatus

This consists of skeleton and muscles. The skeleton is the body’s framework, consisting of almost 200 large and small bones tied together by link and ties. The muscles can move the bones by shortening (contracting) using an impulse from the nervous system. This was a short description of the “human machine”. When experiencing something exciting, frightening, unexpected, stressing, surprising or likewise, energy runs through us like an electrical blow. In such situations, one experiences the effect of endocrine hormones.
The part of us that consists of feelings, thoughts, vibrations, intuition, ergo not physical parts of us, are also an important part of us (in many cases a decisive part). It is very important to provide stimulation and nutrients to these parts, as discussed below.

6.7.12 Thought, Action, Result, Feeling

Positive thoughts and attitudes together with a healthy diet form the basis for good health. We can do a lot ourselves by choosing the right things, as we are free to choose. We now take a look at your work place, onboard a vessel, and the influence this has on your health. We will also discuss what external influences can be found in the atmosphere and the injuries/incidents that may occur on board.

Onboard different types of vessels carrying different types of cargo, danger to health from external influences are considered regarding the vessel’s protective equipment and routines. This protective equipment is placed practically and can be utilized, as necessary. Familiarize yourself with the equipment onboard your vessel and use it!

With a sudden injury or illness on board, medical advice and guidance can be gathered from Radio Medico - the radio medical service for vessels at sea. It is important to have all the important information when help is needed for a serious condition onboard, such as:

- Age
- Sex
- Weight
- Duration of the illness
- Extent of the injury
- Symptoms
- Patient's comments (complaints)
- Clinical findings (sign of a specific illness)
- How the injury happened
- Character of the pain (grumbling, stabbing, squeezing)
- Whereabouts of the pain
- Face colour, limpness, drowsiness, temperature, pulse, breathing trouble, nausea, blood, mucus, urination, etc.

All of the above is important.

There is a “hospital” onboard containing ordered equipment for treatment and medication. The ship medical directions regarding the ship’s hospital deal with the maintenance, supply, inspection, etc.

It is important to know how to protect oneself against harmful skin contact, skin absorption and respiratory absorption of dangerous gases in the atmosphere surrounding us, such as entering tanks and closed spaces.

Help given in the first minutes of an emergency situation is crucial. All must endeavour to have respectable first aid skills.

6.7.13 First aid

First aid is used with sudden unconsciousness, stopped breathing and lack of air.

(Call for help, but do not abandon the patient, immediately start helping.)

A Air: Try to free the air flow, lie the patient on a flat surface, bend the head backwards, remove any dentures, vomit, etc.
Breathing: If the patient is not breathing, start resuscitation with 3-5 breaths/insufflations. Use the “Pocket Mask” as an option. Hold the head curved backward, check the pulse on the neck. If pulse is felt, continue with 12 respiration’s per minute.

Circulation: With deadly paleness and no pulse, give 2-3 powerful knocks over the heart. If this has no effect, start external heart compression once per second.

6.7.14 One rescuer
Alternate 2-3 respirations and 15 heart compressions.

6.7.15 Two rescuers
One respiration for each heart compression. When compressing; press the breastbone down 4-5cm.

6.7.16 ABC
The method stands for air, breathing, and circulation. The priority of first-aid training and practice is of great importance. The better you are at first aid in an emergency; the chance of a good outcome is greater.

6.7.17 Heart problems
Heart problems can be suspected if sudden, strong pain behind the breastbone is experienced. For cardiac arrest, use the ABC.

6.7.18 Shock injuries
Description of shock is acute circular failure. This may be caused by reduced blood volume from bleeding, shock by drop of blood pressure or reduced pump functions from a cardiac infarction. If a big incident occurs, shock must be calculated. The symptoms are fast pulse, coldness, pail and difficulty in breathing. Supply oxygen, warm blankets and fluids.

6.7.19 Head injuries
All knocks against the head must be taken seriously. The symptoms are headache, nausea and dizziness. Flat bed rest for 2-3 days. Limited fluid intake and be sure to supervise.

6.7.20 Poisoning and etch injuries
Refer to the IMCO’s book “Medical First Aid and Guide for use in accidents involving dangerous goods”. This refers to the data sheets on the different cargo onboard. (This is illustrated later on in this part). Poisoning and etch injuries appear in connection with cargo contact, as air absorption, swallowing or skin absorption (skin contact). The symptoms are pink coloured skin, smell of almonds on the breath, headache, dizziness, nausea and vomiting. Remember that in connection with cargo contact, the emergency squad should efficiently use protective equipment, gloves etc. Supply oxygen and follow the instructions on the data sheet for the cargo in question.
6.7.21 Fire injuries

In fire injuries, ensure a stable lateral position for the patient, if possible. Supply oxygen and fluid. With fire injuries, quick help is double the help. Quickly cool for at least 20 minutes. Estimate the extent of the injury. The patient mustn’t freeze. Provide warm blankets and abundant fluid. The patient should rest, be under supervision, and have their pulse checked. Check the medical box for proper use of medication and bandages.

6.7.22 Frost injuries

Localised frost injuries on the skin’s top layer begins with a prickling feeling, then ascends to white spots on the skin. Careless handling of pipeline and cranes onboard vessels, which carry strongly cooled gases, can lead to localised frost injuries. Important: Frozen hands and feet must not be warmed up actively with warm water. Cover frozen skin parts with a soft woollen garment. Do not massage or rub. It helps a lot to warm up frozen skin with warm skin.

6.7.23 Bone, joint & soft part injuries

A lot of injuries are sprains, fracture and soft part injuries. Use the ICE method, as the proper first aid, in such injuries. ICE means ice, compression and bandage, and elevation.

I - stands for ice. Ice the injury in order to lower the injured spot’s temperature. By doing so, the bleeding is reduced in the underlying tissue. Swelling and pain will also be reduced.

C - stands for compression bandage or compression. If cooling the injury is not sufficient, compression around the injured spot is recommended in order to counter the pressure from haemorrhage and reduce swelling and pain. Confer with the patient regarding the tightness of the bandage.

E - stands for elevation and rest. To decrease the blood pressure and reduce the seepage of blood on and around the injured place, raise an injured arm or foot to approximately heart height and rest for 1-2 days.

6.7.24 Infections

Refer to the vessels medical cupboard regarding remedies for infection.

6.7.25 Intake of poison materials

Poisonous materials can be taken in by inhaling (gas, dust), skin penetration, skin absorption (gas and liquid) and swallowing (gas and fluid). If any of this occurs, different reactions will occur depending on the kind of material, how much, etc. Refer to the material’s data sheet regarding treatment. Blood is most important, since it is the higher brain centre that is first affected from lack of oxygen.

A poisonous material emerges quickly to the brain cells and deprives them of oxygen. This may cause unconsciousness, at worst death. By inhaling small concentrations, we are exposed to localised effects (nasal, throat, and lung) or poisonous gas absorption into the blood.

Through skin penetration, gases and fluids are quickly absorbed into the blood and the effects depend on the characteristic of the material, the velocity of the penetration and poisonous elements. If material is swallowed, this is easily absorbed by the mucous membrane in the mouth.
6.7.26 The eyes

The eyes are very exposed to any spill or contact to cargo. There is normally irritation, burns and tears from harmful exposure. It is of utmost importance with a very fast first aid and abundant rinsing with water.

With all injuries and illness it is of the utmost importance to administer first aid and contact competent medical help if any doubt of the outcome exists.

Enclosed is a data sheet for Propane, which illustrates the layout and the content of information. There are such sheets for all types of dangerous cargo, which are made readily available and visible onboard.

The data sheets tell us about the cargo’s character, the emergency procedure for a cargo fire or cargo spill. There is also information about health hazards, fire, explosion, chemical data, reaction data, physical data and the condition of the material in freight. Information regarding the quality of material is required with the freight of the material.
Propane

Appearance  Colourless
Odour        Odourless
UN Number    1978
MFAG Table   310

The Main Hazard
FLAMMABLE

EMERGENCY PROCEDURES

Fire
STOP GAS SUPPLY. Do not extinguish flame until gas or liquid supply has been shut off, to avoid possibility of explosive re-ignition. Extinguish with dry powder, halon or carbon dioxide. Cool tanks and surrounding areas with water spray.

Liquid in eye
DO NOT DELAY. Flood eye gently with clean fresh water. Force eye open if necessary. Continue washing for at least 15 minutes. Obtain medical advice or assistance as soon as possible.

Liquid on skin
DO NOT DELAY. Remove contaminated clothing. Flood affected area with water. Handle patient gently. Continue washing for at least 15 minutes. Immerse frost-bitten area in warm water until thawed. Obtain medical advice or assistance as soon as possible.

Vapour inhaled
REMOVE VICTIM TO FRESH AIR. Remove contaminated clothing. If breathing has stopped or is weak or irregular, give mouth to mouth/hose resuscitation or oxygen, as necessary. Obtain medical advice or assistance as soon as possible.

Spillage
STOP THE FLOW. Avoid contact with liquid or vapour. Extinguish sources of ignition. Flood with large amounts of water to disperse the spill, and to prevent brittle fracture. Inform port authorities or coastguard of spill.

Health Data

TLV 1000 ppm

Effect of liquid
ON EYES Tissue damage due to frost-bite.
ON SKIN Tissue damage due to frost-bite.
BY SKIN ABSORPTION Not absorbed through skin.
BY INGESTION Not pertinent.

Effect of vapour
ON EYES Cold vapour could cause frost-bite.
ON SKIN Cold vapour could cause frost-bite.
WHEN INHALED
Acute effect: Asphyxiation. Headaches, dizziness, unconsciousness and even death.
Chronic effect: Slight narcotic effect.

Odour threshold Odourless
but may be stench to aid detection

Personal protection
Splash-resistant suit, goggles or face shield, gloves and boots.
Propene

Fire and Explosion Data
Flashpoint -105°C.
Auto-ignition Temperature 450°C.
Flammable Limits 2-10% by volume.

Explosion Hazards
Vapour can form a flammable mixture with air which, if ignited, may release explosive force causing structural damage.

Chemical Data
Formula C₃H₈ (CH₃CH₂CH₃).
Chemical Family Hydrocarbon (saturated, aliphatic).

Reactivity Data
Water, fresh or salt Insoluble. No dangerous reaction; can freeze to form ice or hydrates.
Air No reaction.

Other liquids or gases Dangerous reaction possible with chlorine.

Physical Data
Boiling Point at Atmospheric Pressure -42°C.
Vapour Pressure Bar (A) 1.1 at -42°C, 4.8 at 0°C.
Specific Gravity 0.58 at -42°C.
Coefficient of Cubic Expansion 0.003 per °C at 15°C.
Freezing Point -188°C.
Relative Vapour Density 1.55.
Molecular Weight 44.1Kg/K.mole.

Enthalpy (KJ/Kg)
Liquid 75KJ/Kg at -42°C.
Vapour 178KJ/Kg at -42°C.
Latent Heat of Vaporisation (KJ/Kg)
425 at -43°C, 348 at -20°C.
Electrostatic Generation

Conditions of Carriage
Normal Carriage Condition Pressurised. Fully refrigerated.
Ship Type 2G/2PG.
Independent Tank required No.

Control of Vapour within Cargo Tank Oxygen content to be maintained at not more than 2% by volume.

Vapour Detection Flammable.

Gauging Closed, indirect or restricted.

Materials of Construction
Unsuitable Mild steel below 0°C.
Suitable Mild steel above 0°C, aluminium, stainless steel.

Notes and special requirements
Propane

Limits of flammability in air and nitrogen mixtures

Lines of critical dilution are shown in green.

Propane vapour as percentage volume of tank atmosphere

FLAMMABLE ZONE

Atmospheric oxygen as percentage volume of tank atmosphere