2018

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
ΥΠΟΥΡΓΕΙΟ ΝΑΥΤΙΛΙΑΣ & ΝΗΣΙΩΤΙΚΗΣ ΠΟΛΙΤΙΚΗΣ

ΑΚΑΔΗΜΙΑ ΕΜΠΟΡΙΚΟΥ ΝΑΥΤΙΚΟΥ ΜΑΚΕΔΟΝΙΑΣ

ΣΧΟΛΗ ΠΛΟΙΑΡΧΩΝ

ΠΤΥΧΙΑΚΗ ΕΡΓΑΣΙΑ

ΜΕ ΘΕΜΑ :

"Cargo pumps and related systems in M/T"

ΣΠΟΥΔΑΣΤΡΙΑ : ΣΑΡΑΦΟΠΟΥΛΟΥ ΑΓΓΕΛΙΚΗ

ΕΠΙΒΛΕΠΟΥΣΑ ΚΑΘΗΓΗΤΡΙΑ : ΠΑΠΑΛΕΩΝΙΔΑ ΠΑΡΑΣΚΕΥΗ

Α.Μ. : 3619

ΘΕΣΣΑΛΟΝΙΚΗ 2018

ΕΛΛΗΝΙΚΗ ΔΗΜΟΚΡΑΤΙΑ
ΥΠΟΥΡΓΕΙΟ ΝΑΥΤΙΛΙΑΣ & ΝΗΣΙΩΤΙΚΗΣ ΠΟΛΙΤΙΚΗΣ

ΑΚΑΔΗΜΙΑ ΕΜΠΟΡΙΚΟΥ ΝΑΥΤΙΚΟΥ ΜΑΚΕΔΟΝΙΑΣ
ΣΧΟΛΗ ΠΛΟΙΑΡΧΩΝ

ΠΤΥΧΙΑΚΗ ΕΡΓΑΣΙΑ

A.E.N. ΜΑΚΕΔΟΝΙΑΣ

ΘΕΜΑ : ‘‘Cargo pumps and related systems in M/T’’

ΕΠΙΒΛΕΠΟΥΣΑ ΚΑΘΗΓΗΤΡΙΑ: ΠΑΠΑΛΕΩΝΙΔΑ ΠΑΡΑΣΚΕΥΗ –

ΤΗΣ ΣΠΟΥΔΑΣΤΡΙΑΣ: ΣΑΡΑΦΟΠΟΥΛΟΥ ΑΓΓΕΛΙΚΗΣ

Α.Μ.: 3619

ΗΜ/ΝΙΑ ΑΝΑΛΗΨΗΣ ΤΗΣ ΕΡΓΑΣΙΑΣ: 09/05/2017

ΗΜ/ΝΙΑ ΠΑΡΑΔΟΣΗΣ ΤΗΣ ΕΡΓΑΣΙΑΣ:

Α/Α	Ονοματεπώνυμο	Ειδικότης	Αξιολόγηση	Υπογραφή
1				
2				
3				
ΤΕΛΙΚΗ ΑΞΙΟΛΟΓΗΣΗ				

Ο Δ/ΝΤΗΣ ΤΗΣ ΣΧΟΛΗΣ: ΤΣΟΥΛΗΣ ΝΙΚΟΛΑΟΣ

TABLE OF CONTENTS

ABSTRACT:

This project attempts to identify the types of pumps established on ships, i.e. cargo-oil- pumps (C.O.P.) and related systems (such as: inert gas pumps, tank cleaning pumps e.t.c.) that are used mostly in tanker vessels and their functions. Additionally, the process of the operation of pumps is presented, the sealing, bearings and drive transmission that they are equipped with. A detailed reference is made to other systems that are located in M/T vessels, such as pumps in ship propulsion and in ship electric power production systems (Fire pumps, Bilge pumps, and hot water circulation pumps e.t.c.). Moreover, this dissertation offers a description of the A.U.S. system, Framo Hydraulic Cargo Pumping System and standards by OCIMF (Oil Companies International Marine Forum) and ISGOTT (International Oil Tanker and Terminal Safety Guide) of how pumproom, cargo lines and other lines on deck and manifolds should be constructed and arranged. Also the matter of responsibility at cargo handling in pumps is discussed, as well as the pump wear and maintenance. In conclusion there is a short reference to how cargo handling operations are conducted with cargo pumps and other systems (loading and discharging) in tanker vessels.

CHAPTER 1: PUMPS ESTABLISHED ON SHIPS

1.1 INTRODUCTION

A ship consists of various types of fluids moving inside different machinery and systems for the purpose of cooling, heating, lubrication, fuels and as its cargo. These liquids are circulated by different types of pumps, which can be independently driven by ship power supply or attached to the machinery itself. A Pump is a machine used to raise liquids from a low point to a high point. A pumping system on a ship will consist of suction piping, a pump and discharge piping. The system is arranged to provide a positive pressure[1] or head at some point and discharge the liquid. All the systems on board ship require proper operational and compatible pump and pumping system so that ship can run on its voyage smoothly. The selection of a type of pump for a system depends on the characteristics of the fluid to be pumped or circulated. Characteristics such as viscosity[2], density[3], surface tension[4] and compressibility[5], along with characteristics of the system such as require rate of fluid, head to which the fluid is to be pumped, temperature encountered in the system, and pressure tackled by the fluid in the system, are taken into account. Pumps operate via two basic principles rotodynamic and positive displacement but there are also few pump designs outside of the categorization. Rotodynamic pumps try to be constant energy but don’t quite make it work because of the variable inefficiencies and limitations of manufacturing. Positive displacement machines try to be constant flow devices but don’t quite manage to make it work because of the liquid properties and manufacturing requirements.

[1] A positive displacement pump makes a fluid move by trapping a fixed amount and forcing (displacing) that trapped volume into the discharge pipe.

[2] The thickness of a fluid.

[3] The fluid’s mass per unit volume.

[4] It’s the elastic tendency of a fluid surface which makes it acquire the least surface area possible.

[5] Compressibility is the fractional change in volume per unit increase in pressure.

1.2 POSITIVE DISPLACEMENT PUMPS

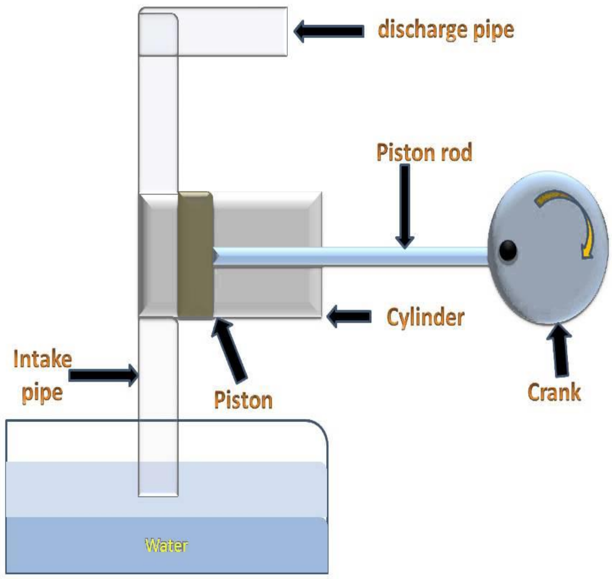
Positive displacement pumps come in a wider variety such as gear, lobe, peristaltic, screw, and many other types of pumps. They are self priming pumps and are normally used as priming devices and they draw fluid into a compartment at the inlet and move it to an outlet for discharge, most typically using a rotary[1], reciprocating, or diaphragm method to move fluid. Also:

- They consist of one or more chamber, depending upon the construction, and the chambers are alternatively filled and emptied.
- The positive displacement pumps are normally used where the discharge rate is small to medium.
- They are popularly used where the viscosity of the fluid is high.
- They are generally used to produce high pressure in the pumping system.

Positive displacement pumps are divided in 4 categories:

1) The Reciprocating Piston Pump

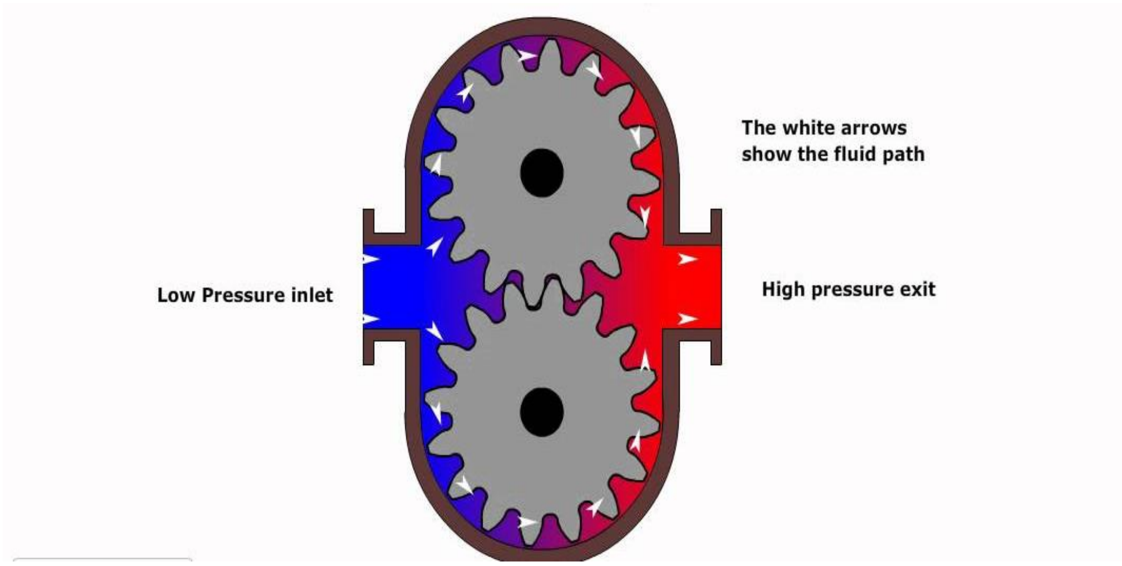
A reciprocating pump is a type of positive-displacement pump which includes the piston pump, plunger pump and diaphragm pump. If the level of liquid to be pumped is below the centre line, then the vacuum is created into the pump due to this the water is automatically sucked.



[1] A rotary pump is a positive-displacement pump that consists of vanes mounted to a rotor that rotates inside of a cavity. In some cases these vanes can have variable length and/or be tensioned to maintain contact with the walls as the pump rotates.

Advantage:	Disadvantage:
It is Self priming Pump, having a high head.	Complex Construction and relief valve is required to release an excessive pressure.

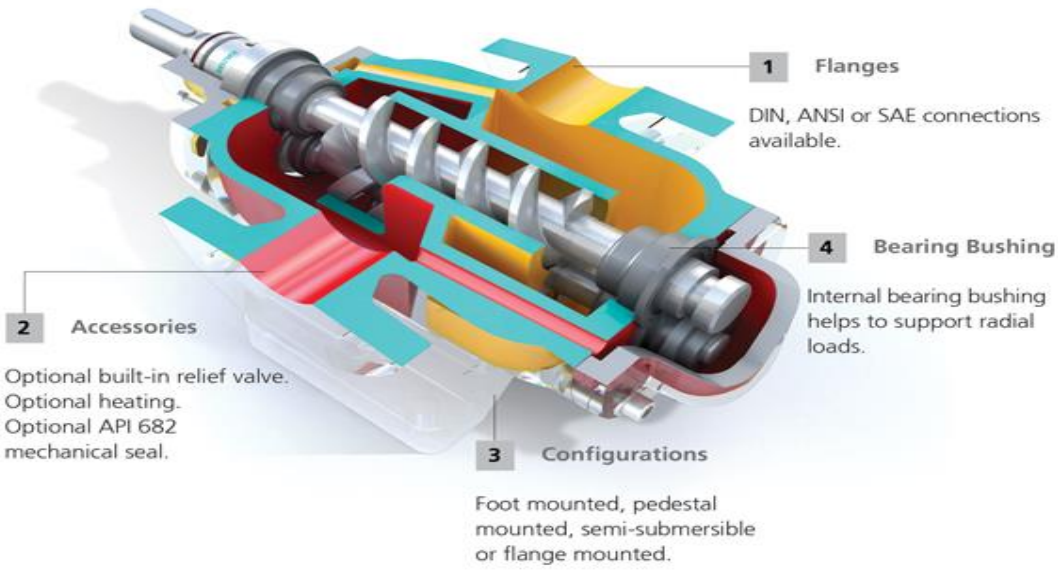
2) The Gear Pump:



The pump shown above is of very common design. It is used for pumping many types of liquid and gas and is capable of delivering at very high pressures. This makes it suitable for hydraulic supply. The tooth profile is similar in volute gear teeth for liquid pumps. For gas pumps special profiling with very fine tolerances is employed. Uses of Gear pump: Lube Oil, Boiler fuel oil pump, main engine driven lube oil pump and many more.

3) The Screw Pump:

These pumps are seen in many applications and have a higher capacity than double row type. Fluid enters the pump and is screwed by the idler shafts along the outer edge to the discharge port. Axial thrust of the idlers is absorbed by the integral thrust collar of the driven shaft. The axial thrust of the driven shaft is absorbed by the thrust bearing. The scroll sits in a replaceable insert which is sealed to the outer casing by O-rings[1].



4) The Diaphragm Pump:

Diaphragm pumps are the reciprocating pump .The Diaphragm is Rubber Membrane which is connected to the piston and its rod. There are two valve Suction and discharge valve on the other side of Diaphragm. Working of Diaphragm is simple as Reciprocating piston pump. This piston is powered by some prime mover like motor and any other. When the Diaphragm moves up, vacuum is created at that place. Due to this the suction valve opens and the inlet is open. And after filling the sufficient suction, the diaphragm moves in the downward direction. As the diaphragm moves downward, pressure is created at the barrel of the pump and discharge valve is opened. Those in which the diaphragm is sealed with one side in the fluid to be pumped, and the other in air or hydraulic fluid. The diaphragm is flexed, causing the volume of the pump chamber to increase and decrease. A pair of non-return check valves[2] prevent reverse flow of the fluid.

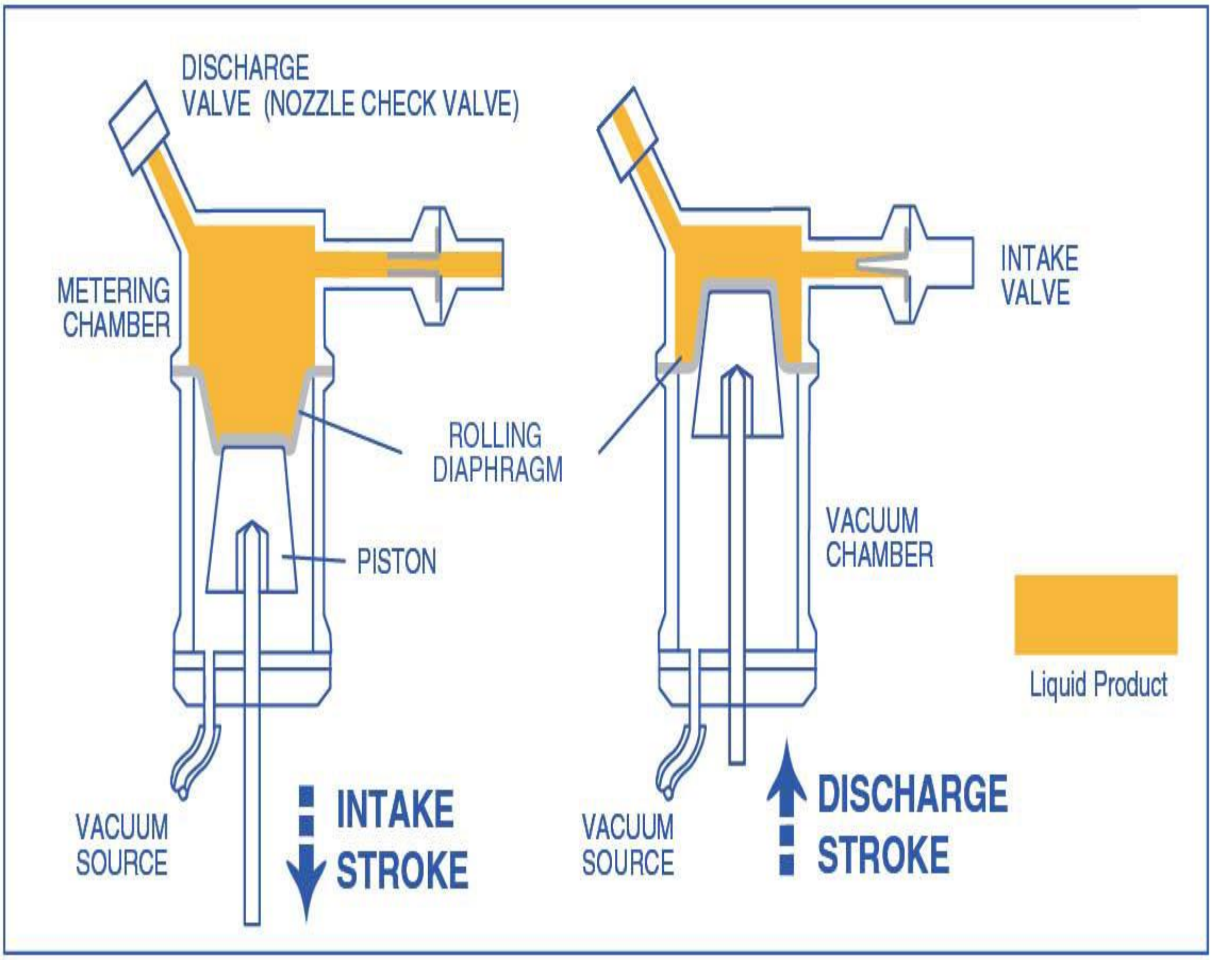
[1] An O-ring, also known as a packing, or a toric joint, is a mechanical gasket in the shape of a torus; it is a loop of elastomer with a round cross-section, designed to be seated in a groove and compressed during assembly between two or more parts, creating a seal at the interface.

[2] A non-return valve allows a medium to flow in only one direction. A non-return valve is fitted to ensure that a medium flows through a pipe in the right direction, where pressure conditions may otherwise cause reversed flow.

4.1 Photo of a Diaphragm Pump

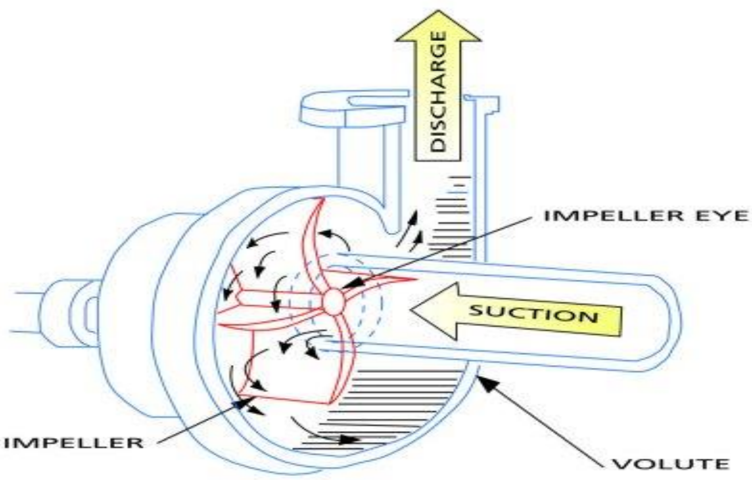
Uses of the Diaphragm Pump are mostly in Air Compressor.

4.2 Photo of the operation of Diagraph Pump



1.3 CENRTIFUGAL PUMPS

Centrifugal pumps belong to the category of Dynamic pressure pumps or Roto-dynamic pumps. Centrifugal pumps are a sub-class of dynamic ax symmetric work-absorbing turbo machinery. Centrifugal pumps are used to transport fluids by the conversion of rotational kinetic energy to the hydrodynamic energy of the fluid flow. The rotational energy typically comes from an engine or electric motor. The fluid enters the pump impeller along or near to the rotating axis and is accelerated by the impeller, flowing radically outward into a diffuser or volute chamber (casing), from where it exits. Common uses include water, sewage, petroleum and petrochemical pumping a centrifugal fan is commonly used to implement a vacuum cleaner. The reverse function of the centrifugal pump is a water turbine converting potential energy of water pressure into mechanical rotational energy. Like most pumps, a centrifugal pump converts rotational energy, often from a motor, to energy in a moving fluid. A portion of the energy goes into kinetic energy of the fluid. Fluid enters axially through eye of the casing, is caught up in the impeller blades, and is whirled tangentially and radially outward until it leaves through all circumferential parts of the impeller into the diffuser part of the casing. The fluid gains both velocity[1] and pressure while passing through the impeller. The doughnut-shaped diffuser, or scroll, section of the casing decelerates the flow and further increases the pressure.



[1] It is a physical vector quantity both magnitude and direction are needed to define it.

CHAPTER 2: CARGO PUMPS AND RELATED SYSTEMS

2.1 INTRODUCTION

Cargo pumps are used for the transfer of liquid cargoes carried by tankers (M/T). M/T types include ultra large crude carriers (ULCCs) and very large crude oil carriers (VLCCs), distillate petroleum product tankers, chemical cargo tankers and tankers for liquefied petroleum gas (LPG). On these ships, apart from the pumping system, other networks with installed pumps are used, associated with the safe handling of the cargo or the cleaning of tanks. During unloading, as the height of the free surface of the liquid in the cargo tank is reduced and because a lot of cargoes due to their volatility[1] have a high vapor tendency, the cargo pumps have to operate at relatively low values of the net positive suction head available (NPSH).

Also, during the emptying of tanks, vortices may often be formed on the liquid surface, through which the cargo gases or inert gases[2] are transported into the pump suction. To reduce the cavitation due to low NPSH[3] in the pump impeller suction, as well as the reduction of vortex formation that transfers gases in the suction, the discharge rate of the tanks is controlled either by pump speed setting or through valves of piping system at the latter stages of the unloading process. These valves may be controlled manually and/or by an automated arrangement located in the ship's cargo control room (CCR). The material used for the manufacture of components of these pumps must be compatible with the cargoes handled, to prevent the creation of sparks that pose fire hazards due to cargo flammability. Also, the possibility of seawater pumping should be considered that is used for the washing of tanks. In this case, the pump must be constructed of corrosion-resistant materials. Generally cargo

---

[1] The tendency of a substance to vaporize. Volatility is directly related to a substance's vapor pressure. At a given temperature, a substance with higher vapor pressure vaporizes more readily than a substance with a lower vapor pressure. (Evaporative liquid)

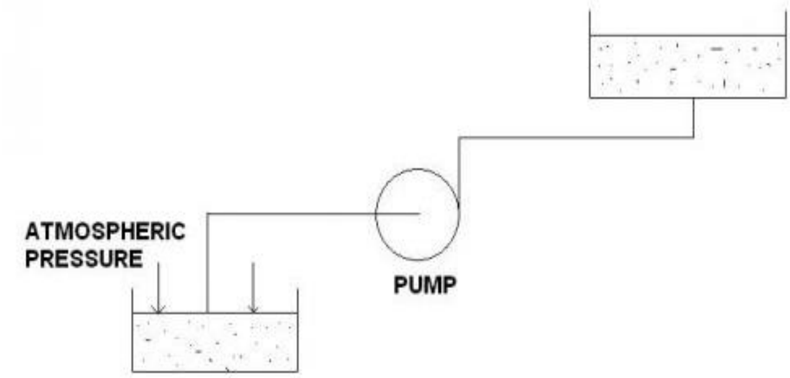
[2] The inert gas system is used to prevent the atmosphere in cargo tanks or bunkers from coming into the explosive range. IG keeps the oxygen content of the tank atmosphere below 5%, thus making any air/hydrocarbon gas mixture in the tank too rich (too high a fuel to oxygen ratio) to ignite. It is produced on board ships it has extremely low reactivity with other substances

[3] Positive suction head (NPSH in feet) is the amount of positive pressure, measured at the pump suction nozzle flange, which is available to prevent vaporization of the liquid or cavitation at the impeller eye inlet area within the system, taking velocity head into account.

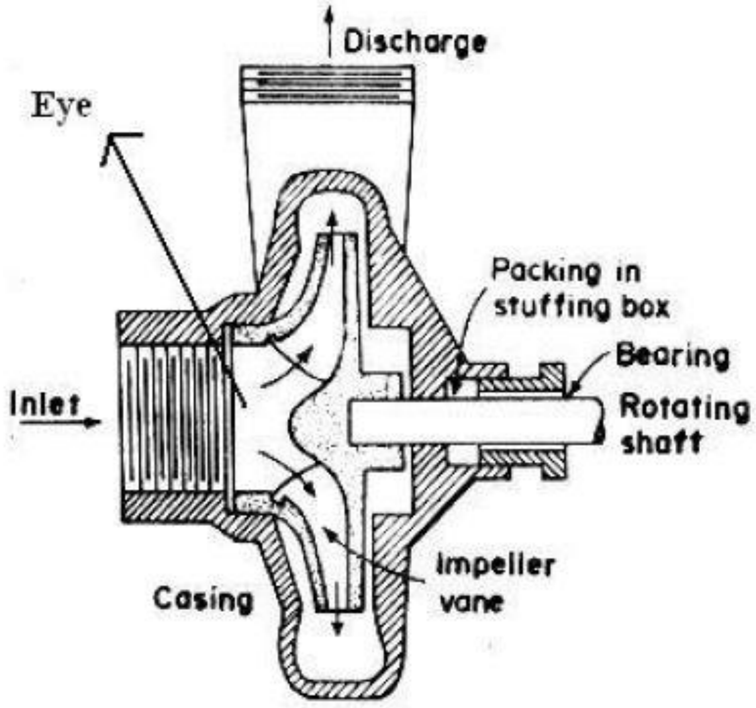
pumping in tankers and demands attention in regard to needed international unity pump safety and test standards.

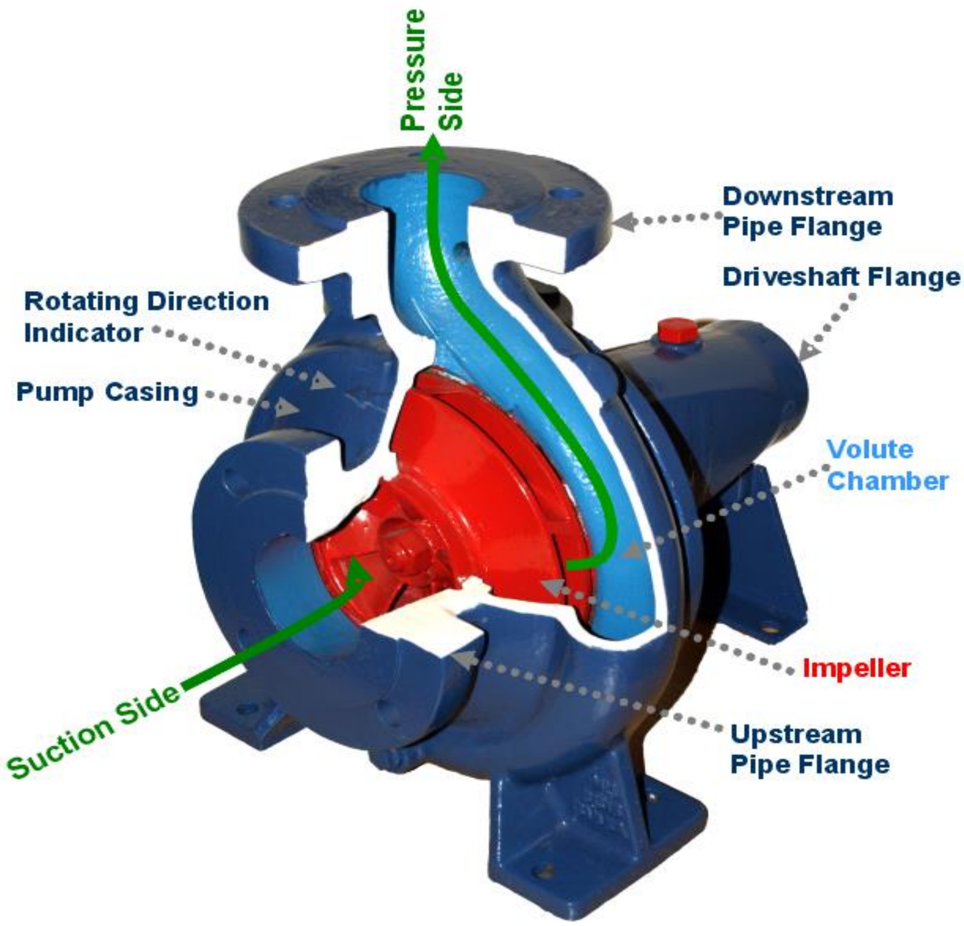
2.2 CENRTIFUGAL CARGO PUMPS

Centrifugal cargo pump is a device, which adds to the energy of a liquid or gas causing an increase in its pressure and perhaps a movement of the fluid. These pumps are single-stage and are frequent encountered in ships for transporting a limited number of liquid cargoes including crude oil and a few distillate products such as diesel, kerosene, etc. Three or four pumps are used, which are installed as low as possible into the vessel's pump room. Through piping interfaces, each pump is able to suck from various tanks, and discharges the cargo onshore through a pipe that corresponds to each pump and is connected to the manifold connection on deck. The pumps are installed vertically or horizontally, and the type of impeller used to achieve high flow rate is usually double suction impeller. This type of pump only adds to the energy of the fluid in the system. Energy required to bring the fluid to the pump is an external one and in most practical conditions is provided by the atmospheric pressure.

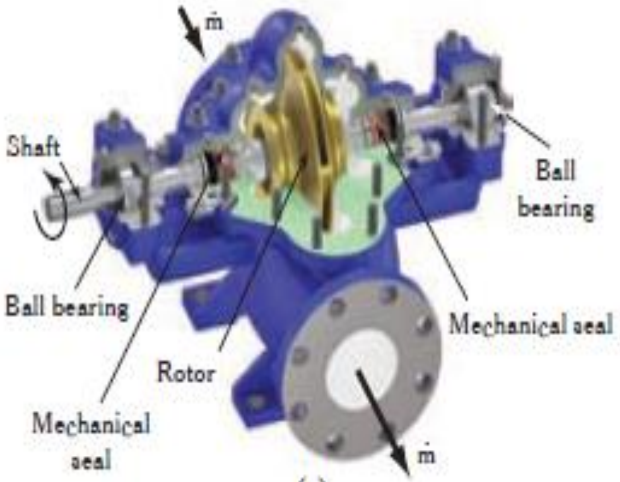


Flow through the pump is induced by the centrifugal force imparted to the liquid by the rotation of an impeller or impellers. Centrifugal pumps are not self-priming pumps. These pumps must be primed by gravity or by priming equipment external or internal with the pump. These pumps are basically radial flow, axial flow or mixed flow type. It consists of a rotating impeller within a stationary casing. The impeller construction has two discs joined at in between surface by a set of internal curved vanes. Impeller has an eye (opening) at the center and is mounted on shaft, which is driven by a suitable prime mover such as an electric motor, steam engine through crank mechanism, or a turbine. Opening in the sides of the impeller near shaft, called eye, communicates with the suction branch as shown in the figures below.





Assume there is a certain amount of fluid at the eye of the rotating impeller. The fluid will flow radically outwards (because of centrifugal action) along the curved vanes in the impeller, increasing its linear velocity. The fluid leaves the impeller in a similar manner to sparks shooting from a Catherine wheel. The high velocity fluid is collected in specially shaped casing called volute casing, where some of the kinetic energy of the fluid is converted into pressure energy. Fluid under pressure now leaves the impeller producing a drop in pressure behind it at the eye of the impeller. (Throwing off the water from the eye of the impeller leaves the space with vacuum). This causes the fluid from the suction pipe to flow into the pump under atmospheric pressure and subsequently that fluid also gets discharged like earlier one. This way fluid in the pump acts like a piston moving outward causing drop in pressure behind it. However, if initially there is no liquid at the eye; there will be no pumping action as explained, since there is no vacuum formed at the eye of the impeller. Centrifugal pump therefore is not a self-priming pump. In such case, where normally at the start of the pump the level of the liquid is below the eye of the pump, a self priming unit is normally attached to the pump which helps to create vacuum at the eye of the impeller hence priming the pump. As soon as pump starts taking suction self priming unit is automatically disengaged.



(a)


(b)

Fig. 8.62
Between bearings pump impeller, in (a) horizontal and (b) vertical arrangement.

To optimize the damping of radial thrusts, because of the pump shaft length, there might be two support points with ball bearings located on both outputs on the shell. The support with ball bearings on both outputs of the axis on the shell is performed in vertical as well as in horizontal pumps, which are identified as “between bearings pumps”. The sealing of the shaft, between bearings in pumps where two outlets on the pump casing exist or in pumps with one shaft outlet from the casing, is achieved by mechanical seal. The pump bearings shell is frequently equipped with a sensor, allowing the operator to perceive the temperature increase. The increase of the temperature indicates abnormality during pump operation and enables the operator to take appropriate action before serious damage occurs.

Possible causes of temperature increase of the bearings are inadequate lubrication, high rotational speed, wear of bearings, excessive increase of load, high temperature of transferred cargo, the misalignment or the improper assembly of the pump after maintenance repair, exceeding the wear limits of the rings that are placed on rotating portions between the impeller and the casing of the pump. In order to improve the suction conditions (i.e., the net positive suction height), apart from installing the pumps at the lowest point in the pumproom, one or more vent systems are used. These are installed on the side of suction for removing air and cargo gases during pump operation. These pumps are powered either by steam turbines or by electric motors. In both cases, the drive machine is installed in the engine room and the transmission of movement is accomplished by a connection axis (jackshaft), which passes through the bulkhead separating the engine from the pumproom.

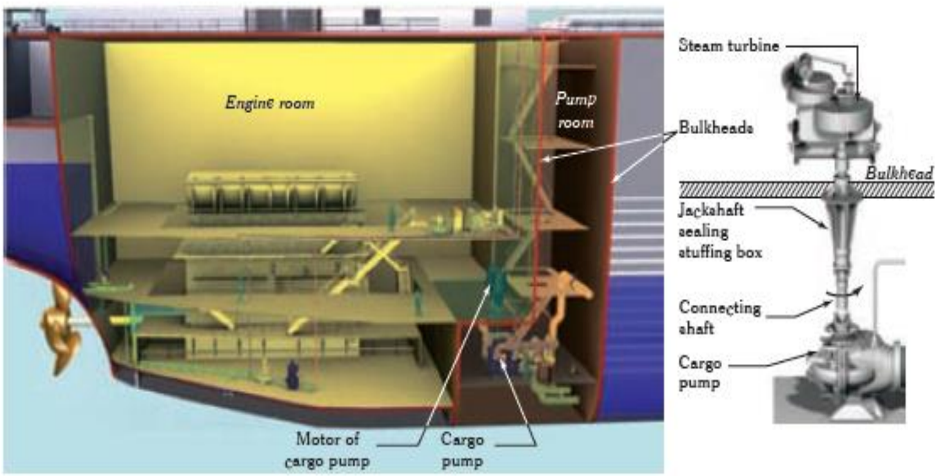


Fig. 8.63
Typical arrangement of pump room in a M/T.

The installation of the drive machine out of the pumproom achieves the insulation of the explosive cargo vapors that are inevitably generated in the pump room and pose risk of explosion and fire. The opening in the pump-room bulkhead (for a horizontal pump) or overhead through which the jackshaft passes is ordinarily sealed with a gas-tight stuffing box to prevent explosive vapors, originating in the pump room, from entering the machinery space.

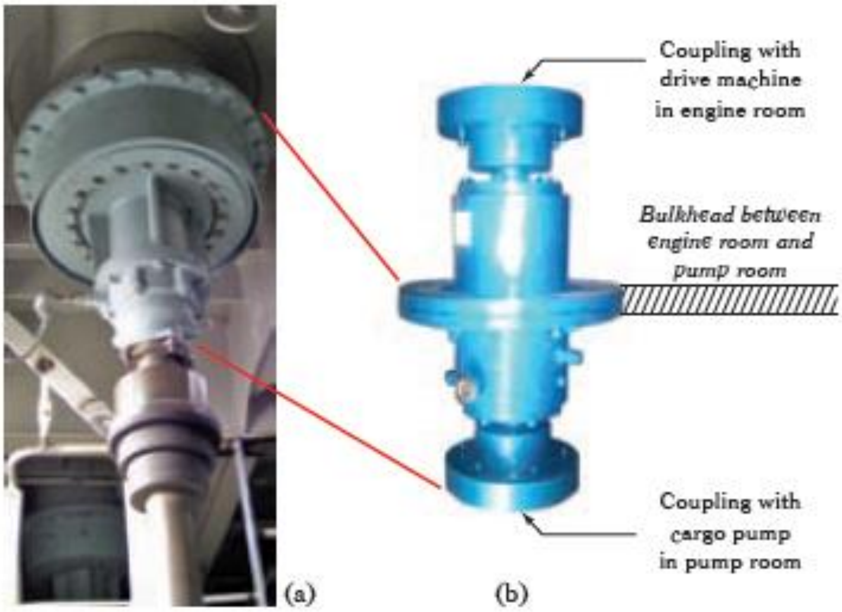


Fig. 8.64
(a) Arrangement of stuffing box of the jackshaft on bulkhead to the side of the pump room, (b) connection of the pump shaft through the bulkhead.

The weight of the jackshaft as well as the thrusts from the rotation is received by a thrust bearing that is established in the shaft crossing point at the bulkhead. During pump operation, as tanks are emptied, the net suction discharge head is respectively decreased, which is improved by the provision of inert gas in the tank, by the appropriate system. Inevitably, though, the level of the cargo inside the tank approaches the inlet to the suction tailpipe, so the centrifugal pump loses suction before the cargo tank is emptied. Therefore, the remaining cargo in the tank is pumped by a positive displacement piston pump, the stripping pump, which typically delivers much lower capacities than large centrifugal cargo pumps. The material used in making of a centrifugal pump differs at its parts that it is consisted of. The casing is constructed of cast iron. Cast iron has the good property by taking the desired shape, so easy to mold into any shape. The wear rings are made of the metal brass and the mechanical seal is made of brass metal.


Finally it can be noted that if the pump discharge head is lesser the flow rate of the liquid is higher and therefore pumping of the liquid is faster and if the pump runs at normal duty flow rate by maintaining normal duty discharge head the liquid will be pumped utilizing least possible rate of energy by the pump or in other word at this point efficiency of the pump is maximum. In the following table there is a comparison of centrifugal and reciprocating pumps:

Comparison of Centrifugal and Reciprocating/Stripping pumps:	
➢ Centrifugal pumps:	➢ Reciprocating pumps:
✓ Loses flow as the viscosity goes up	✓ Increases flow due to thickening of the flow
✓ Changes in pressure have a dramatic effect on efficiency	✓ Changes in pressure has a little effect on efficiency
✓ Very efficient at even modest viscosity	✓ Very efficient with high viscosity

2.3 VERTICAL DEEP-WELL CARGO PUMPS

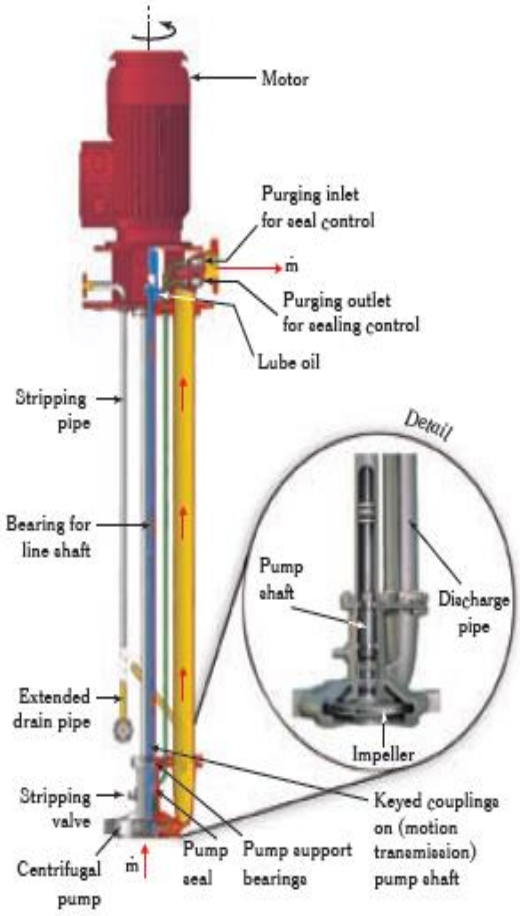


Fig. 8.65
Electric-motor driven centrifugal pump of M/T.

Deep-well cargo pumps are used to pump cargo from tanks in multi-product and chemical carriers carrying different quality and quantity of petroleum products. Therefore, a pump of this type should usually be suitable for pumping a wide range of liquids having different specific gravities, vapor pressures, viscosities and temperatures. Some cargoes, such as lubricating oils, and other viscous cargoes, may be heated to preserve their fluidity and improve pumpability. In addition, deep-well pumps are sometimes used to pump cryogenic cargoes, in LPG carriers, such as liquefied petroleum gas. A deep-well cargo pump can normally be driven by a vertical electric or hydraulic motor mounted on top of the pump discharge head above the out flow of the discharge tube to the deck. The motor drives the pump installed near the bottom of the tank through a long length axis. In some cases where the pumps are driven by hydraulic motors, the hydraulic oil is supplied by a central hydraulic power unit. The pump hydraulic motor is installed on the bottom of a well and, the shaft passes through a bulkhead, and is connected to the pump.

Alternatively, deep-well pumps may be driven through angular motion gear transmission by horizontal drive motor, steam turbine or diesel engine. The driver gear motion is converted to rotational movement of the vertical shaft. While the discharge of these pumps is typically located on the deck, in some cases they are located lower in the pumping room. The deep-well pumps are centrifugal and the casing is usually constructed as a multi-stage assembly, wherein at each stage there is a single-suction impeller. Over the shell, at its connection point with the motion transmission axis there is a short addendum (spool), which facilitates the works during inspection or repair of the pump.

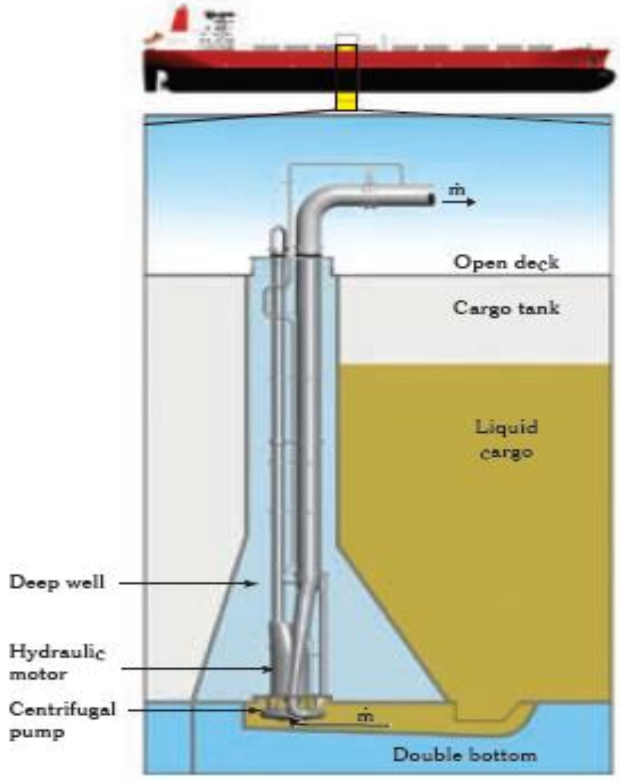
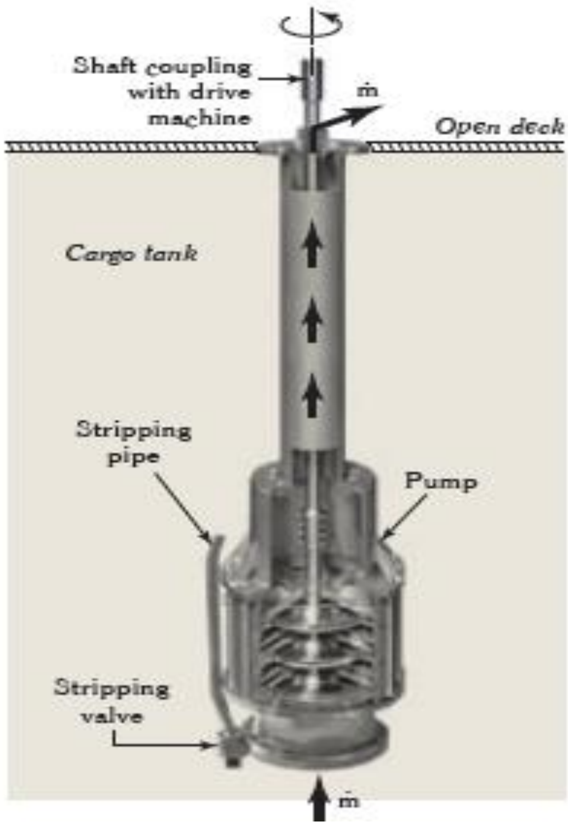


Fig. 8.66
Deep-well cargo pump in vertical arrangement, with hydraulic motor and discharge pipe outflow on deck.

In pumping of liquids having high vaporization tendency or low viscosity, an induction rotor is installed prior of the first suction stage impeller on the end of the rotation shaft (inducer, which has a specific helix forming shape). As the inducer rotates, it provides liquid to the inlet of the first stage impeller, lowering the required net positive suction head of the pump suction. Thereby, the suction and the performance of the pump are improved. Alternatively, when an inducer is not used, the first stage impeller is designed specifically to operate under conditions of low net positive suction head, or the first impeller is double-suction type.



During deep-well pump operation, the cargo is transferred to the shore facilities from the bottom of the tank, where the suction is located, and discharged through the riser pipe located overhead of the pump to the manifolds on deck. Because of the long distance that exists between the drive machine and the pump, located at the bottom of the tank, the motion transmission shaft is comprised by sections associated with thread or with keyed couplings. Also, because of the long length of the shaft, radial bearings that support the line shaft are frequently mounted on brackets, sometimes referred to as spiders, which are sandwiched between mating sections of the column pipe. Impeller and line-shaft bearings are often lubricated by the pumped cargo. Consequently, bearing materials must typically be compatible with all the fluids that are transported by the ship. The bearings should also be able to tolerate operation with loss of suction if the deep-well pump is used for stripping or during tank cleaning.

2.4 SUMBERSIBLE CARGO PUMPS MOVING BY HUDRAULIC MOTOR

Hydraulic motor driven submersible cargo pumps are used for pumping the cargo in chemical M/T, as well as in product carriers, whereas they can also be installed in crude oil tankers. In each tank usually one or two pumps are installed. Thereby the suction between the tanks is avoided and the probability of cargo mixing is minimized, because each pump is usually connected to an independent discharge network set up on deck. The increasing of the pressure of the hydraulic oil which is used to operate the hydraulic motor of the pump is performed by a central hydraulic power unit, installed in the engine room. The hydraulic power unit serves the cargo pumps, but it may also provide hydraulic oil to other auxiliary equipment, such as cranes, mooring machinery or the hydraulic motor of the bow thruster.

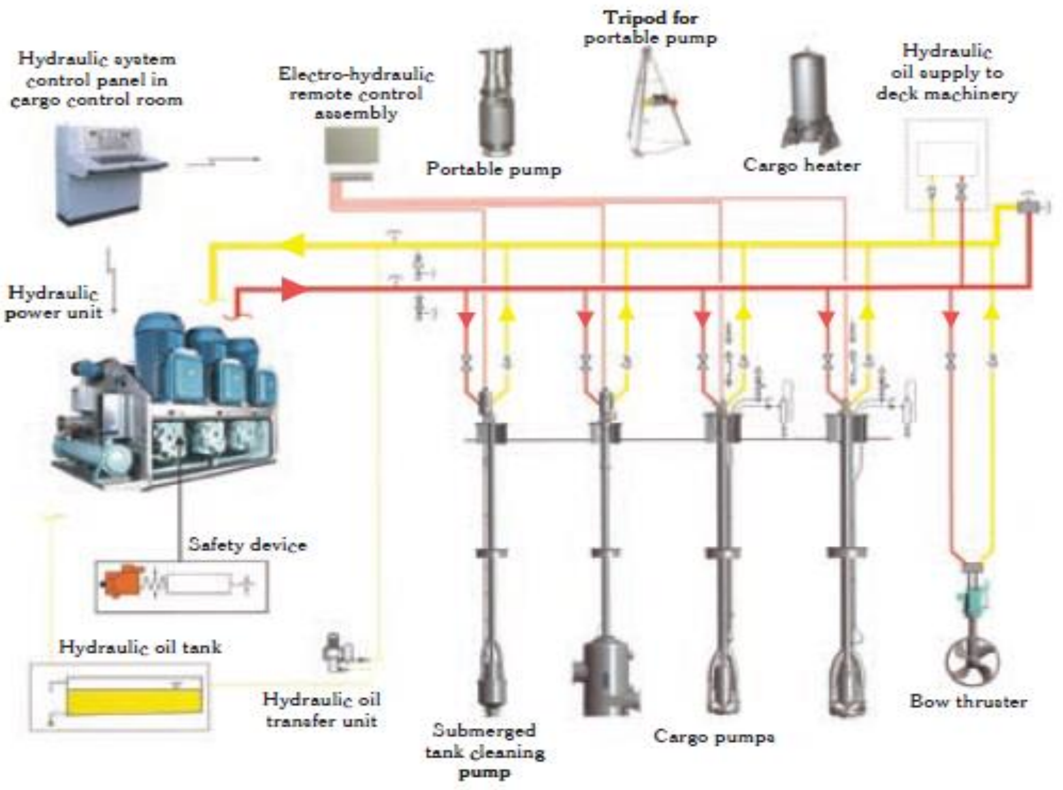
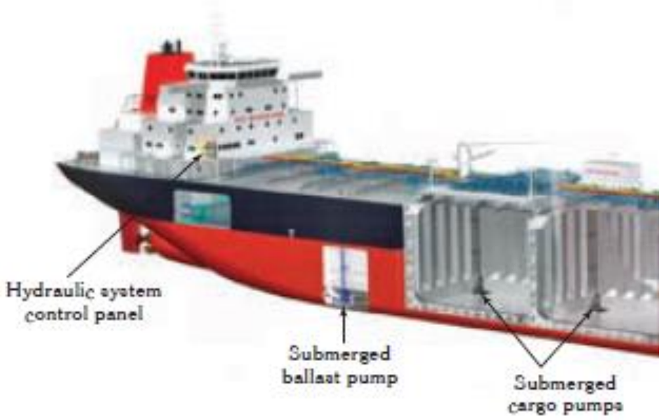


Fig. 8.69
Typical hydraulic oil supply system configuration from a central power unit.



The submersible hydraulic motor pumps are single stage vertical arrangement pumps, and consist of a centrifugal single suction impeller. The hydraulic motor pump is mounted on the lower end of a vertical pipe, and its upper end is connected to a top plate slightly raised from the vessel's main deck. The vertical pipe has a triple wall so as to form three concentric pipes. In the central pipe passes the hydraulic oil that is pressed by the power unit, while through the second wall passes the returning hydraulic oil towards the power unit. Inside the third wall passes air or inert gas, creating a leak proof space between the hydraulic oil and the cargo, in case of a leak or pipe failure. The rotor shaft is short

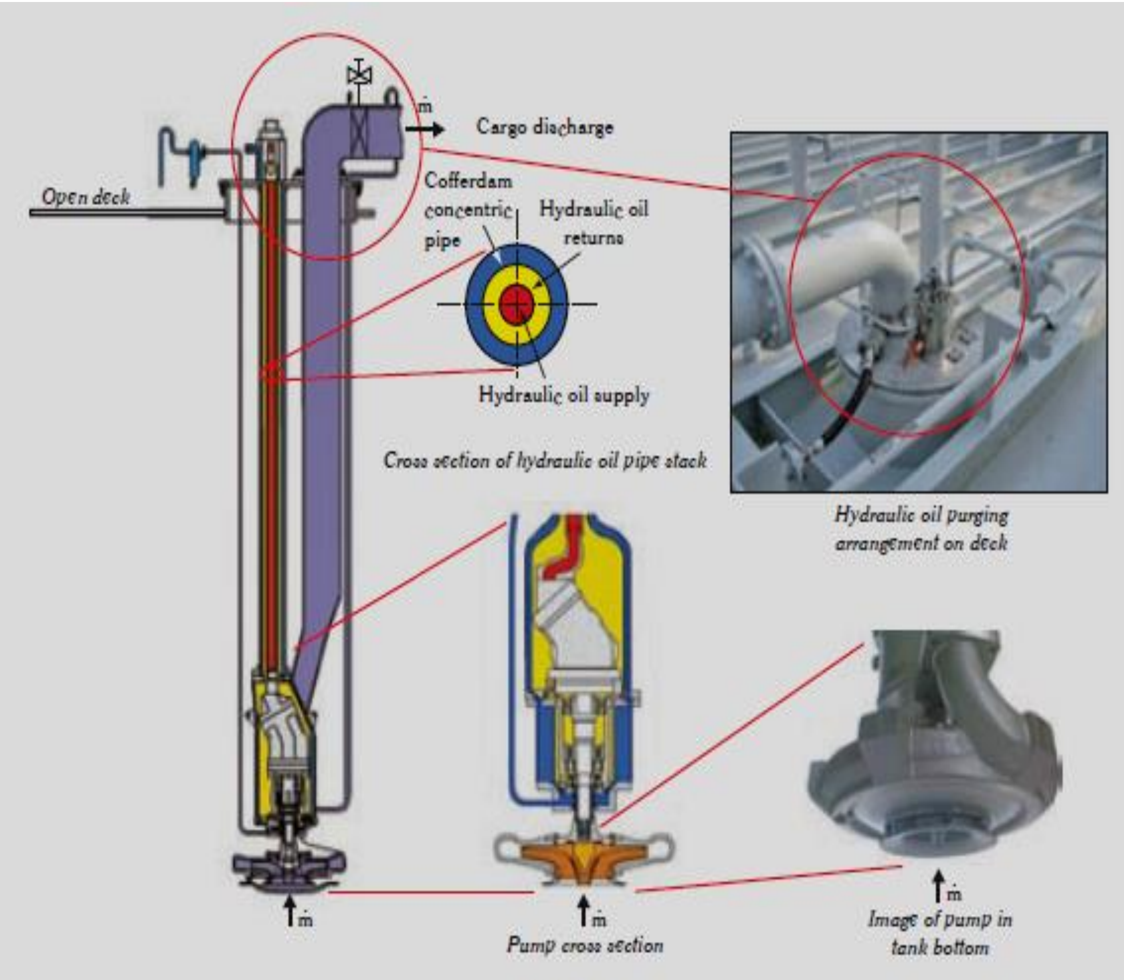


Fig. 8.71
Typical pump configuration, the hydraulic oil supply pipe

and is connected to the hydraulic motor by a coupling that may have wedge shaped configuration or an appropriately shaped slot in which a pump coupling key is placed. The shaft support is achieved with ball bearings, which are lubricated by the hydraulic oil returning from the hydraulic motor to the power unit. The seal of the circulation pipe of the hydraulic oil with the pump shaft and the outer seal pipe is performed by particular lip type seals or with mechanical seals. With this intention mixing of the cargo with the hydraulic oil is prevented. The control for any leakage of hydraulic oil is achieved by supplying air or inert gas under appropriate pressure inside the sealing tube. The discharge is performed through a small diameter bypass line, ending in a collector of leakage on the deck near the extraction point of the discharge pipe. The control is carried out by measuring the amount of leakages that is collected in a given operating time period. Above the top plate of the vertical pipe for the supply of operational oil to the pump, the hydraulic oil supply valve is installed, by which the speed of rotation of the pump is controlled. The liquid from the volute casing of the pump is discharged through a pipe that is established in parallel to the hydraulic oil pipe. The discharge pipe reaches up to the deck, where the discharge valve is installed, which is used to check the flow towards the ship's discharging piping system. The drainage of the pump and the vertical discharge pipe after completion of tank discharging is realized by compressed air or inert gas.

Moreover the injection of air or inert gas is achieved through a small valve appropriately connected on the discharge pipe on deck. So, the stripping of the discharge pipe is performed through the bypass pipe whose one end is connected to the bottom of the discharge pipe, and the other after the discharge valve. Because there is no non-return valve installed at the suction of the submersible pumps, the discharge pipe stripping process must be done before the pump shutdown. The pump's installation onto the piping system is performed so that it can easily be removed in case of damage or repair without requiring disassembly of the hydraulic oil pipe and the discharge pipe. The lack of a non-return valve on the pump suction allows the discharge system to be used for the loading process of the tanks. In this case, an arrangement in the pump prevents the rotor to rotate backwards. The loading speed is reduced due to resistances in flow by the impeller.

Lastly these pumps can be also used for ballast seawater management. The ballast management pump operation is similar to the cargo pumps, except that the rotor of these pumps is designed for seawater management and it must always be immersed in water to facilitate initial suction.

2.4 ELECTRIC-MOTOR-DRIVEN SUMBERSIBLE CARGO PUMPS

Electric - motor - driven submersible cargo pumps are used to discharge cargo from liquefied natural gas (LNG) and liquefied petroleum gas (LPG) carriers. Their application for such cargoes is related to the very low cargo temperatures (cryogenic cargoes-approximately –162℃ for LNG and below –50oC for many LPG cargoes). In those temperatures the hydraulic oil that is used to operate the hydraulic - motor - driven submersible cargo pump is unsuitable. Each motor - driven submersible unit typically consists of a vertical centrifugal pump with single or double stage. One or two impellers are mounted on the lower end of an electric motor shaft.

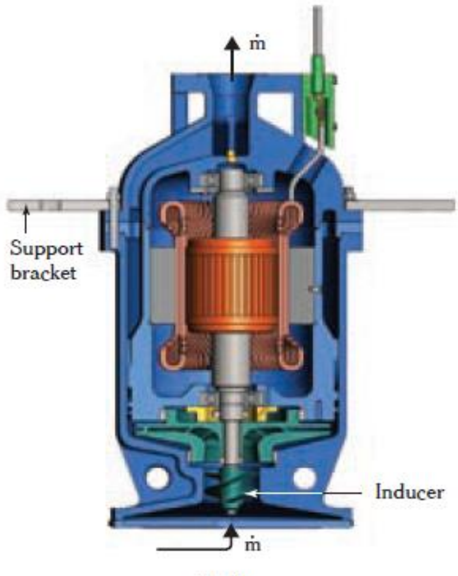


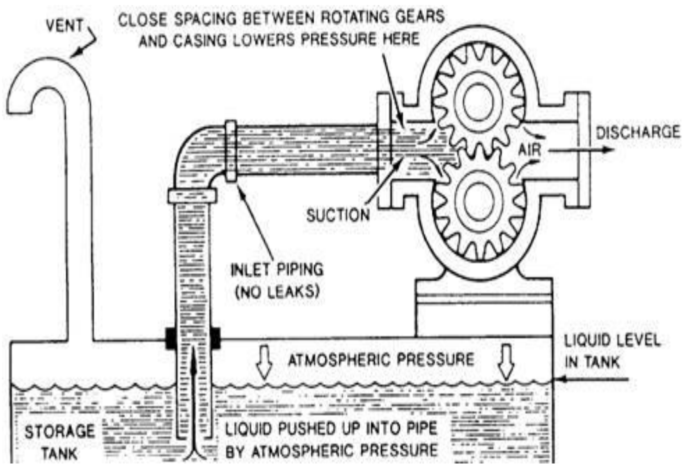
Fig. 8.75
Electric-motor-driven submersible cargo pump.

Furthermore, an inducer (auxiliary propeller-type impeller) is often installed at the inlet to the first stage impeller (the only impeller in a single-stage pump) to reduce the pump net positive suction head requirements. The submersible pump with electric motor is an integrated unit and a pump is placed in each tank. The liquid cargo enters at the bottom of the pump from the suction opening of the rotors and as it is discharged it enters an annular passage formed between the motor frame and an outer casing that surrounds the motor. A portion of pumped liquid usually passes through openings in the motor frame and flows through the motor. In addition to cooling the motor, this bypass flow lubricates the ball bearings that support the common pump and motor shaft, where the pump impeller is installed.

After leaving the top of the annular passage, the cargo that has been discharged by the pump passes through a connection located above the motor and enters a vertical pipe that leads to the discharging piping system on the main deck. The motors of the pumps are specially designed to operate without risk of causing an explosion (explosion-protected, Ex-e) following the strict regulations set by the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IGC Code)

2.5 ROTARY CARGO PUMPS

Rotary cargo pumps are used as main unloading pumps on vessels that carry high-viscosity cargoes. They are multiple-screw or lobe-type rotary pumps. Furthermore, in vessels that have centrifugal type main cargo pumps, it is sometimes possible to also have lower-capacity screw[1], lobe, or sliding-vane pumps that are used to strip cargo tanks. When the rotary pumps are used as the main cargo pumps, they may be located either in the pump room and a suction and discharge network is developed in the ship through which the cargo passes or as deep-well pumps typically by installing the pumps in the bottom of each tank. The electric motor that is used to operate the pumps in the pump room is installed in the engine room and the drive shaft of the pump passes through the bulkhead between the pump room and the engine room. In this way the driver can be isolated from explosive vapor in the pump room, because it is installed in an adjacent space and is coupled to the pump with a jackshaft that passes through a bulkhead stuffing box. In deep-well pumps, where a pump is installed in each tank, that pump is driven by an electric motor installed on the deck, and the transmission of motion is carried out by a line shaft that reaches the bottom of the tank where the pump is installed. The discharge of the pump is performed by a vertical pipe above the pump that reaches up to the deck. In many pumps the drive line shaft is enclosed within a vertical column pipe. Hence the cargo that is discharged by the deep-well rotary pump may pass through the column, or it may pass through a separate vertical pipe mounted adjacent to the column.



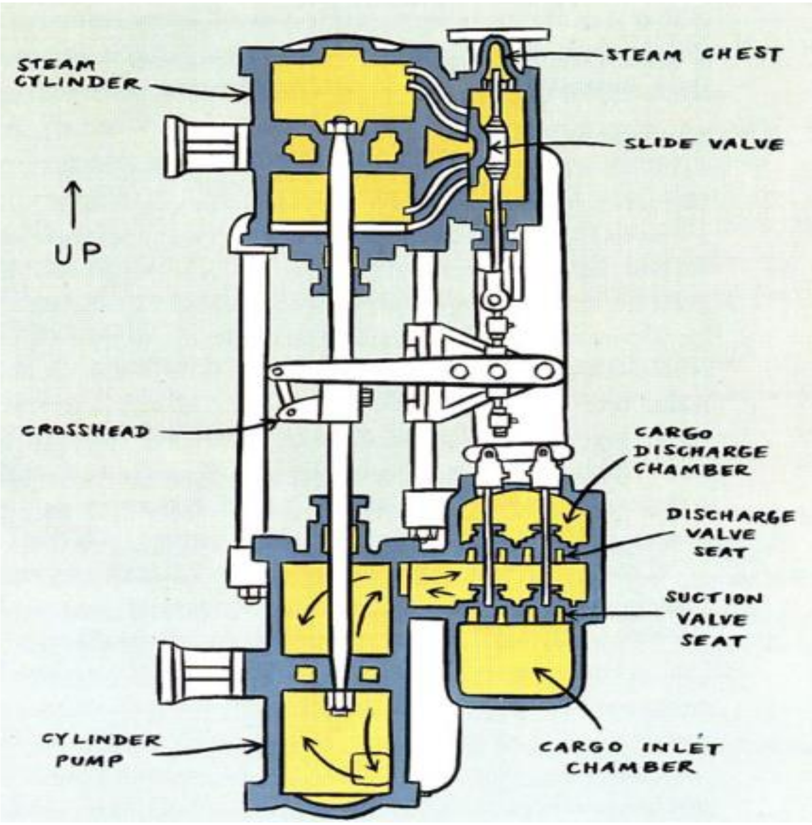
[1] A screw pump is a positive-displacement (PD) pump that uses one or several screws to move fluids or solids along the screw(s) axis.

2.6 RECIPROCATING/STRIPPINNG CARGO PUMPS

Stripping cargo tanks is carried out to ensure that as much cargo as possible is discharged during discharging operation in M/T vessels. Normally the vessel will use stripping pumps and lines for this purpose as they will reach the last drop of cargo that the bulk discharge pumps cannot reach. Stripping is an integral part of the discharge and if carried out properly should cause little delay to the vessel. Normally, the discharge plan will see the ship’s tanks discharged in a certain order. As soon as the first tanks become empty stripping can commence. Stripping can be carried out whilst the vessel is bulk discharging the remainder of the tanks and as the next tanks become empty, stripping of those tanks will tanks will begin. It is only at the end of bulk discharge that there will be a period of time when the vessel is only carrying out stripping. Stripping is carried out to get as much cargo as possible out of the vessel which the Owner is obliged to do.

The Charterer and the Receiver are also eager to see this happen as none of the parties wants to deal with a cargo shortage claim. Most stripping pumps are based on an operating principle called 'positive displacement'. The oil which enters the pump is mechanically moved from the suction side to the discharge side. This action creates a vacuum at the suction side of the pump, enabling the pump to 'lift' cargo from the tank into its pumping chambers. It is consisted normally of duplex (two pumping chambers), double-acting design. The internal mechanism is designed so that the cargo piston pumps on both the upstroke and the down stroke. The key components to the proper function of reciprocating pumps are the condition of the internal cargo valves. These should be examined regularly to ensure that their springs and seating arrangements are in good order. Reciprocating pumps are steam powered. To reduce the hazard from hot steam lines in the pumproom, the lines must be completely and tightly insulated to prevent vaporization or ignition of any cargo leaks which could spray or flow onto them.

A second type of stripping pump is a rotary or gear pump. These usually consist of two meshing gears which move the cargo between the pump casing and the gear teeth as the gears are rotated. These pumps are usually powered by an electric motor. They are very efficient and particularly suited for pumping high viscosity oils, such as lubricating oils or molasses. A third method of stripping tanks does not use a pump at all, but a device called an eductor. The eductor obtains its vacuum or 'lift' by use of a drive fluid, normally the stream of cargo from the main cargo pump discharge. The principal advantage of the eductor is that it cannot lose suction or be damaged by being run dry. The disadvantage is that once the main cargo pump is stopped, there is no drive fluid available and no further stripping is possible.



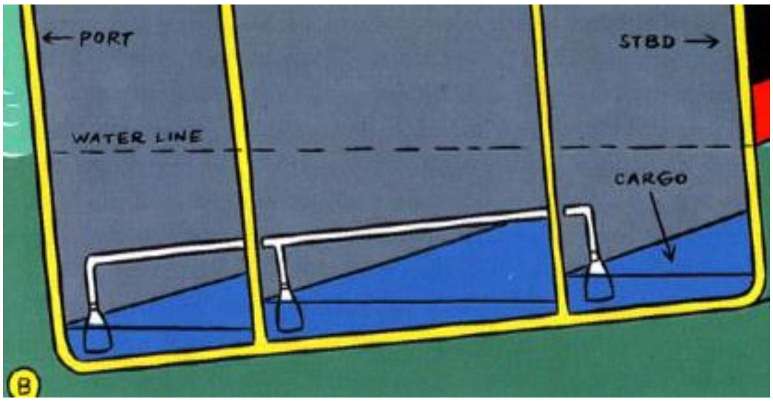
Stripping in high vapor pressure cargo[1] can be done but it requires pumps to be in good mechanical condition and carefully operated. Pumps should be operated at slow to moderate speed, else the rapid piston action of the reciprocating pumps will tend to 'flash'[2] the cargo in the cylinder, forming vapor or gas. The vapor or gas reduces the effectiveness of the pump and may cause it to lose suction entirely be becoming vapour bound. It is particularly important to keep enough cargo in one tank for priming the pumps when stripping high vapour pressure cargo. Keep stripping pumps separated making their suction lines common increases the tendency to become vapour

[1] The vapor pressure of a substance is the pressure at which its gas phase is in symmetry with its condensed phases (liquid or solid). The higher the vapor pressures of a liquid at a given temperature, the higher the volatility and the lower the normal boiling point of the liquid.

[2] Burn, Light up the cargo.

bound. The discharge valve of the pump may be closed slightly to provide additional back pressure to improve pump performance. Increasing the inert gas pressure in the tanks being stripped will increase the effective positive suction head in the tank and reduce the tendency to cargo vaporization, however if COWing[1] is being performed it will add additional pressure to the tank, which could cause the pressure relief valve [2]to lift. Stripping operations will be more successful if the ship is properly trimmed and listed. The largest trim aft, acceptable within the vessel's stress limitations, will provide the best draining of tanks.

On a 300 meter vessel (VLCC), according to the COW manual a trip of 4-6 meters should be maintained during stripping operation. More trim provides better draining. The ship should be listed to port or starboard, or trimmed with no list depending on the location of the tank suctions and on the according manual. In some ships the tank suctions are located in the aft, port corner of each cargo tank. It is important that these ships be listed to port when stripping to achieve the best drainage. Other ships have the stripping suctions in the inboard corners of the wing tanks and at the centre of the centre cargo tanks. These ships must have zero list for best stripping. The cargo watch officer must know the suction locations in the tanks and the chief officer should include stripping trim instructions in the discharging orders. If a list is required for stripping, the aft wing tanks should be retained to provide it.



[1] Crude oil washing (COW) is washing out the residue from the tanks of an oil tanker using the crude oil cargo itself, after the cargo tanks have been emptied.

[2] The pressure relief valve (PV) is a type of valve used to control or limit the pressure in a system or which can build up for a process upset, instrument or equipment failure, or fire. The pressure is relieved by allowing the pressurized fluid to flow from an auxiliary passage out of the system. The relief valve is designed or set to open at a predetermined set pressure to protect pressure vessels and other equipment from being subjected to pressures that exceed their design limits.

At the same time, the tanks can perform additional service as pump priming tanks. Recording the amount of stern trim in the logbook[1] every two hours while stripping is a good tip. Automatic then ullage tape [2] floats will tend to stick to the bottom of the tank after discharging heavy or viscous[3] cargo. Have the pumpman[4] roll up and secure the tapes immediately after stripping is completed. The pulsating discharge pressure of reciprocating pump can occasionally set up a harmonic oscillation in cargo transfer arms. The deck watch should be instructed to watch for this and to advise the cargo watch officer if it begins. The oscillation can normally be stopped by reducing the speed of the stripping pump. If stripping with an eductor system the smallest tank possible should be used to provide drive fluid for the eductor during the final stripping. This final tank will have to be drained with the main cargo pump, making complete draining unlikely.

If a charterer or terminal representative is on board, he should be encouraged (or challenged), to witness and confirm that the stripping operation was thorough and successful. This will, at the least, put to the test his commitment and the authority of his position. It may avoid the difficulties of proving effective stripping efforts and results to the independent inspector at the final survey. Independent inspectors will rarely undertake any form of initial survey (inspection before completion of discharge), on behalf of their clients.

---

[1] A logbook (a ship's logs or simply log) is a record of important events in the management, operation, and navigation of a ship. It is essential to traditional navigation, and must be filled in at least daily.

[2] Ullage Tape-and-Bob Procedure is an established way of measuring petroleum in tanks. This procedure is carried out by measuring the leftover space between the reference point on the ullage hatch and the top level of the liquid inside the storage tank. Once this is recorded, the liquid level inside the tank is found by subtracting the outage measurement from the gauging height of the tank.

[3] Cargo with viscosity.

[4] A pumpman is an unlicensed member of the Deck Department of a merchant ship. Pumpmen are found almost exclusively on tankers, and on oil tankers in particular. A pumpman performs all work necessary for the safe and proper operation of the liquid cargo transfer system. This includes but is not limited to: liquid cargo transfer pumps, liquid cargo stripping pumps, liquid cargo coalesces and separators, strainers, filters, associated piping, valves, fittings, and deck machinery directly related to the transfer of liquid cargo.

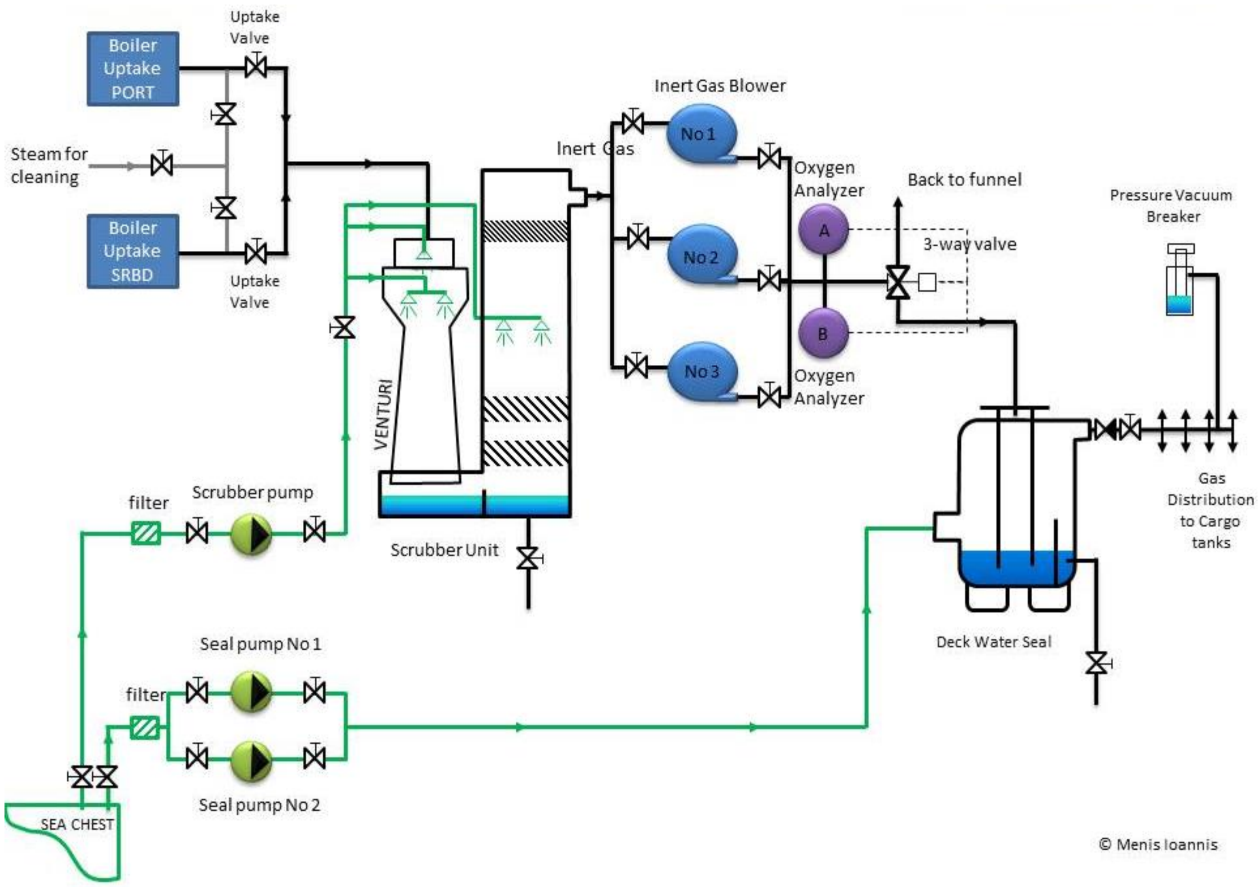
2.7 INERT GAS SYSTEM PUMPS

Oil tankers carry oil of different grades and quality, having property to produce flammable vapors and gases when loaded for transportation. Even with no cargo on board, there can be harmful flammable gases present in the hold. When the vapor produced by an oil cargo is mixed with certain concentration of air primarily containing oxygen, it can result in explosion which results in damages to the property, marine pollution and loss of life For safety against such explosion, Inert gas system is used on board. It can be through as a separate inert gas plant or flue gas produced by ship's boiler. Inert gas is the gas which contains insufficient oxygen (normally less than 8 %) to suppress combustion of flammable hydrocarbon gases. Inert gas system spreads the inert gas over the oil cargo hydrocarbon mixture which increases the lower explosion limit LEL (lower concentration at which the vapors can be ignited), simultaneously decreasing the Higher explosion limit HEL (Higher concentration at which vapor explodes). When the concentration reaches around 10 %, an atmosphere is created inside tank in which hydrocarbon vapors cannot burn. The concentration of inert gas is kept around 5% as a safety limit.

Inert gas systems may be classified into flue gas type, fuel oil type/fuel gas and nitrogen generator type depending on different sources of inert gas. In vessels where flue gas from a fossil-fueled steam boiler is used, a pump is usually required to deliver seawater to a scrubber (tower for cooling and cleaning of exhaust). In the scrubber the water is used to cool, clean, and desulfurize the inert gas. The scrubber pumps used are frequently single-stage electric - motor - driven, single suction impeller centrifugal pumps in vertical arrangement. These are installed at the lower level in the engine room and discharge seawater through appropriate nozzles to the scrubber. Additionally, on some vessels flue gas is used from a special oil-fired inert-gas generator where the inert gas for cargo tanks is produced. There, the seawater is provided by similar scrubber pumps. A separate centrifugal pump is also frequently required at inert gas systems to supply seawater to a wet-type deck seal that is used to prevent vapor in the vessel's cargo tanks from flowing backwards through the inert-gas supply piping and into the machinery spaces. It is installed in the engine room and is named deck seal seawater pump, because it is used to send the seawater in the wet-type deck device. The procedure through the pumps of inert gas is below:

a) Boiler uptake gases are drawn to the scrubber unit via flue gas isolating valve(s) to the scrubber unit.
b) In the scrubber unit the gas is cooled, cleaned and dried before being supplied in to the tanks.
c) Motor driven inert gas blowers supplies the treated gas from scrubber tower to the tanks through. They are mounted on rubber vibration absorbers and isolated from the piping by rubber expansion bellows.
d) Regulation of gas quantity delivered to deck is taken care of by the gas control valves and the deck pressure is managed by pressure controller. If the deck pressure is lower than the set point the output signal will be raised to open the valve more, and vice versa if the deck pressure is lower than the set-point. These valves will then work in cooperation to keep both the deck pressure / blower pressure at their respective set point without starving or overfeeding the circuit.
e) Before entering the deck line, the gas passes through the deck water seal which also acts as non-return valve automatically preventing the back-flow of explosive gases from the cargo tanks.
f) After the deck seal the inert gas relief is mounted to balance built-up deck water seal pressure when the system is shut down. In case of a failure of both the deck seal and the non-return valve, the relief valve will vent the gases flowing from the cargo tank into the atmosphere

g) The oxygen analyzer which is fitted after the blower separates the “production” and “distribution” components of the plant and analyzes the oxygen content of the gas and if it is more than 8%, it alarms and shut downs the plant.



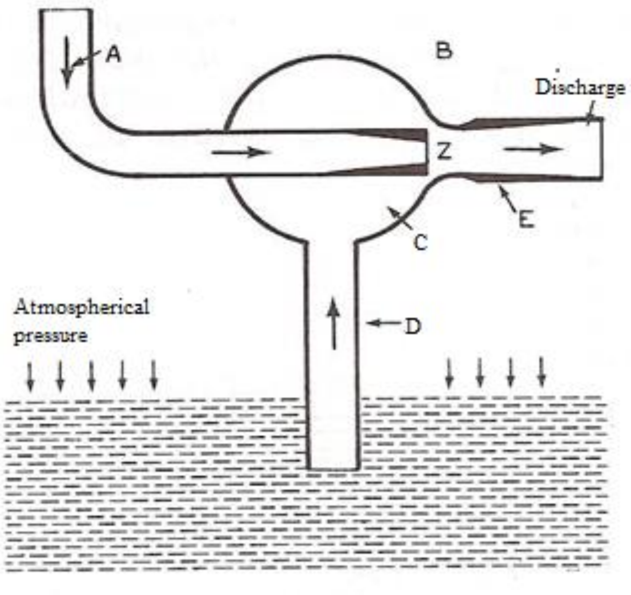
2.8 TANK CLEANING PUMPS

Ships use heavy fuel oil which has a very high viscosity. When stored in fuel tanks, this oil tends to stick inside the tanks forming layers of semi-solid substance. Moreover, many impurities of the oil settle down and stick to the surface of the tanks. It is therefore imperative that the fuel oil tanks are cleaned on a regular basis on ships. Generally, fuel oil tanks cleaning on the ship is done during dry dock and whenever the inspection of the fuel tanks is due. Cleaning is done for surveyor inspection or if there is any work to be done inside the tanks such as crack in fuel tank, leaking steam lines etc. For cleaning a tank various safety precautions are to be considered as it contains flammable gases and oil inside it.

On some vessels, either hot seawater is used to clean cargo tanks of residue that remains in the tanks after the liquid cargo has been discharged (tank cleaning), or the cargo itself is used during discharging to clean cargo tanks (cow-crude oil washing). A tank-cleaning or tank-washing pump takes suction from a sea chest and discharges seawater through a header in tank washing machines. This pump may be a separate pump or the fire and general service pump. Hence single and two-stage centrifugal pumps that are driven by steam turbines, electric motors, or hydraulic motors may be used in this application. In the crude oil washing process, the cargo pump that is used during cargo discharging takes suction by the same cargo tank and discharges in tank washing machines. So, for each vessel, the pump characteristics for the crude oil washing are those that apply for the cargo pumps. 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.

2.9 STRIPPING EDUCTOR PUMPS

Eductors are liquid Jet pumps that use water or other liquids under pressure to create a pumping action. In standard eductors drive the pressure liquid discharges through a single nozzle to start the pumping action. Ejectors are self priming and can handle liquid and solid mixtures. There are no moving parts to break down or wear out. Eductors are available with flanged or threaded connections, for portable use or for permanent installation. Ejectors are used to pump liquids from chain lockers, bilges, cargo holds, or any space that has to be pumped dry. They consist of a nozzle Z as shown in the image below through which liquid or gas passes through pressure. Passing the pressure drops and speed increases, so blank space is created in area C. The atmospheric pressure exerted on the surface of the liquid pushes it into the suction tube D and thus the pumping energy of the device is fully generated.



CHAPTER 3: CARGO AND PIPPING SYSTEMS ON CHEMICAL TANKERS

A chemical tanker is a type of tanker ship designed to transport chemicals in bulk. As defined in MARPOL Annex II, chemical tanker means a ship constructed or adapted for carrying in bulk any liquid product listed in chapter 17 of the International Bulk Chemical Code. As well as industrial chemicals and clean petroleum products, such ships also often carry other types of sensitive cargo which require a high standard of tank cleaning, such as palm oil, vegetable oils, tallow, caustic soda, and methanol. Chemical tankers normally have a series of separate cargo tanks which are either coated with specialized coatings such as phenolic epoxy or zinc paint, or made from stainless steel. The coating or cargo tank material determines what types of cargo a particular tank can carry: stainless steel tanks are required for aggressive acid cargoes such as sulfuric and phosphoric acid, while 'easier' cargoes — such as vegetable oil — can be carried in epoxy coated tanks[1]. The coating or tank material also influences how quickly tanks can be cleaned.

Typically, ships with stainless steel tanks can carry a wider range of cargoes and can clean more quickly between one cargo and another, which justifies the additional cost of their construction. Modern chemical tankers are arguably the most technologically advanced vessels of all the major commercial ship types. The complexity of this vessels results from wide range of cargo that they are designed to carry and the diverse nature and characteristics of these cargoes. Many of the cargoes carried on the modern chemical tankers are considered hazardous materials that require careful handling. The cargo systems of chemical tankers are what truly differentiate them from product and crude tankers. A vessel's cargo system, together

[1] An epoxy coating is the use of epoxy compounds as coatings or paints. It is generally two parts, which are mixed prior to application and consist of an epoxy resin that is cross-linked with a co reactant or hardener. Epoxy coatings are formulated based on the end product's performance requirements.

with its cargo tank arrangement and safety systems determines the cargoes that the vessel can or cannot carry. A chemical tanker's cargo system includes tanks, pumping systems, piping, venting systems, cargo monitoring systems, environmental control systems and tank cleaning systems.

The cargo pumping and piping systems are the principal systems in determining a vessel's operational flexibility. Although the IBC[1] code allows for a cargo pump room and shared piping systems, these features are no longer used in modern chemical tankers. The modern chemical tanker is based on the concept of the complete segregation of cargoes. Each cargo tank and its associated systems are independent from the vessel's other cargo tanks. At the heart of the complete segregation approach is the deepwell cargo pump. As its name suggests a deepwell pump is submerged in the fluid that it is pumping with its impeller placed in a well in the cargo tank top. Deepwell cargo pumps are of the centrifugal type and are driven by either a hydraulic motor located in the tank with the impeller or by an electric motor that drives a shaft that runs from the deck down to the impeller in the tank.

Hydraulic driven pumps of this type are more popular on chemical tankers than the electrically driven pumps because the electric motors can be eliminated from the cargo area and because variable speed control makes them attractive. Since centrifugal pumps do not pump high viscosity cargoes well, ships that have centrifugal deepwell cargo pumps and that frequently carry high viscosity cargoes, such as molasses[2] are typically outfitted with a deck mounted booster pump to assist in the discharge process. These booster pumps are of the positive displacement type, with screw pumps being used most often. The cargo pumping system must be

[1] Chemical tankers are required to comply with the various safety aspects detailed in Part B of SOLAS Chapter VIII, but are additionally required to comply with the mandatory International Bulk Chemical Code (IBC Code).

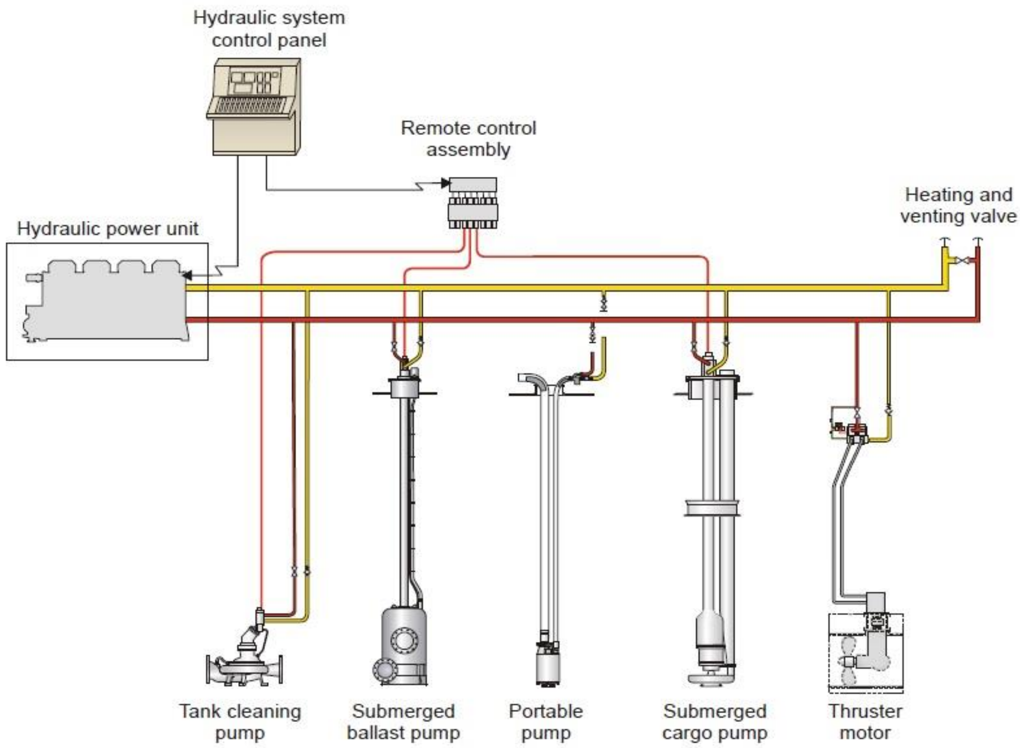
[2] Thick, dark brown juice obtained from raw sugar during the refining process.

constructed of a material which is compatible with, and resistant to, the cargoes carried. The cargo piping is not permitted to enter any other enclosed spaces such as the engine room or superstructure, and must be installed inboard of the damage penetration limits defined in the Code. Modern chemical tankers are designed from the outset with efficient stripping in mind and wherever possible the cargo tanks are smooth-walled, the bulkheads being either corrugated or provided with stiffening located in the adjacent ballast spaces or cofferdams. To promote good drainage the ship may be trimmed and heeled for cargo stripping in order that the cargo drains to the suction well. The bottom of the cargo tank may also be sloped to aid this process. The clearance between the impeller of a submerged pump and the bottom of the suction well can be as little as 20mm thus resulting in virtually complete drainage of the cargo tank. The cargo left in each pump and its associated piping can be stripped to shore by blowing air or nitrogen through the system. Using this arrangement, residue quantities in the region of 50 liters per tank are achievable on all of the ship configurations considered in this paper.

Means are being provided for measuring the cargo temperature, whilst ensuring protection of the crew. A cargo temperature alarm is also provided in a continuously manned location such as the bridge of the ship, in cases where overheating or overcooling could result in a dangerous condition. Furthermore the cargo tanks are required to have a closed gauging system, and hence a closed system of temperature monitoring, the tanks containing the cargo are provided with remote reading thermometers, which continuously measure the cargo temperature without exposing the crew to cargo vapors, and which give an alarm on the bridge if the maximum allowable temperature is exceeded. Lastly chemical tankers also use inert gas system but with nitrogen generators which produce inert gas and deliver it to the cargo tanks.

CHAPTER 4: THE FRAMO HYDRAULIC CARGO PUMPING SYSTEM

The Framo hydraulic cargo pumping system is designed for a flexible and safe cargo and tank cleaning operation on ships. It consists of one hydraulic motor driven cargo pump installed in each cargo tank, ballast pumps, tank cleaning pumps, portable pumps and other consumers, all connected via a hydraulic ring line system to a hydraulic power unit as shown in figure below. The submerged cargo pump is a single stage centrifugal pump with the impeller close to the tank top, giving a good pumping performance of all kinds of liquids and with excellent stripping performance. The hydraulic section is surrounded by a cofferdam that completely segregates the hydraulic oil from the cargo.



The hydraulic power unit consists of electric motor and/or diesel engine driven hydraulic power packs, where the hydraulic pumps are of axial piston type and swash plate design with variable displacement. The pump displacement is hydraulically controlled via the pressure regulator on each pump and by this system the oil delivery from the hydraulic pumps will always be the same as the oil consumption for the hydraulic motors. To control and limit the speed of the motor, a control valve is fitted for each motor. To keep the hydraulic oil clean and hydraulic oil temperature within desired range, a full flow filter and cooler are installed in the main return line. To regulate the oil temperature, a cooling water inlet valve is controlled from the Framo control system. To prevent impurities from entering the hydraulic system, the system is also pressurized (2-6 bar) when not in operation. Depending on the installation, this is done by a jockey or feed pump. The discharge from all cargo, ballast and other pumps connected to the system may be remotely controlled from Framo control panel, vessel's integrated control system (ICS) or locally at each pump via the control valve. The portable pump is controlled locally at the pump via the control valve. The equipment is manufactured in Norway 'Framo' facility and the most important benefits of the system are:

- Segregation of cargoes for vessel's safety and the environment.
- Maximum transport volume.
- Efficient stripping and tank cleaning.
- Hydraulic system without any electrical power equipment in cargo area.
- Automatic regulation of power needed and impossible to overload.

The Framo cargo pumping system is controlled by a Programmable Logic Control (PLC) installed inside the control panel. The PLC is programmed by Framo and provides the logic for safe operation of the system. All alarm inputs, except "Wear indication" are normally closed, meaning that the system is built up on normally closed contacts. Hence if a contact opens or there is a loose wire, an alarm condition occurs, i.e. FAIL TO SAFE. The alarms are divided into two groups:

- ✓ Shut down
- ✓ Alarm for indication (pre-warning) only

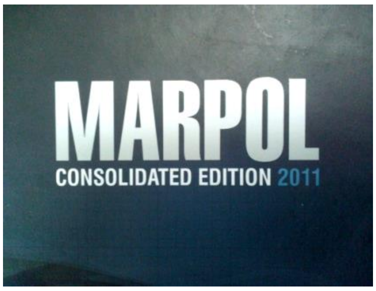
Each alarm is indicated with a flickering light and an acoustic signal. The "Horn silence" button must be operated before it is possible to confirm the alarm by the "Acknowledge" button.

Group a) alarms: The "Reset" button must be operated to clear the alarm.

Group b) alarms: Automatic reset

There are also used feed pumps that are started/stopped manually from control panel or from the electric starter cabinet. However, when initiating start of the first main power pack, two of the feed pumps will automatically be started (high capacity mode) before the power pack is started. When the power packs are stopped, the feed pump will switch from high capacity mode to low capacity mode (only one feed pump running) automatically after 10 minutes if this is not done by operator. A running signal is provided for indication on the control panel. The high capacity mode is used to keep feed pressure on the suction side of the main hydraulic pumps. Two feed pumps must therefore be running before the main power packs can be started. If one of the feed pumps stops when running in high capacity mode and the power packs are running, the third feed pump will start automatically. If the running signal for the third feed pump is not obtained within 3 seconds, the feed pressure low alarm will be initiated and the system will be shut down. One of the feed pumps must always be running when the system is not in operation and if it stops, the protection pressure low alarm is initiated.

CHAPTER 5: PUMPROOM, PIPPING-LINE ARRANGEMENT AND MANIFOLD STANDARDS FOR TANKERS



The oil companies, organizations and forums decided after a few incidents at sea including ship wrecks and serious pollution to produce some standards for all the oil tankers that are seaworthy and transfer cargo worldwide. The international maritime treaty such as SOLAS (Safety Of Life At Sea), the international forum OCIMF (Oil Companies International Marine Forum), the convention of MARPOL (Marine Pollution convention), the association INTERTANKO (International Association of Independent Tanker Owners) and other organizations such as IMO (International Maritime Organization) have introduced some amendments and specifications for oil tankers that all ships shall comply for safety reasons. Furthermore these specifications produced by all these companies and forums and conventions refer to the structural part of the ship and also the machineries that should be used and all the important details that have to comply with safety on board. From all these only OCIMF and MARPOL describe the procedures and the construction of cargo pumps and related systems and they are analyzed below.

5.1 STANDARDS BY OCIMF

OCIMF (Oil Companies International Marine Forum) was formed in April 1970 in response to the growing public concern about marine pollution, particularly by oil, after the Torrey Canyon incident in 1967. OCIMF was granted consultative status at the IMO in 1971 and continues to present oil industry views at IMO meetings. Since then, its role has broadened to take account the changing maritime activities of its membership. Its remit now covers tankers, barges, offshore support vessels and terminals and its advice extends to issues like shipping in ice and large-scale piracy, which rarely troubled the oil industry when OCIMF was first created in the 1970s. The current membership of OCIMF comprises 112 companies worldwide .It is a voluntary association of oil companies with an interest in the shipment and terminal ling of crude oil, oil products, petrochemicals and gas.

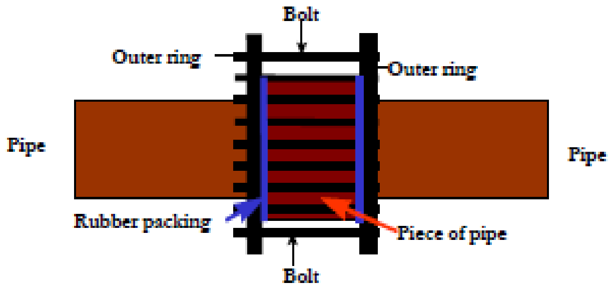
The design of a tanker must take into account the particular trade for which it is intended. A high rate of loading and discharging is desirable, pumping capacity and size of pipelines being important in this respect. The safety factor must be borne in mind with the provision of a fire smothering installation and the provision of cofferdams at the ends of cargo spaces, ventilating pipes to tanks, etc. Ships intended for the carriage of heavy oils would have steam heating coils fitted in tanks. The cargo space is generally divided into three sections edgeways ships by means of two longitudinal bulkheads and into individual tanks by transverse bulkheads. The maximum length of an oil tank is 20%L (L is length of vessel) and there is at least one wash bulkhead if the length of the tank exceeds 10%L or 15 m.

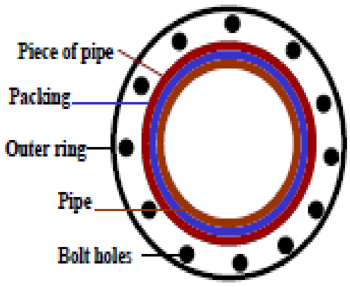
Tanks are generally numbered from forward, each number having port, centre and starboard compartments. Pump rooms are often located aft so that power may easily be supplied to the pumps from the engine room, but ships designed to carry many grades of oil at once may be fitted with two pump rooms placed so as to divide the cargo space into three sections. The system of pipelines used in a tanker is such that great flexibility is possible in the method of loading or discharging, and different parcels of cargo may be completely isolated from one another during loading and subsequently during discharge. In some cases a small, separate line is used for stripping the last few inches of oil from each tank. (MARPOL line) . 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. In every oil tanker, a discharge manifold for connection to reception facilities for the discharge of dirty ballast water or oil-contaminated water shall be located on the open deck on both sides of the ship.

In every oil tanker, pipelines for the discharge to the sea of ballast water or oil contaminated water from cargo tank areas which may be permitted under regulation 9 or regulation 10 of MARPOL 73/78 Annex I shall be led to the open deck or to the ship's side above the waterline in the deepest ballast condition. In new oil tankers means shall be provided for stopping the discharge into the sea of ballast water or oil contaminated water from cargo tank areas, other than those discharges below the waterline permitted under paragraph (6) of regulation 18 of MARPOL 73/78 Annex

I, from a position on the upper deck or above located so that the manifold in use referred to in paragraph (1) of this regulation and the discharge to the sea from the pipelines referred to in paragraph (2) of this regulation may be visually observed. Means for stopping the discharge need not be provided at the observation position if a positive communication system such as a telephone or radio system is provided between the observation position and the discharge control position. The line system has a diameter and thickness adapted for use and necessary capacity of pressure and flow. The pipes are adapted in handy sized lengths, to position easily in place during construction and to ease prospective disconnecting when repairs and renewals are required. The lines are made of either entirely cast iron or rolled steel plates which are completely welded in the pipe's length direction. To connect pipe lengths, flanges are used. These flanges are rings of steel welded to the pipe ends. The flanges have plain surfaces, and with a gasket in between, a liquid proof connection of the pipes is achieved. In the flanges, holes are drilled for the steel bolts. Usually the number of drilled holes is similar to the pipe's diameter in inches.

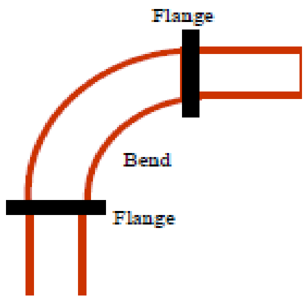




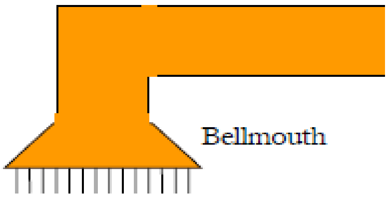
This makes it easy to control the reducers between the vessels manifold and the load/discharging arms (hoses). The lines rest on supporters, which are welded to the tank bottom, pump room bottom, main deck and so on. To reduce wear and tear when steel meets steel, a shim of wood or another soft material is placed in between the pipe and supporter. The pipes are fastened to the supporter with hoops.

Now and then, a vessel is exposed to heavy weather forces. When standing on the bridge, viewing pitching on the main deck, it is possible to observe how the hull is bending and distorting due to the weather condition. A stiff line system would easily be shaken badly. To make these lines follow the vessel's movements, caused by the power in these forces, the use of expansion couplings is necessary. An expansion coupling is a coupling, which makes the pipes capable of moving back and forth inside the coupling. The coupling consists of a ring (piece of pipe), two rubber packings and two outer rings with holes for bolts. The “piece of pipe” is enclosing the two pipe ends, which are placed towards each other. The end of “the piece of pipe” has a fold where the rubber packing fits in like a wedge. On each side, there is an outer ring enclosing the rubber packing and the “piece of pipe”. Bolts through the outer rings keep the coupling together. Remember to cross tighten the bolts to achieve uniform tightening. The expansion coupling is very efficient.

It functions 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.



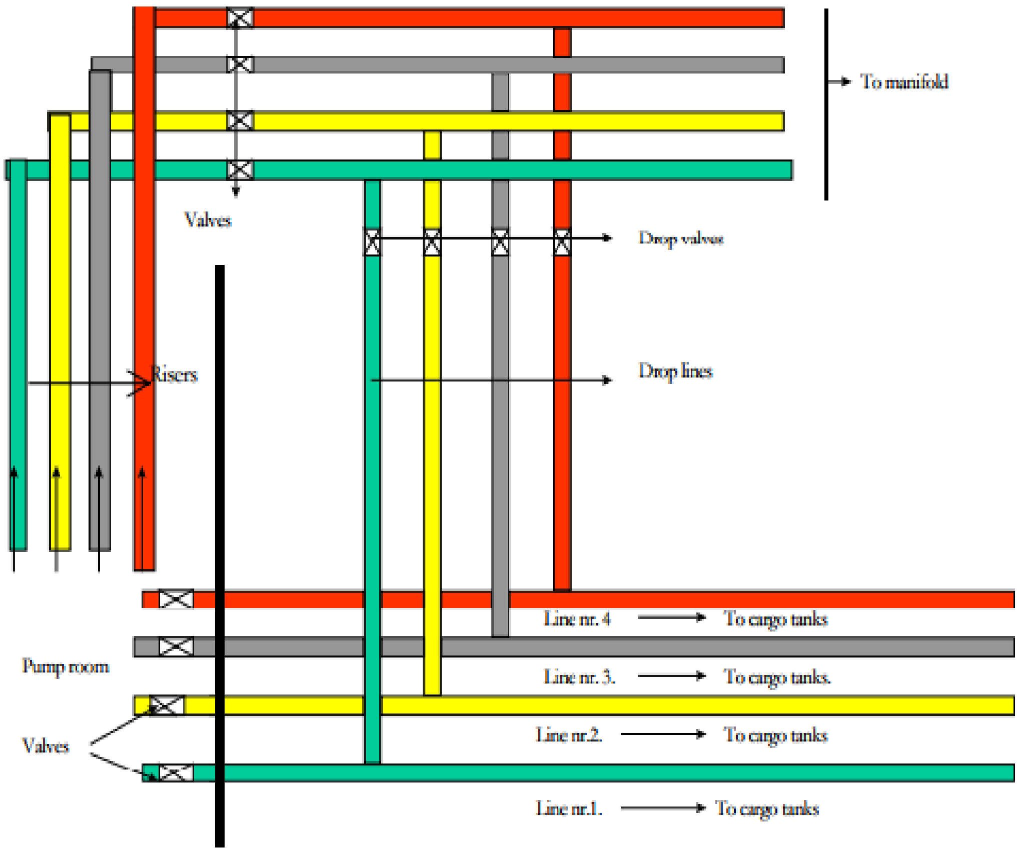
Suction (bellmouth, "elephant foot")

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. In the centre tanks, the main suctions are placed approximately in the middle, and two stripping suctions are placed (one on the port side in the tank and one on the starboard side in the tank .The suction "stub" is shaped like an inverted hopper and is called the bellmouth or "elephant foot". The area of the bellmouth is required to be one and a half times the size of the loading line. Beneath the bellmouth are welded bars, which subdue the movement of liquid influx and thereby avoid or reduce pump cavitation. The bellmouth is placed with the opening toward the tank bottom, with as little space as possible, without blocking. Usually, the bellmouth on the main suction is placed with a clearance of approximately 10cm from the tank bottom and with the stripping suction, a clearance of approximately 3 - 5cm.

The oil tanker additionally consists of Drop Lines. The vessel is fitted with 4 centre tanks and 5 pairs of wing tanks for cargo. The cargo main lines are located in the vessel's centre tanks. With the term "bottom lines" we understand that the location of these lines will be on the bottom of the vessel, usually supported about 4 - 6 feet above the vessel's bottom. Crossover valves[1], 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. Moreover 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.

1 Athwart ships tank lines joining the main lines are known as crossover lines and crossover valves separate the main line from each other as well as separating individual tanks in other words crossover valves separated in at athwart ships direction.

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. These drop lines are used during loading. By closing the deck line's master valves[1], the cargo is lead to the vessel's cargo tanks when using these drop lines. So, the pump room is completely isolated from the cargo during loading. However, during discharging the drop lines are isolated from the cargo by keeping the drop valves closed. You must, however, during loading not forget to keep a routine for checking the pump room both for leaks and being gas free for entry.



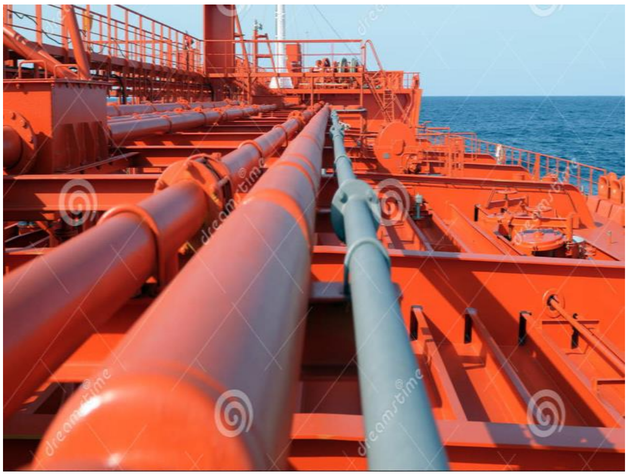
On a crude oil carrier the pump room is the main point between the cargo tanks and the main deck, all the way to the manifold, where the ship lines are connected to shore lines. From the cargo tank the bottom lines lead all the way to the main cargo pumps. To simplify the matter we divided the pump room in two parts. One part is called the cargo pumps free flow side the other part is called the cargo pumps deliver side.

[1] At each place where a fore & aft pipeline passes through a bulkhead a valve is fitted in the line. This is known as a master valve and separates the tank served by the same fore & aft line.

These sides are commonly called suction side and pressure side. Note: a centrifugal pump does not have any ability of suction. On the cargo pumps free flow side, the bottom lines end at the cargo pumps. On this side, some cross over lines connect the systems to each other. The first crossover after the tank area is the stripping cross. The stripping cross is located crosswise from the bottom lines, and connected to the bottom lines with pipe bending and valves. Further towards the COP, on the bottom lines, you find a valve on each of these lines, usually called the “bulkhead valve”. This is because the location is normally close to the bulkhead, separating cargo tank area and pump room area. Further on the free flow side of the cargo pump, is the seawater suction crossover line. This line is also crosswise from the bottom lines and is connected to the sea chest on each side (port and starboard). This line supplies the cargo pumps with seawater during water washing of tanks and lines, and used when ballasting for departure, if or when necessary.

Crossing between different lines and pumps is also a possibility with this cross over line. From the other hand we have and the delivery side of the pumps. In this side of pumps the first stop is the first valve after the cargo pumps, the delivery valve or throttling valves. Names like discharging-valve, pressure-valve is also common. The most descriptive is “delivery valve”. With this valve, we can adjust the backpressure and the load conditions for what the pump is going to work against. Centrifugal pumps are working their best against a certain load. When starting a centrifugal pump, start it against a closed delivery valve, which compares with the recommendation. On the delivery side, the rise lines lead from the cargo pumps to the main deck. The first is the cow cross over line. With this line, we can bleed off from any riser for supplying crude oil washing during discharging, or supplying water during tank washing. The same line also supplies “drive” when using the ejector for stripping. The second cross over line leads to a higher inlet in the port slop tank (primary slop) and to the line called “High Overboard”. The high overboard line is the line where ballast water and washing water is discharged overboard via oil detection monitor equipment.

As the drawing shows, it is possible with any cargo pump to cross over to any of the risers. The pump room is also fitted with other equipment for handling cargo and ballast. The ballast pump is only used for the segregated ballast. The segregated ballast system is totally isolated from the cargo systems. The ballast pump is connected to the FP-tank (Fore Peak). The ballast system has its own sea chest. Still there are some vessels, which have separated lines from the ballast pump to the main deck, which end in drop lines to the cargo tanks that are dedicated for departure/arrival ballast. These tanks can be ballasted without involving any part of the cargo line systems. The stripping pump is operating its own system, which (via a stripping cross over) strip the last amount of cargo from tanks, cargo pumps and lines, through the small diameter line and ashore. In addition to a stripping pump and an ejector, the vessel is equipped with a vacuum stripping system, which gives the cargo pumps the ability to maintain suction when only a small quantity is left in a tank.



When it comes to deck lining the main line system changes name, depending on where it is placed. From cargo tanks to the cargo pumps, the main lines are called “bottom lines”. From the cargo pumps delivery side, the name changes to risers. When they appear on the main deck, the names are deck lines. Very often the systems are numbered from one side of the ship to the other, for instance from port to starboard or vice versa.

The deck lines are a lengthening of the risers from the pump room. Each deck line can be isolated to the pump room by the deck master valve. The deck lines end up at the manifold crossover lines. These manifolds are where the vessel is connected to the terminal by hoses, kick arms etc. The manifold line is numbered with the same number as the main line it belongs to. The conclusion will then be: Manifold no 1 is connected to drop line no 1, which leads down to bottom line no 1, which leads to cargo pump no 1, which leads to riser no 1, which leads to deck line no 1, which leads to manifold no 1. The same occurs with system no 2, 3, and 4.

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

Furthermore at the oil tankers also exists on deck the cow main line with branches leading to the ships crude oil washing machines. This line comes from the cow cross over line on the delivery side in the pump room. The branch lines from the cow main line are gradually reduced in dimension all the way forward to the cow machines. This reduction is to avoid pressure fall on the flow used for crude oil washing. It is possible to bleed off to the cow main line from any of the main cargo lines. This contributes to several alternative solutions in the cow operation. There are always variations from ship to ship, but the main principle is the same.

Lastly also inert lines are located on main deck to control the atmosphere in the cargo tanks 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 (mast) riser[1], 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.

[1] A mast riser is used to maintain a positive pressure of inert gas at the time of loading of cargo and during the loading time it is kept open to avoid pressurization of cargo tank.

5.2 STANDARDS BY MARPOL

MARPOL

~Annex I- Regulations for the Prevention of Pollution by Oil~

~Chapter 4 - Requirements for the cargo area of oil tankers. Part A – Construction~

(Regulation 30 - Pumping, piping and discharge arrangement)

In every oil tanker, a discharge manifold for connection to reception facilities for the discharge of dirty ballast water or oil-contaminated water shall be located on the open deck on both sides of the ship. Additionally in every oil tanker of 150 gross tonnages and above, pipelines for the discharge to the sea of ballast water or oil-contaminated water from cargo tank areas (which may be permitted under regulation 34[1] of this Annex) shall be led to the open deck or to the ship's side above the waterline in the deepest ballast condition. Different piping arrangements to permit operation in the manner permitted in subparagraphs 6.1 to 6.5[2] of this regulation may be accepted. In oil tankers of 150 gross tonnage and above delivered after 31 December 1979, as defined in regulation 1.28.2[3], means shall be provided for stopping the discharge into the sea of ballast water or oil-contaminated water from cargo tank areas, other than those discharges below the waterline permitted under paragraph 6 of this regulation, from a position on the upper deck or above located so that the manifold in use (referred to in paragraph 1 of this regulation and the discharge to the sea from the pipelines referred to in paragraph 2 of this regulation) may be visually observed. Means for stopping the discharge need not be provided at the observation position if a positive communication system such as a telephone or radio system is provided between the observation position and the discharge control position. Moreover every

[1] See appendix for regulation 34 (page:

[2] See appendix for subparagraphs 6.1 to 6.5 (page:

[3] See appendix for regulation 1.28.2 (page:

oil tanker delivered after 1 June 1982, as defined in regulation 1.28.41, required to be provided with segregated ballast tanks or fitted with a crude oil washing system, shall comply with the following requirements:

1. It shall be equipped with oil piping so designed and installed that oil retention in the lines is minimized and
2. Means shall be provided to drain all cargo pumps and all oil lines at the completion of cargo discharge, where necessary by connection to a stripping device. The line and pump draining shall be capable of being discharged both ashore and to a cargo tank or a slop tank. For discharge ashore a special small diameter line shall be provided and shall be connected outboard of the ship's manifold valves.

Under regulation 30.2, lines for discharge to the sea above the waterline must be led either:

1. To a ship's discharge outlet located above the waterline in the deepest ballast condition or
2. To a midship discharge manifold or, where fitted, a stern or bow loading/discharge facility above the upper deck

[1] See appendix for regulation 1.28.4 (page:

CHAPTER 6: PUMP WEAR, COROSSION AND MAINTENANCE

6.1 PUMP WEAR, COROSSION AND MAINTENANCE IN GENERAL

Pump wear is a result of erosion and mechanical stress, and constitutes a high economic burden on the ship's budget. Furthermore, in order for a pump to respond to the particular environmental operating conditions, it is necessary for it to be made of durable material suitable for the fluid that is handled. But despite the strength of the construction material, continuous operation causes damages in different areas, depending on the pump type, affecting its performance. Problems can arise in stretches of pipeline that run at lower pressures. In these spots, water droplets can coalesce and fall out of the oil flow. They might inundate globs of sand or dirt that have also fallen out of the crude-oil mix and form a watery sludge on the edge of the pipe. Once a watery muck forms in one part of the pipe, the natural process of corrosion speeds up.

The crude can also serve as a breeding ground for anaerobic bacteria[1], which form slimy, sulfur-producing colonies on the inside of the pipe. To make matters worse, crude oil comes out of the ground hot, and the pipelines are insulated to maintain those high temperatures. Oil flows better when it's hot, but heat also exacerbates

[1]Anaerobic bacteria, or anaerobes, are bacteria that do not need oxygen to live. In humans, these bacteria generally live in the gastrointestinal tract, but they may also be found in other places outside the body, including in the soil and water, in foods, and in animals. Some anaerobes are beneficial to humans, but others can cause illnesses.

.

corrosion within the pipes. Sometimes the oil companies introduce corrosive bacteria, water, or gas into reservoirs themselves. When an oil pipeline gets old, it starts to lose pressure, and it becomes harder to draw out the remaining crude. Thus, for each type of pump one can mention that:

1) In piston pumps, wear appears at the piston rings, at gland packings that seal the piston rod and at the valves. The wear in the glands can easily be detected due to the external leakages, so appropriate maintenance and repair actions should be taken by the ship's crew. However, a leak due to the wear of the piston rings and the valves creates internal leakages which can only be detected by crew's attention, since the pump flow and the pressure that develops inside the cylinder are decreased. To address the wear, maintenance jobs are performed, which include replacement of the piston rings, the valves or the sealing elements of the valves. These parts may be constructed by copper alloy or elastomeric o-rings.

2) In positive displacement rotary pumps, the wear appears in the leakages between the rotating parts and the casing. It is essentially a function of the pressure exerted on the surfaces of the pump components and the frictions developed among them, or a combination of both. Moreover, the heat which is developed per surface unit depends on the pressure and the friction due to the number of rotations and contributes to the wear of the components. For these reasons, the impellers, especially for pumps which transfer liquid with abrasive properties, are either constructed by durable material or function at lower rotation speeds. If the reduction on rotations still does not limit the wear conditions, then the surface pressure at the pump components is reduced. Exception to these ways of addressing the wear is the use of flexible materials for the construction of liquid transfer rotors which prevent the leakages. The transport of liquid in peristaltic pumps constitutes an example.

The term "pump maintenance" refers to several inspections and works that must be performed at regular intervals during the pump's operational "life". Considering that the wear of a machine is roughly proportional to the square of operating time, prudential controls as well as repairs on defects and wear that are detected manage to:

1) Protect the pump from serious damage,

2) Extend the duration of its operational life,

3) Ensure the reliability and

4) Limit the costs, since the failure is restored at an early stage. As regards pumps maintenance, apart from external controls during operation, the lubrication of bearings, the control of glands and the transmission system (coupling) of the drive and the motor, regular inspections-repairs are performed which are determined by the manufacturers. These inspections are made by disassembling the pump, and include:

1) Inspection of bearings.

2) Control of packing rings on stuffing box or the mechanical seal of the shaft.

3) Alignment of the coupling and its elastic elements, for possible damage.

4) Inspection of the internal surfaces of the housing for damage from erosion and cavitation.

5) Measurement of the rotor bearings for wear.

6) Control of the radial clearances between impeller and wear rings.

7) Inspection of the rotor surfaces for possible cavitation.

8) Checking the stability of the rotor support on the shaft.

9) Inspection of the sealing to the suction and discharge valves, if any. Components that exceed the operating limits of wear (according to the ones specified by the manufacturer) are replaced with new, while spare parts numbers of those which have been used are recorded in a list for ordering and storage, in order to be readily available for use when necessary.

These days (almost) all repairs that are required, as well as all the necessary inspections, are contained in a table (check list) completed by the crew which performs the maintenance, and kept in a log file. This table is an aid not only during maintenance, but it is also used as a reference point for the pump status and provides evidence during the audits carried out by the authorities. The malfunctioning of pumps may be due to various causes. Therefore, the symptoms of abnormal operation and the possible causes could be designated in tabular form, which includes proposals on how to address them. This table, covering each pump type, is usually contained in the manufacturer's manual and it is a quick reference point which helps to solve the problems presented. See appendix for “Symptoms and possible causes of pump abnormal operation and proposals for restoring them.” (page:)

6.2 MAINTENANCE OF CENRTIFUNGAL PUMP

Maintenance is a vital part for the pumps all around the oil tanker. For the centrifugal pumps that are found almost in all tankers nowadays operating problems that may cause damage to the centrifugal pump can be either hydraulic or mechanical. In the first category (hydraulic), a pump may fail to deliver liquid, it may deliver an insufficient capacity or develop insufficient pressure, or it may lose its prime after starting. In the second category (mechanical), it may consume excessive power or symptoms of mechanical difficulties may develop at the seal chambers or at the bearings or vibration noise or break-age of some pump parts. For example increased wear at the running clearances must be classified as a mechanical trouble but it will result in a reduction of the net pump capacity—a hydraulic symptom—without necessarily causing a mechanical breakdown or even excessive vibration. So it is important to classify symptoms and causes separately. Daily inspections should be made and any irregularities in the operation of a pump should be recorded and reported immediately. This applies to changes in sound of a running pump, abrupt changes in bearing temperatures and seal chamber leakage. A check of pressure gauges and of flow meters and vibration should be made regularly during the day. If recording instruments are provided a daily check should be made to determine whether the current capacity, pressure, power consumption or vibration level indicates that further inspection is required. Trending charts should be produced to allow observation of changes as a function of time. Certain trends may allow for scheduled outages to address deterioration of specific performance values. One routine maintenance that can be made during pump operation is:

- Clean bearing bracket from any oil if found.
- Check oil drain plug.
- Lubricate the bearings.
- Inspect suction and discharge flanges for any leak.
- Inspect pump casing for any unusual damage signs.

- Inspect the seal.
- If the pump is offline check the coupling and its shims for any damage.
- Make sure that the coupling guard s well tightened to pump base plate.
- Check that motor alignment bolts are all in place.

6.3 MAINTENANCE OF FRAMO CARGO PUMPING SYSTEM

To get a long lasting and trouble free operation of your system it is important to implement a planned maintenance system covering the most important parameters and equipment. Following a planned maintenance system will reduce the risk for expensive break down and repair. Correct operation is also an important parameter to keep the maintenance cost at an acceptable level. It is therefore important that operation instructions are followed carefully. Generally there are few maintenance activities on the system but we would like to highlight following:

- Purging of cargo pump cofferdam or level control of liquid filled cofferdam according to instruction in the manual. This gives the condition of the seals in the cargo pump, and evaluations of the result enable marine engineers on board to plan any seal change. Open cofferdam on the cargo pump is important to ensure you have the barrier between the hydraulic section and cargo tank. A pump with a blocked cofferdam should not be used since the condition of the seals cannot be checked.
- Do not use higher hydraulic pressure on the system than necessary. This will increase the lifetime of hydraulic components.
- Avoid air in the hydraulic system. Vent the system regularly and always after service on the hydraulic part.
- Mixing of different hydraulic oils should be avoided.
- Only use genuine spare parts to ensure a trouble free operation.
- Keep a few sets of spare seals and critical spare parts on board if they are needed at a difficult situation. The cargo set for cargo pumps consists of an upper and a lower seal, and both must be changed together.
- Ensure that the portable pump is included in planned maintenance programs. The pump must be ready when needed.
- Move service valves annually to ensure they are operational when needed.
- Keep the hydraulic system clean.

If a leakage is detected, check if the flange connection is tight, retighten if necessary. If this does not stop the leak, drain and open the equipment for repair. If the equipment does not operate properly or there is evidence of damage, overhaul the equipment in accordance with the instruction for the damaged component in the manual. Before opening the hydraulic pumps or other hydraulic driven equipment, drain the oil. Always refill with oil upon completion of the repair operation. Ensure proper air venting. Moreover anodes should be inspected regularly until rate of consumption is established. Inspection intervals for the zinc anodes assembled on ballast pumps and other pumps depends mainly on time of exposure, water level in tank, water corrosivity and temperature. Please note that the anodes included by Framo are only intended for protection of the pump, not the tank. On deck soot and dust, in addition to humidity and chloride concentrations present in the marine atmosphere may affect both the corrosion resistance and the visual impression of the stainless steel surface unless it is cleaned regularly. The cleaning can be done either by chemicals or mechanically. For equipment which is painted a brush-up painting may be necessary.

Lastly wear on the cargo pump wear rings depend on the type of cargo and also the running hours. Normally this is indicated by poor stripping performance and problems related to parallel pumping. Further analyses can be carried out by testing the cargo pump against closed discharge valve. This test requires calibrated manometers and accurate measurements. These tests are normally carried out and analyzed by a Framo service engineer either at a predocking inspection or special attendance for this activity. Worn wear rings will increase the discharge time. It is therefore recommended to change wear rings if the pump is overhauled for other reasons. See appendix (page:) for table of the symptoms and possible causes of pump abnormal operation and proposals for restoring them.

CHAPTER 7: PUMP OPERATION

The installation and operation of each pump depends on its type and is described in the manufacturer's instruction book. Furthermore, the starting and performance is related to other factors, such as the position of installation in relation to the system that it serves, the number of pumps used in the same pumping system, e.g., if two pumps in one pumping system operate in parallel to each other or in series. Generally, regarding the starting and operation of pumps, one can mention that:

1) The pump installation must be as close as possible to the suction source of the liquid so that the operation, inspection and monitoring is facilitated.
2) The piping system must be simple, with the smallest possible number of curves and the right alignment, so as to prevent the creation of air cavities that impede the liquid flow.
3) The motor of the pump must be protected from exposure to humidity, even if defined by the regulations as being constructed as a protected type.
4) The base of the pumps must be reinforced so as to withstand the ship's vibrations and the tendencies which are developed during the start of its operation.
5) The coupler of the pump with the electronic motor must be properly aligned, because a misalignment can create wear and overheating of the bearings which lead to damage of the motor and the pump.

After starting and during operation of the pump, the following must be periodically inspected:

1) The operation of the pump and the motor must be smooth and quiet (e.g., check for noises of metallic percussions, whistles, or other noises beyond the normal ones).

2) The temperature of the shell bearings and the motor (if used as a drive machine) must not exceed the permissible limits.

3) The motor power consumption must be kept constant, according to the operating characteristics of the pump that are designated by the manufacturer. It should be noted that the variation that occurs in the power supply parameters (Amperes, Volts) during starting of the pump motor are considered normal if they do not exceed the limits set by the manufacturer.

4) The developed pressure and flow rate should be kept constant and consistent with the structural features of the pump, depending on the operating conditions.

5) The leakages to the glands should be maintained at a minimum, since, in this way, pump shaft overheating is prevented. When the sealing is achieved by mechanical seals, there should not be any leakages. Throughout pump operation, it is essential to perform checks at regular intervals, in spite of the fact that control mechanisms and automations are installed in modern ships. By these checks, it is determined that the pump operates normally, and serious damages that may be caused to the pump by sudden failures are avoided. We should note that, in centrifugal pumps, to avoid the occurrence of hydraulic hammer, which may appear if the pump stops suddenly, gradually close the discharge valve, then switch off the motor, and finally close the suction valve.

7.1 PUMP STARTING PROCEDURE

Prior to starting a pump, the execution of the following preparation checks is indispensable:

1) Check the cock valves[1] of the monitoring devices, such as pressure gauges, thermometers, etc., to ensure that they are open.

2) Check the lubricant supply in the bearings to ensure adequate lubrication and cooling or open the cooling supply in the water-cooled bearings, if any, and in the glands. This prevents wear and overheating of the bearings, which may lead to other damage.

3) Check for sufficient quantity of liquid inside the pump for initial starting (depending on pump type). If the liquid level that is sucked is higher than the pump's highest point or the suction system is under pressure, then, the filling of the pump with liquid can be achieved by opening the suction valve and the air vent valve that is installed at the top of the shell (then close it again). Otherwise, if the liquid level is below the pump shell center, the filling with liquid as well as the air extraction is achieved as follows: in positive displacement pumps, by opening the air vent (on discharge side, then close it again), and in dynamic pumps, by a priming pump or an external source of liquid supply.

4) Check that the suction valves of the pump are open.

5) Check the pump shaft and ensure by hand that the pump shaft is rotating freely (power is OFF at this point), otherwise it must be checked and corrected. For new

[1] Cock valves are the small valves that are used in order to stop or supply a fluid to the monitoring gauges.

pumps, at first starting or after maintenance, it must also be checked that the motor rotation is the same as that required for pump operation.

6) Check the discharge valve, which:

a) In positive displacement pumps, it must be open.

b) In centrifugal pumps, at starting the discharge valve must be closed or almost closed. In this manner, the minimum load of the electric motor which operates the pump is required. Hence, less power is required, which, at starting (if the discharge valve is open), due to overload, reaches the cut-off point of the power supply to the motor. This practice is intended to protect the pump motor (which is designed to operate at the maximum discharge head), and due to resistance to the flow (back flow) of the piping system by the liquid present in it, it results in an increase in power consumption. After starting, it is necessary for the discharge valve of the pump to the piping system to be opened. On ship piping systems where a check valve is installed to the discharge, the disc opening is realized by the liquid, since the operation of the pump causes the liquid pressure to increase.

c) In axial and mixed flow pumps, at start-up the discharge valve should be open, because the torque reaches its nominal value before the pump reaches the normal operating speed.

d) In ejectors, at the outlet (if any) the discharge valve should be open at starting. Also, the suction valve should not be open if the flow of the operating fluid does not reach the normal operating pressure.

7.2 PUMP STOPPING PROCEDURE

To stop a pump, after the desired duration of operation, switch off the driving machine and then close the suction and discharge valves, and the valve of the cooling line for the glands, if any. The pump discharge valve should be closed at the same time as the pump RPM's are reduced. When the pump has stopped, the suction valve should be closed. When pumps are kept on rolling RPM with the discharge valve shut, a careful watch should be maintained on the parameters and temperatures. A lower RPM will generate lesser adverse effects. For prolonged periods, consider shutting down. Detailed procedures of stopping cargo pumps are below:

1) When the float in the forward tank touches the base point, close the tank main valve and fully open the main valve of the aftward tank.

2) Even if the pump draws in gas during the discharging of the final tank, adequate precautions should be taken since there is no tank that can do the "priming" of the pump.

3) Reduce the pump rpm to approximately the minimum rpm (650 to 750), and open the delivery valve to about 10% or less so that no gas is drawn in. Under these conditions, very fine adjustments, should be made little by little, to the pump rpm and the delivery valve. Although it is not preferable to use the pump this way, the stripping time taken by the cargo pump is short, and no problem in particular occurs.

4) If the pump is operated carefully, the tank can be stripped until the float touch level.

5) A little while after the float in the final tank touches the base point, gas starts being drawn in. Immediately close the delivery valve fully and reduce the pump rpm to the minimum rpm. The quantity of oil remaining in the tank is almost negligible.

EPILOGUE

Having considered the types of cargo pumps and related systems used in tanker ships and the way they are operated, there are certain conclusions to be drawn: The pumping system is the most vital part of tanker ships. Without the proper caution and maintenance, no operations would be carried out on the vessel. Due to this fact, cargo pumps and other systems that are used for cargo operations require proper attention. Only crew members with proper knowledge and skills should handle and maintain them.

REFERENCES

- Pumps Merchant Marine Academies Educational Book, Chapters 7-10 (2017 Edition) http://www.eugenfound.edu.gr/appdata/documents/books_pdf/pumps_site.pdf
- Personal material
- https://en.wikipedia.org/wiki/Pump (Retrieved on:10-07-17)
- https://en.wikipedia.org/wiki/Gear_pump (Retrieved on:10-07-17)
- https://www.google.gr/search?q=gear+pump&source=lnms&tbm=isch&sa=X&ved=0ahUKEwj_gc7B1_PZAhXCB8AKHcwJCqIQ_AUICigB&biw=1366&bih=637#imgrc=Cl5KfsMNxZZHuM: (Retrieved on:17-07-17)
- https://www.google.gr/search?biw=1366&bih=637&tbm=isch&sa=1&ei=yjWtWrrxJoHIwQKKqoiYAQ&q=reciprocating+pump+piston&oq=reciprocating+pump+piston&gs_l=psy-ab.3..0i8i30k1l2j0i24k1.21120.25556.0.26017.11.11.0.0.0.0.281.1526.0j5j3.8.0....0...1c.1.64.psy-ab..3.8.1509...0j0i67k1j0i30k1j0i13k1.0.2iJlFfVmzuQ#imgrc=tFhRLkd1z75svM: (Retrieved on:17-07-17)
- https://www.google.gr/search?q=screw+pump&source=lnms&tbm=isch&sa=X&ved=0ahUKEwi7ps_x1_PZAhUPaFAKHfacBxQQ_AUICigB&biw=1366&bih=637#imgrc=uZ1P2FWSCySp8M: (Retrieved on:17-07-17)
- https://en.wikipedia.org/wiki/Screw_pump (Retrieved on:17-07-17)
- https://marinerspotted.com/2017/02/diaphragm-pump/ (Retrieved on:15-07-17)
- https://en.wikipedia.org/wiki/Centrifugal_pump (Retrieved on:15-07-17)
- https://www.globalspec.com/learnmore/flow_transfer_control/pumps/centrifugal_pumps (Retrieved on:15-07-17)
- http://seagoing.narod.ru/html/cargoequ.html (Retrieved on:19-07-17)
- http://marineengineeringonline.com/centrifugal-pumps/ (Retrieved on:29-07-17)
- https://www.engineersedge.com/pumps/centrifugal_pump.htm (Retrieved on:29-07-17)
- http://empoweringpumps.com/differences-centrifugal-pumps-vs-positive-displacement-pumps/ (Retrieved on:29-07-17)

- http://sailor-ru.narod.ru/chapter5/5-28.htm (Retrieved on:07-08-17)
- https://www.wartsila.com/encyclopedia/term/cargo-tank-stripping (Retrieved on:07-08-17)

- http://silipump.com/application/stripping-pump/ (Retrieved on:07-08-17)
- http://www.nyk-training.com/vlccstarship/manuals/1/discharge-05.pdf (Retrieved on:10-08-17)
- http://marineandoffshore.com/wp-content/uploads/2013/09/PumpRoomSystems.pdf (Retrieved on:10-08-17)
- https://aenmchios.webnode.gr/inert-gas-system/ (Retrieved on:13-08-17)
- http://slideplayer.com/slide/4180389/ (Retrieved on:13-08-17)
- https://www.marineinsight.com/guidelines/cleaning-cargo-tanks-with-ig-system/ (Retrieved on:13-08-17)
- http://www.m-o-s.com.tr/ (Retrieved on:13-08-17)
- https://en.wikipedia.org/wiki/Chemical_tanker (Retrieved on:11-08-17)
- http://marineengineeringonline.com/framo-hydraulic-cargo-pumping-system-on-ships/ (Retrieved on:11-08-17)
- https://www.ocimf.org/ (Retrieved on:14-08-17)
- https://www.dreamstime.com/stock-image-pipes-deck-tanker-image8732041 (Retrieved on:04-08-17)
- http://www.marpoltraining.com/MMSKOREAN/MARPOL/Annex_I/r34.htm (Retrieved on:05-08-17)
- http://www.aukevisser.nl/supertankers/part-4/id350.htm (Retrieved on:01-08-17)
- http://www.belzonagreatlakes.com/en/applications/pumps.aspx (Retrieved on:02-08-17)
- http://www.rumfordgroup.com/en/industries/steel.aspx (Retrieved on:01-08-17)
- http://www.pumpgroup.co.uk/2012/10/01/rheinhutte-pumps-solve-customers-corrosion-problems/damaged-centrifugal-pump/ (Retrieved on:01-08-17)
- https://seelio.com/w/1kt1/a-week-in-the-life-on-an-oil-tanker (Retrieved on:01-08-17)
- ISGOTT 5th Edition (International Safety Guide for Oil Tankers and Terminals)

APPENDIX

1. Regulation 34 – Control of discharge of oil

I.Discharges outside special areas

1. Subject to the provisions of regulation 4 of this Annex and paragraph 2 of this regulation, any discharge into the sea of oil or oily mixtures from the cargo area of an oil tanker shall be prohibited except when all the following conditions are satisfied:

a. the tanker is not within a special area

b. the tanker is more than 50 nautical miles from the nearest land

c. the tanker is proceeding en route

d. the instantaneous rate of discharge of oil content does not exceed 30 litres per nautical mile

e. the total quantity of oil discharged into the sea does not exceed for tankers delivered on or before 31 December 1979, as defined in regulation 1.28.1, 1/15,000 of the total quantity of the particular cargo of which the residue formed a part, and for tankers delivered after 31 December 1979, as defined in regulation 1.28.2, 1/30,000 of the total quantity of the particular cargo of which the residue formed a part and

f. the tanker has in operation an oil discharge monitoring and control system and a slop tank arrangement as required by regulations 29 and 31 of this Annex.

2. The provisions of paragraph 1 of this regulation shall not apply to the discharge of clean or segregated ballast.

II.Discharges in special areas

3. Subject to the provisions of paragraph 4 of this regulation, any discharge into the sea of oil or oily mixture from the cargo area of an oil tanker shall be prohibited while in a special area.

4. The provisions of paragraph 3 of this regulation shall not apply to the discharge of clean or segregated ballast.

5. Nothing in this regulation shall prohibit a ship on a voyage only part of which is in a special area from discharging outside the special area in accordance with paragraph 1 of this regulation.

III.Requirements for oil tankers of less than 150 gross tonnage

6. The requirements of regulations 29, 31 and 32 of this Annex shall not apply to oil tankers of less than 150 gross tonnage, for which the control of discharge of oil under this regulation shall be effected by the retention of oil on board with subsequent discharge of all contaminated washings to reception facilities. The total quantity of oil and water used for washing and returned to a storage tank shall be discharged to reception facilities unless adequate arrangements are made to ensure that any effluent which is allowed to be discharged into the sea is effectively monitored to ensure that the provisions of this regulation are complied with.

IV.General requirements

7. Whenever visible traces of oil are observed on or below the surface of the water in the immediate vicinity of a ship or its wake, the Governments of Parties to the present Convention should, to the extent they are reasonably able to do so, promptly investigate the facts bearing on the issue of whether there has been a violation of the provisions of this regulation. The investigation should include, in particular, the wind and sea conditions, the track and speed of the ship, other possible sources of the visible traces in the vicinity, and any relevant oil discharge records.

8. No discharge into the sea shall contain chemicals or other substances in quantities or concentrations which are hazardous to the marine environment or chemicals or other substances introduced for the purpose of circumventing the conditions of discharge specified in this regulation.

9. The oil residues which cannot be discharged into the sea in compliance with paragraphs 1 and 3 of this regulation shall be retained on board for subsequent discharge to reception facilities.

(Subparagraphs 6.1 to 6.5)

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

1. Segregated ballast and clean ballast may be discharged below the waterline
   1.1 in ports or at offshore terminals,
   1.2 or at sea by gravity, or
   1.3 at sea by pumps if the ballast water exchange is performed under the provisions of regulation D-1.1 of the International Convention for the Control and Management of Ships' Ballast Water and Sediments,

   provided that the surface of the ballast water has been examined either visually or by other means immediately before the discharge to ensure that no contamination with oil has taken place.

2. Oil tankers delivered on or before 31 December 1979, as defined in regulation 1.28.1, which, without modification, are not capable of discharging segregated ballast above the waterline may discharge segregated ballast below the waterline at sea, provided that the surface of the ballast water has been examined immediately before the discharge to ensure that no contamination with oil has taken place.
3. Oil tankers delivered on or before 1 June 1982, as defined in regulation 1.28.3, operating with dedicated clean ballast tanks, which without modification are not capable of discharging ballast water from dedicated clean ballast tanks above the waterline, may discharge this ballast below the waterline provided that the discharge of the ballast water is supervised in accordance with regulation 18.8.3 of this Annex.
4. On every oil tanker at sea, dirty ballast water or oil contaminated water from tanks in the cargo area, other than slop tanks, may be discharged by gravity below the waterline, provided that sufficient time has elapsed in order to allow oil/ water separation to have taken place and the ballast water has been examined immediately before the discharge with an oil/ water interface detector referred to in regulation 32 of this Annex, in order to ensure that the height of the interface is such

that the discharge does not involve any increased risk of harm to the marine environment.

5. On oil tankers delivered on or before 31 December 1979, as defined in regulation 1.28.1, at sea dirty ballast water or oil contaminated water from cargo tank areas may be discharged below the waterline, subsequent to or in lieu of the discharge by the method referred to in subparagraph 6.4 of this paragraph, provided that:

   5.1 a part of the flow of such water is led through permanent piping to a readily accessible location on the upper deck or above where it may be visually observed during the discharge operation; and

   5.2 such part flow arrangements comply with the requirements established by the Administration, which shall contain at least all the provisions of the Specifications for the Design, Installation and Operation of a Part Flow System for Control of Overboard Discharges adopted by the Organization.

Regulation 1.28.2

28.2 Ship delivered after 31 December 1979 means a ship:

1. for which the building contract is placed after 31 December 1975

Regulation 1.28.4

3. Which has undergone a major conversion

4.1 For which the contract is placed after 31 December 1975 or

4.2 In the absence of a contract, the construction work of which is begun after 30 June 1976 or

4.3 Which is completed after 31 December 1979.

Proposals of restoring pump symptoms

No discharge of liquid of the pump, no flow.	Closed valve.	Check the valves.
	Low rotational speed of the pump.	Check the motor. In case of electric motor, the voltage should be checked. If the motor is driven by steam or compressed air, the correct pressure and flow rate should be checked.
	The pump rotates in wrong direction.	Check the direction of rotation.
	Incorrect motor speed.	Check and adjust speed according to the construction characteristics of the pump.
	The impeller or the suction filter in the piping system is completely clogged.	Disassembly and cleaning of impeller or filter.
	Wear of the pump.	Replacement of worn parts.
Low discharge of the pump.	Air inlet from suction or by the gland.	Check the suction system; replace the packings or the mechanical seal.
	Low rotational speed of the pump.	Check the motor. In case of electric motor, the voltage should be checked. If the motor is driven by steam or compressed air, the correct pressure and flow rate should be checked.
	High temperature of the pumped liquid (vapors within the pump - cavitation in suction).	Reduce the liquid temperature, reduce the speed of the pump.
	The viscosity of the liquid is greater than expected.	Heat up the liquid.
	Mechanical damage or wear, e.g., wear to sealing rings of centrifugal pumps, damaged impeller, damaged gland seal or mechanical seal.	Inspection, repair and replacement of worn parts.

The pump does not develop sufficient pressure.	Low rotational speed of the pump.	Check the motor. In case of electric motor, the voltage should be checked. If the motor is driven by steam or compressed air, the correct pressure and flow rate should be checked.
	Air in the liquid.	Venting the shell, check the suction system.

Symptom - Failure	*Possible causes*	*Restoration/Treatment/Solution.*
Weak or low pump suction	Leak in the sealing system (packing or mechanical seal).	Check sealing for damage.
	Wear of the pump.	Replacement of worn parts.
	Air in the suction pipe due to damage to the pipe (hole or rupture) or loose bolts in piping system.	Replace the pipe, tightening of the bolts (screws).
	Reduction of the cross section of the suction tube from fouling.	Replace or clean the pipe.
	Incorrect motor speed.	Check and adjust speed according to the construction characteristics of the pump.

Symptom - Failure	*Possible causes*	*Restoration/Treatment/Solution.*
The pump does not develop sufficient pressure.	Wrong direction of rotation.	Check of the drive machinery.
	Mechanical damage or wear, e.g. wear of sealing rings of centrifugal pumps, damaged impeller, damage of seal.	Inspection, repair and replacement of worn parts.
Pump operates and excessive noise is produced.	Noises from motor.	Check motor bearings.
	Noises from pump.	Mechanical wear, stop the pump and check.
	Noises from pump - may operate in cavitation conditions.	Reduce the pump speed - regulate flow through the valve, reducing the temperature of the liquid handled.
	Noises from the pump bearings.	Mechanical wear, stop the pump and check the bearings, lubricate or replace.
	Incorrect alignment of the transmission link (coupling).	Alignment of coupling.
Leakage of liquid from the pump.	Wear on the sealing system.	Replacement/repair of sealing system.
	Wear of the sealing of the casing.	Replacement/repair of sealing area on the casing.
The pump suddenly stopped.	Foreign object has entered the pump.	Removal of foreign object, check the pump for damage.
	Damage of motor or of the drive machine.	Check the power supply to the motor and the panel fuses, check the drive machine.
	Possible damage in motor.	Disconnect the pump from the motor and rotate manually.
Lateral (side) wear of rotor.	Incorrect positioning of rotor.	Replace the rotor.
	Incorrect alignment.	Replacing rotor, check of alignment.