TRAINING MODULE FOR PUMPMAN

I. DUTIES AND RESPONSIBILITIES

- The Pumpman must, in accordance with the instructions and orders of the Chief Officer and Boatswain, carryout the following work:
- Operate the cargo pumps and valves during loading and discharging operations.
- Cargo watch.
- Sound tanks and bilges twice a day.
- Carry out the work of taking on, transferring and discharging drinking water, fresh water, and ballast water.
- Carry out tank cleaning, inerting and gas-freeing work.
- Maintenance work on cargo pumps, ballast pumps, fresh water pumps, valves, piping and other deck related machinery and equipment.
- Inspect cargo pumps, ballast pumps, fresh water pumps, valves, piping and other deck related machinery and equipment, and when there is an abnormality, report to the Chief Officer and the Boatswain.
- Oil cargo pump operating parts, valves, deck equipment, etc.
- Other work instructed by the Chief Officer or the Boatswain.

I.1. Maintenance

I.1.1. Cargo pump (crude oil maintenance)

I.2. Maintenance procedure

The cargo pump (crude oil) maintenance should be carried out in accordance with the instruction books of each ship and the following:

I.2.1.1. Ball bearing

a.1. Keep the bearing temperature below 75 C.
a.2. Grease up periodically depending on the recommended type of grease and interval.

a.3. Grease up to the lower bearing with the grease drain plug removed.

I.2.1.2. Mechanical seal

b.1. Pay special attention so that no dirt enters the clearance between the pump shaft and the mechanical seal cover.
b.2. Confirm that there is no heat generation and abnormal noise in the vicinity of the sliding part.
b.3. If leakage from the mechanical seal has been found, take necessary measures at an early stage.

I.2.1.3. Gear coupling

c.1. Since a misalignment of the shaft center of the pump and the drive shaft causes a slide between gear teeth to increase wear or generate vibration, leading to damage of gear coupling, keep the alignment within the allowable range.
c.2. Lubricating oil supply is very important. Be sure to confirm the amount of lubricating oil before entering a discharge port, and supply oil if required.
c.3. Renew lubricating oil according to the recommended interval of renewal.

I.2.1.4. Procedure of supplying lubricating oil

d.1. Remove the oil plug.
d.2. Supply oil until the oil leaks from an oil plug hole.
d.3. Upon completion of supplying oil, tighten the oil plug, and turn the shaft by several turns to spread the oil until it reaches the inside of the coupling. Though excessive oil supply can cause oil leakage through a key way, it may be left out of consideration, because this secures the necessary volume of oil.

I.2.1.5. Bulkhead stuffing box

e.1. For the first operation after putting the gland packing, turn once to tighten the gland securely, and then loosen the gland nuts to a degree that the coupling can be turned freely with a turning bar.
e.2. Supply the gland packing with the designated grease for lubrication and gas tightness.

e.3. After starting the pump, tighten the gland nuts lightly and evenly. Since abrupt, too much, or uneven tightening may cause dangers of overheat or burning. Tighten the bolts carefully.

e.4. If tightening the gland can not stop leakage due to aged packing, replace the packing with a new one.

I.2.1.6. Renewing lubricating oil

f.1. Use lubricating oil of the brand designated for the machinery and equipment of the ship.

f.2. Though the interval of renewing lubricating oil recommended by the instruction books may be standard, renew or supply lubricating oil appropriately depending on the actual deterioration and contamination.

I.2.1.7. Suspension

Freezing is likely to occur, drain the pump completely. For suspension, thoroughly clean sliding parts, and take anti-corrosive measures.

I.2.2. Overhauling of cargo pump

In addition to the following procedures in general, carry out overhaul in accordance with the instruction book of each pump.

I.2.2.1. Dissembling

For replacing the impeller, ball bearing, mouth ring, and the like, disassemble the pump in accordance with the following procedure:

a. Removing the volute cover

a.1 Removing the sealing pipe for the mechanical seal

a.2 Unscrew the tightening nuts of the mechanical seal cover, and move the cover until it touches the flinger.

a.3 Remove the tightening nuts and knock pins of the volute cover, and remove the cover by the jacking bolts.

b. Pulling out the ball bearing

b.1 For the upper bearing, remove the bearing cover after removing the snap ring.

b.2 For the lower bearing, remove the bearing cover, and then remove the snap ring.

b.3 compress the ring of the mechanical seal with special tools, so that the shock caused by removing the ball bearing should not be transmitted to the mechanical seal directly.
b.4 Pull-out the ball bearing together with the inner case by a bearing puller.

c. Removing the mechanical seal

After pulling the ball bearing and flinger out of the shaft, remove the mechanical seal from the shaft with a special tool.

d. Removing the impeller

d.1 After removing the ball bearing, flinger and mechanical seal, remove the set screws of the impeller nut, and then remove the nut.
d.2 Pull the impeller out of the shaft. If the impeller is difficult to remove, it may be helpful to hear the impeller boss a little.

I.2.2.2. Assembling

1 For assembling the pump, follow the disassembling procedure in the opposite order.

a.1 Clean each part thoroughly in washing oil, remove rust and scale completely, and remove flaws, burr, and the like on the parts to be fitted together.
a.2 Be sure to set tallying marks of parts to be fitted together.
a.3 Screw the nuts of the rotating part tightly, and set the turning stoppers securely.
a.4 Wash the ball bearing in clean washing oil (kerosene), and do not allw dirt or foreign matters to enter the bearing.

1 Assembling the mechanical seal

Assembling the mechanical seal with special tools in the following procedure:

b.1 Wash the sliding surface, O-rings, and O-ring grooves in clean washing oil, wipe up with soft cloth, and do not allow for dirt or foreign matter to stick to them.
b.2 Do not cause scratches or bruises on the sliding surface.

b.3 Before assembling, be sure to apply lubricating oil to the sliding surface and O-rings.
b.4 Insert the floating seat carefully not to damage the sliding surface, and pressure-fit to the bottom.
b.5 Set the stopper ring to the mounting stage, and fix it by a set screw.
b.6 Confirm that the winding direction of the spring conforms to that of the rotation of the pump.
b.7 Fit the rotor and the cover of the mechanical seal to the shaft.
b.8 Compress the spring evenly with a special tool.
b.9 Mount the flinger and the ball bearing to the shaft. Hold the special tool until the rotor is contained in the volute casing with the spring compressed.
b.10 Remove the special tool after the rotor is contained in the volute casing.

1 Shaft Center Line

Confirm that the alignment of the center line shaft is within the allowable range.

I.2.3. Valve and Pipelines

I.2.3.1. Valves

a. Maintenance during dry docking

a.1 Overhaul, inspect and service the valve body.
a.2 Carry-out a leakage test with Nitrogen (positive and negative pressure).
a.3 For a hydraulically driven valve, carry out overhauling the actuator and renewing the O-rings and packing.

b. Maintenance other than that during dry docking period

b.1 Check the hydraulic pipeline for leakage periodically. Tighten the pipe joints additionally as needed.
b.2 Confirm the tightening force of the bonnet block tightening bolts by a torque wrench periodically, and tighten them additionally as needed.
b.3 Check the body and valve handle of the actuator for rust, and treat them as required.

c. Pipes and expansion joints

c.1 Confirm the tightening force of flange tightening bolts by a torque wrench periodically, and then tighten additionally as needed. Make a torque check for leakage very carefully, when cryogenic conditions have been recovered after a dry docking particular.
c.2 Inspect the flange bonding cable, and replace it as needed.
c.3 Take the expansion joint ashore, and make a penetration test color to check it. Check the tie bolts for a bend and the like at the same time.
c.4 Repair the defective insulation material during dry docking.
c.5 Inspect the pipe supports and U-bolts, and take measures necessary to protect pipes from improper stress.

II. VESSEL LAY-OUT

II.1. Cargo tanks

Cargo tanks are enclosed spaces where liquid cargo is being loaded and stored. The material from which these spaces are constructed are dependent to the cargoes which by the vessel is designed to carry.

II.1.1. General precautions

During the handling of volatile petroleum and loading of non-volatile petroleum into tanks containing hydrocarbon vapour, and while ballasting after the discharge of volatile cargo, all cargo tank lids should be closed and secured.

Cargo tank lids or coamings should be clearly marked with the number and location (port, center and starboard) of the tank they serve.

Tank openings of cargo tanks which are not gas free should be kept closed unless gas freeing alongside by agreement.

II.1.2. Sighting and ullage ports

During any of the cargo and ballast handling operations, sighting and ullage ports should be kept closed unless required to be open for certain operational purposes. If for design reasons they are required to be open for venting purposes, the openings should be protected by a flame screen which may be removed for a short period during ullaging, sighting, sounding and sampling. These screens should be a good fit and be kept clean and in good condition. Closed loading of cargoes having toxic effects should be adopted.

II.1.3. Cargo tank vent outlets

The cargo tank venting system should be set for the operation concerned and, if required, the oultets should be protected by a device to prevent the passage of flame. High velocity vents should be set in the operational position to ensure the high exit velocity of vented gases. When volatile cargo is being loaded into the tanks connected to a venting system which also serves tanks into which non-volatile cargo is to be loaded, particular attention should be paid to the setting of p/v valves and the associated venting system, including any inert gas system, in order to prevent flammable gas entering the tanks to be loaded with non-volatile cargo.

II.1.4. Tank washing openings

During tank cleaning or gas freeing operations, tank washing covers should only removed from the tanks in which these operations are taking place and should be replaced as soon as these operations are completed. Other tank washing covers may be loosened in preparation, but they should be left in their fully closed position.

II.2. Pumproom

Pumprooms are normally called the "grand central station" of an oil tanker where all pipelines meet and interconnect in a relatively small area, usually located aft of the cargo tanks.

II.2.1. General precautions

Cargo pumprooms, by virtue of their location, design and operation which require the space to be routinely entered by personnel, constitute a particular hazard and therefore necessitatespecial precautions. A pumproom contains the largest concentration of cargo pipelines of any space within the ship and leakage of a volatile product from any part of this system could lead to the rapid generation of a flamable or toxic atmosphere. The pumproom may also contain a number of potential ignition sources unless formal, structured maintenance, inspection and monitoring procedures are strictly adhered to.

II.2.2. Routine maintenance

Pumproom bilges should be kept clean and dry. Particular care should be taken to prevent the escape of hydrocarbon liquuids or vapour into the pumproom.

It is important that the integrity of pipelines and pumps is maintained and any leaks are detected and rectified in a timely fashion. Pipelines should be visually examined and subjected to routine pressure tests to verify their condition.

Valve glands and drain ccks should be regularly inspected to ensure that they do not leak.

The security of critical bolts on the cargo pumps and associated fittings, such as pedestal fixing bolts, pump casing bolts and bolts securing shaft guards, should be ensured.

II.2.3. Ventillation

The pumproom should be continously ventillated during all cargo operations. Before any one enters a pumproom, it should be thoroughly ventilated, the oxygen content of the atmosphere should be verified and checked for the presence of hydrocarbon and toxic gases.

Ventilation should be continous until access is no longer required or cargo operations have been completed

II.2.4. Pumproom entry

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

A communication system should provide links between the pumproom, navigation bridge, engine room and cargo control room. In addition, audible and visual repeaters for essential alarm systems, such as general alarm, should be provided within the pumproom.

Arrangements should be established to enable effective communication to be maintained at all times between personnel within the pumproom and those outside.

II.3. Segregated ballast tank (SBT)

Segregated ballast tanks are exclusive ballast tanks constructed to provide adequate deadweight during ballast passage. SBT tankers are not required to have additional ballast in cargo tanks except under extraordinary rough weather condition.

II.3.1. General precaution

Ballast carried in segregated tanks maybe retained on board in order to restrict the freeboard if this is necessary because of weather conditions or to keep within the envelop restrictions of the terminal metal loading arms or shore gangway. Care must be taken , however, not to exceed the maximum draught for the berth and to include the ballast weights in the hull stress calculation.

II.3.2. Segregated ballast tank lids

Segregated ballast tank lids should be kept closed when cargo or ballast is being handled as petroleum gas could be drawn into these tanks. Segregated ballast tank lids must be clearly marked as such.

II.4. Slop tank

Slop tanks are spaces that can be used to gather or retain dirty slops or heavy oil/water emulsions. The tank or tanks used for slops should be fitted with heating coils. Slop tanks are provided for modern tankers into which the oily residues of tank cleaning and any dirty ballast are pumped. These are allowed to settle for sufficient time for the oil and seawater to separate. Seawater is then pumped overboard whilst the oil is handled as normal cargo.

II.5. Deep tanks

Deep tanks are often fitted adjacent to the machinery spaces amidships to provide ballast capacity improving the draft with little trim, when the ship is light.

III. PIPING CONFIGURATION

III.1. Ring main or circular line

This pipeline system is better suited to the center line bulkhead type ship. Each tank or oil compartment has two suctions – one direct suction and the other indirect suction. The direct suction for the port tanks are all on the port cargo line, and feed the port cargo pump. The indirect suction for the port cargo tanks feed the starboard cargo line and the starboard cargo pump. Master valves are provided on each line between tanks, so as to isolate each tank from the other when necessary. This particular vessel is not fitted with stripping line and pump.

This type of pumping system providing for the handling of several different types of oil, was a natural development from the earlier types which were only really suitable for one grade of oil. As previously mentioned, the summer tanks were fitted with drop valves, which when opened allowed oil to flow into the main tank below.

Due to their size, the main cargo pumps are not really suitable for draining tanks, wear and tear being excessive, therefore when the level of oil in any particular tank has fallen to a foot or less, the main pumps are switched to another full tank, and the stripping pump is brought into operation. This stripping pump is served by a 6-inch stripping line which reduces to 4 inches in the transverse lines which feed the suctions.

III.2. Cargo line system

Cargo line system includes lines, valves and cargo pumps dedicated or used during the vessel's loading/discharging operations.

III.3. Ballast line system

Ballast line system is a system involving lines, valves and pumps dedicated for ballasting (loading seawater) into the vessel's ballast tanks.

IV. VALVES

IV.1. Gate valve

As the name implies, this type of valve employs a metal gate, fitted in grooves, which slides across the valve opening. The gate is fitted with a threaded spindle which connects to the valve stem. When turned by means of a handwheel, the spindle edges the gate slowly upward or downward.

It is necessary to turn the handwheel many times – perhaps 30 or more – to move the gate from fully open to fully closed. Gate valves are therefore too slow and cumbersome to be easily adapted to automatic control.
But they have advantages. They are dependable and durable. When fully open, the gate retracts into the valve body and offers no resistance to the flow of oil – a definite advantage over valves with swinging gates. In addition, gate valves provide an accurate adjustment to the rate of flow.

IV.2. Butterfly valves

On tankers with automatic valve control, butterfly valves are commonly used instead of gate valves. They possess the following advantages:

- They operate easily and quickly (1/4 turn swings the gate from fully open to fully closed).
- They adapt readily to automatic control.
- They are more compact and less expensive than gate valves.

They also have several disadvantages:

- They fail to provide a precise adjustment to cargo flow; in most cases they must be operated fully open or fully closed.
- The valve gate remain s in the center of flow, even when fully open, thus offering resistance and slowing the rate.
- Butterfly valves tend to develop leaks more readily and need more frequent maintenance than gate valves.

IV.3. Globe valve

Globe valves are not as common in cargo systems as gate and butterfly valves, but they are favored on some vessels. They operate as follows: A round disc is fitted on the end of a threaded stem and as the stem is turned with the handwheel, the disc wedges into the valve aperture, directly against the flow of oil. This action is a little like stopping a bottle with a cork. Globe valves tend to be difficult to operate in large sizes and at high pressures, and because oil must change direction as it flows through the valve, an undesirable pressure drop may occur on the outlet side. Nevertheless, globe valves are valuable whenever a precise throttling, or control of pressure is desired.

IV.4. Special valves

IV.4.1. Check valves

To prevent oil from backflowing into the tanks, a check valve is normally installed on the discharge side of each centrifugal pump.

Each valve contains a weighted or spring-loaded gate which swings up under pressure, allowing oil to flow out the discharge line. When the pump stops and pressure ceases, the gate swings shut against the valve seat, preventing oil from running back into the tanks.

Because check valves operate automatically, many officers tend to forget them or take them for granted. They are foolish to do so: check valves sometimes stick, causing spills when least expected. You should never assume a check valve is working properly. Whenever the pumps are stopped, even temporarily, close the block valves at the manifold for sure protection against cargo back flow.

IV.4.2. Relief valves

Each cargo pump is equipped with a relief valve and a short recirculating line. Whenever the pressure becomes excessive on the discharge side of the pump, the relief valve opens and allows oil to recirculate to the suction side, thereby relieving the pressure.

IV.5. Butterfly and non-return valves

Butterfly and pinned back non-return valves in ship and shore cargo systems have been known to slam shut when cargo is flowing through them at high rates, therefore setting up very large pressure surges which can cause line, hose or metal arm failures and even structural damage to jetties. These failures are usually due to the valve disc not being completely parallel to, or fully withdrawn from, the flow when put in the open position. This can create a closing force which may shear either the valve spindle in the case of butterfly valves, or the hold open pin in the case of pinned back non-return valves. It is therefore important to check that all such valves are fully open when they are passing cargo or ballast.

IV.6. Valve operation

To avoid pressure surges, valves at the downstream end of a pipeline should be as a general rule, not be closed against the flow of liquid except in an emergency. This should be stressed to all personnel responsible for cargo handling operations both on the tanker and at the terminal.

In general, where pumps are used for cargo transfer, all valves in the transfer system (both ship and ashore) should be open before pumping begins, although the discharge valve of a centrifugal pump may be kept closed until the pump is up to speed and the valve then opened slowly. In the case of ships loading by gravity, the final valve to be opened should be at the shore tank end of the system.

If the flow is to be diverted from one tank to another, either the valve on the second tank must be opend before the valve on the first tank is closed, or pumping should be stopped while the change is being made.

Valves which control liquid flow should be closed slowly. The time taken for power operated valves to move from open to shut and from shut to open should be regularly checked at their normal operating temperatures.

V. PUMPS

V.1. Pump theory

Strictly speaking, a pump does not draw up liquid, but rather creates a vacuum on the suction side, allowing atmospheric pressure to push the liquid into the pump. In theory, a pump could therefore draw up liquid column corresponding to the atmospheric pressure, which equals about 10 meters of liquid.

In practice, the situation is different. Theoretical suction height is influenced in a positive way by atmospheric pressure, inert gas pressure and the height of the liquid in the tank, it is negatively influenced by the Net Positive Suction Head (NPSH) of the pumps, frictional loss in the pipelines, true vapour pressure of the liquid being pumped, and the height of the pump and suction piping above the tank bottom. All these can be expressed in meters liquid column.

The NPSH of a pump is a combination of friction and vacuum losses associated with a particular pump on board. These losses can be reduced by decreasing fluid velocity through a pump i.e. decreasing the flow.

Piping friction is caused by the liquid passing through the suction piping and depends on the length of piping and fluid velocity. Again friction losses may be reduced by decreasing the flow.

Although the pumpman operates and maintains the pumps, it is important for the ship's officers to understand this equipment thoroughly. The following types of pumps are likely to be encountered on tankers: 1) reciprocating; 2) centrifugal; 3) rotary (such as gear or screw pumps); 4) jet (such as eductors); and 5) propeller.

Main cargo pumps are almost exclusively of the centrifugal type. Strippers are normally reciprocating or rotary, or eductors.

V.2. Reciprocating pumps

A basic reciprocating pump consists of a piston, usually powered by steam, which slides back and forth in a cylinder. On the intake stroke, the movement of the piston creates a vacuum, thus drawing oil into the cylinder through the intake valve. On the discharge stroke, the piston forces oil through the discharge valve, creating a pressure on the discharge side of the pump.

Reciprocating pumps are sometimes called **positive displacement pumps**.

V.3. Centrifugal pumps

These are continous-flow, gravity-fed pumps, consisting of one or more spinning impellers. These impellers draw oil through a central inlet and hurl it outward by centrifugal force. This action creates a vacuum on the inlet side and pressure on the discharge side of the pump.

Centrifugal pumps cannot function without a continous gravity-flow of cargo. For this reason they are generally located in the after pumproom, thus using the normal stern trim to drain cargo efficiently. If the pumps are self-priming – or if they are otherwise carefully primed by "cracking" a full tank – it is often possible to strip tanks with centrifugal pumps alone. Centrifugal pumps are superior to reciprocating pumps in several important ways:

1. They pump more cargo in less time.
2. They are smaller, more compact, and easier to install.
3. They are less expensive.
4. They are more reliable and require less maintenance.
5. They produce a steady flow, rather than pulsating.
6. They produce less noise and vibration.
7. Since they are usually located in an after pumproom adjacent to the engine room, they can adapt to various power sources, including steam turbines, electric motors, and diesel engines.

When using centrifugal pumps always be careful to switch tanks in ample time to avoid losing suction. Many centrifugal pumps used on tankers are now self-priming. A typical system works in the following manner. When the pump loses suction, a venturi device automatically activates the system. The pump is primed from a recirculation tank as cargo is automatically recirculated through a special valve. At the same time, air is vented through an extraction line. When priming is finished, the pump automatically resumes normal operation.

V.4. Deepwell pumps

Deepwell pumps are centrifugal pumps of a special design used mainly on ships carrying a great diversity of refined products. Each pump is permanently installed above an individual cargo tank. The impeller is located at the end of a long vertical shaft extending to the bottom of the tank. The shaft is enclosed in a discharge pipe which carries oil from the impeller to the above-deck piping. This arrangement takes advantage of the speed and efficiency of a centrifugal pump while minimizing the disadvantages. Because the impeller operates so close to the bottom of the tank, it can discharge nearly all cargo before losing suction. Stripping is usually unnecessary.

V.5. Eductors

Eductors work on a simple principle. A driving fluid is pumped down the main line, through a constriction, and past a relatively smaller opening, thus creating a vacuum. When eductors are used for clean ballast, the driving fluid is seawater. When used for stripping crude oil, the driving fluid is the cargo itself – delivered by means of a bypass from one of the main cargo pumps. When used for stripping tank washings, the driving fluid is often drawn from the slop tank – and then recirculated back to the slop tank in a closed system. In the latter case, the driving fluid is either crude oil or seawater, depending on the tank cleaning method.

Eductors are simple and rugged, have no moving parts, and do not become air bound like other types of pumps. They are widely used on tankers of all types and sizes.

V.6. Priming pumps

When a pump loses suction as a result of excessive suction lift, or gas or air entering the pump, the pump needs to be primed before suction can be regained. When a full tank is available, the suction head can be utilized to flood the pump chambers, and the gas and air is released from the pump via the air cock. A centrifugal pump can be primed whilst the pump is stopped or stationary, but a reciprocating pump must be put in motion. When no suction head is available, the static head is utilized by opening the drop valve and allowing the oil to reach the suction and fill the pipeline.

V.7. Suction supply conditions

Atmospheric pressure exerts a pressure on the surface of the liquid being pumped. It is the source of energy which causes the liquid to flow through the suction line as far as the pump, only when the liquid reaches the pump does the pump take over and superimpose conditions on the flow. Atmospheric pressure is for convenience converted into terms of liquid head when pumping problems are under consideration, and in terms of water is represented by a column 34 feet high. Atmospheric pressure varies from to place place with altitude and latitude, therefore the pressure it exerts is also variable, and this fact must be carefully borne in mind.

V.8. Suction head

It is possible that liquid head representing atmospheric pressure may be supplemented or increased by an actual head consisting of the head or column of the liquid being pumped. The liquid head is measured from the center line of the pump to the surface of the liquid above the pump and is expressed in feet and inches.

V.9. Suction lift

Sometimes however, the level of the liquid being pumped is below the center line of the pump. The distance measured vertically from the surface of the liquid to the center line of the pump is referred to as the suction lift. The energy required to lift or push the liquid up the suction pipe as far as the pump, is proportionate to the amount of suction lift, and results in a considerable loss or reduction in the head created by atmospheric pressure.

V.10. Friction losses

A considerable loss of energy or reduction in the head is due to friction caused by the flow of liquid as it passes through the strum and the entrance to the suction pipe. Friction losses are increased by any bends, valves and strainer plates that may be encountered between the tank and the pump suction. It is also true to say that friction loses are proportionately higher with smaller bore pipes than with large ones, whilst the greater the velocity. Of the liquid through a given size pipe, the greater will be the friction losses.

It should be reasonably clear by now that great care has to be taken in designing and installing the suction supply lines in a ship's pumping system, as there is a definite limit to the energy or head available for supplying liquid to the cargo pumps. It is not sufficient for the suction head to be capable of supplying liquid to the pump, it must be capable of accelerating the liquid through the length of the suction line at sufficient speed to keep the pump properly fed. In addition to accelerating the liquid to keep pace with the requirements of the pump there must also be sufficient reserve head or pressure left to stop the liquid from vaporizing.

V.11. Resistance to flow

The resistance to flow which the pump has to overcome is composed of the following:

1. The internal resistance to flow of the particular liquid being pumped. Liquids with a high viscosity provide more resistance to flow than those with low viscosity.
2. Friction in the discharge pipeline.
3. The static head or liquid head measured from the center line of the pump vertically to the surface of liquid in shore tank.

V.12. Cavitation

Cavitation effects centrifugal pumps as well as reciprocating pumps. Should the supply of liquid be restricted so that a portion of the liquid passes into vapour immediately in front of the bucket of a reciprocating pump or the impeller of a centrifugal pump, cavitation takes place. When discharging low flash products in warm climates, or products such as crude oils that require heating, cavitation occurs much more easily , especially as the level of oil falls below the suction lines and it has to be lifted higher and higher.

To counter such conditions, the obvious answer would be a reduction in the temperature of the cargo. This can be effected in the case of cargoes that are being heated, by reducing or cutting off the heating in plenty of time. In the case of spirit cargoes in warm climates, however, there is no such easy solution, but it sometimes helps if the discharge is arranged so that the draining operations are done during the night, thus taking advantage of any drop in temperature that might be experienced after the sun has gone down. As has been previously mentioned, the speed of a reciprocating pump should be reduced to give the pump a chance to fill with liquid, whilst the centrifugal pump should be assisted at this stage by the small gas extractor pump provided, this pump will draw off the gas and air before it reaches the impeller and breaks the flow of oil through the centrifugal pump. It sometimes helps a centrifugal pump if the discharge valve is throttled in against the pump, thus reducing the flow of oil, thereby helping to maintain pressure with the reduced quantity available.

V.13. Pressure surges

The incorrect operation of pumps and valves can produce pressure surges in a pipeline system. These surges may be sufficiently severe to damage the pipeline, hoses or metal arms. One of the most vulnerable parts of the system is the ship to shore connection. Pressure surges are produced upstream of a closing valve and may become excessive if the valve is closed too quickly. They are more likely to be severe where long pipelines and high flow rates are involved.

Where the risk of pressure surges exist, information should be exchanged and written agreement reached between the tanker and the terminal concerning the control flow rates, the rate of valve closure, and pump speeds. This should include the closure period of remote controlled and automatic shut down valves. These arrangements should be included in the operational plan.

V.14. Control of pumping

Throughout pumping operations no abrupt changes in the rate of flow should be made.

Reciprocating main cargo pumps can set up excessive vibration in metal loading/dicharging arms which in turn can cause leaks in couplers and swivel joints, and even mechanical damage to the support structure. Where possible such pumps should not be used. If they are, care must be taken to select the least critical pump speed or, if more than one pump is used, a combination of pump speeds to achieve an acceptable level of vibration. A close watch should be kept on the vibration level throughout the cargo discharge.

Centrifugal pumps should be operated at speeds which do not cause cavitation. This effect may damage the pump and other equipment on the ship or at the terminal.

VI.TANKER OPERATIONS

VI.1. Before loading

Most tanker oil spills occur while loading; the loading operation should therefore command extra diligence from the ship's officers. Nearly all spills are preventable. Most are caused by human errors, with carelessness, impatience, and simple negligence leading the list.

The prevention of spills starts before the first barrel of oil enters the tanks. In fact, before any cargo operation, loading or discharging, the ship's officers perform a series of inspections, which greatly reduce the chance of cargo contamination, spills, explosions and fires.

Some companies use a checklist for this purpose. This is an excellent practice, especially since the accidental omission of even one item could cause a disaster. A new officer would be wise to make a list and use it religiously, even if his fellow officers do not.

Such a list should include the following items, each to be checked carefully before starting any cargo operation:

1. **Scupper plugs.** Make sure all deck scuppers have been plugged and, if necessary, cemented in place.

2. **Sea suctions.** While checking the pumproom, make sure the sea valves have been lashed in closed position. They should never be secured with locks.

3. **Hose connections** should be checked for tightness, making sure a drip pan is in place.

4. **"Bravo" flag and red light** must be displayed prominently.

5. **Cargo system line up.** At least two officers should check the line up, paying particular attention to crossovers and drops. The appropriate drops must be open and, if loading two or more products, the crossover separating these systems must be closed.

6. **Cargo tanks and tank valves.** Check that all tanks to be loaded are empty. Make sure each tank valve is closed, and remove the hand wheel lashings from tanks to be loaded. Tanks already containing cargo should be lashed closed, in order to prevent accidental opening. In addition, it is a good idea to check void spaces, such as peak tanks and cofferdams, to make sure they are empty.

7. **PV valves** should be open on all tanks to be loaded.

8. **Pre-transfer conference.** Find out the following from the terminal:

   In what sequence will the various products load? What loading rate can be expected? How many shore pumps will be used? How much notice will the terminal need before the cargo finishes. What signal should be used for shutting down? Will there be a line displacement?

9. **Mark hoses with chalk**. It is a good idea to mark each hose with the name of the product being loaded. In the event of a spill or broken hose, it would be disastrous to shut down the wrong product.

10. **Mark cargo status board.** This is most often a chalkboard with a plan of the cargo tanks superimposed on it. Display this board in a prominent place, so that each watch stander can maintain a clear mental picture of all cargo activity.

11. **Declaration of inspection.** This form lists certain inspections, which the law requires tankermen to perform prior to cargo transfer. It must be signed by each watch officer and by the shore operator.

VI.2. Loading

Start cargo slowly

Begin the transfer slowly, making sure that there are no leaks at the hose connections and that cargo is, in fact, entering the tanks. Do this by checking the automatic tapes for movement, if your vessel is so equipped.

At the same time, make sure that the float has not stuck to the bottom of the tank, a common problem on ships carrying heavy, sticky fuel oils. Roll the tape up and down several inches by using the head clutch fitted in the tapewell.

As oil flows into the tank, it is normal to hear the sound of air escaping around the ullage plug. This is a good sign that oil is, indeed, entering the tank and that all valves on line are open.

Removing the list

Some ships have a natural list, and this may cause problems when loading the wing tanks. Oil tends to gravitate toward the low side, causing a further tendency to list, which in turn causes more oil to gravitate, etc.

Therefore, one of the first steps when loading should be to remove the list. This is done by loading cargo in a wing tank on the high side of the ship until the list has been removed. Most experienced tankermen can tell by "eyeball" when their ship is straight, but it never hurts to check the clinometer, which is generally more precise.

Stress

Stress is a vital consideration on tankers, even alongside the dock. Virtually all tankers tend to hog when empty, so its is important to avoid loading cargo in the extreme ends without placing some weight in the middle. The best procedure is to spread the load more or less uniformly through the tank range, thus equalizing stress and preventing a dangerous hog or sag condition during loading operation.

On large ships, stress must be checked at regular intervals -even hourly- while loading. This is most often done with a loading calculator or computer.

Loading at the centers

There are many methods in loading a tanker –almost as many methods as there are tankermen. So it is difficult to generalize or offer a single procedure to fit all circumstances. However, one generality holds true: all loading methods strive to fill the tanks without spilling oil.

Most tanker mates prefer to load the center tanks first, but this is not an immutable rule. A tanker can be loaded quite successfully by the opposite method -wing tanks first, then the centers.

Center tanks are considerably larger than wing tanks, and the cargo level rises more slowly. It follows that centers offer a greater margin of safety when topping off. During the final phase of loading, this margin of safety can be more valuable, especially when the terminal is slow shutting down. It is advisable therefore to save at least one center tank for last.

Chief Mate's loading orders

For the guidance of watch officers, the chief mate normally fills out a cargo plan with the following information:

1. Products to be loaded in each tank
2. Final ullage for each tank
3. API gravity and approximate temperature of each product
4. Total gross and net barrels of each product
5. Final draft and trim

The mate posts this plan in a prominent place in the ship's office or Cargo Control Room. In addition, he makes out a set of loading orders outlining the way I which he wants the cargo loaded. Here he specifies loading sequence and any special instructions he may have, such as important valves to be opened, closed or lashed.

Each officer is expected to study these orders carefully before taking charge of the deck. Should any doubt arise about the loading orders, it is always best to call the chief mate and ask him to clarify the situation.

At the start of the loading watch, a good practice is to check every tank valve to make sure each is in the position indicated on the status board. Likewise the ullage on each tank, not just the ones being loaded should be checked.

Oil moving into or out of a "closed" tank could indicate several potentially serious problems:

1. A valve which has been opened by mistake.
2. A broken reach rod.
3. A jammed valve.
4. A break in the below-deck piping.

If this happens, shut down until the source of problem has been found and corrected.

Cargo control room

On automated tankers, the cargo watch officer spends most of his time in the cargo control room; from here he can monitor cargo levels and operate valves remotely. A typical control room contains the following:

- Cargo ullage indicators.
- Controls for valves and pumps.
- Cargo system pressure gauges.
- Tank atmosphere oxygen indicator (inert gas system).
- Loading calculator for figuring stress, draft and trim.
- Communication equipment such as telephones and radios.

When in doubt, shut down

Possibly the single most important thing for a tankerman to learn is: Never hesitate to shut down cargo operations. Whenever in doubt, the first step should be to shut down. Do this first then straighten out the problem. It is far better to lose a few minutes than risk a spill.

Shut down without hesitation in the following situations:

- The pressure rises suddenly for no apparent reason.
- You see oil in the water adjacent to the ship.

- The hose fouls between the ship and dock or begins to leak.
- A valve or automatic tape jams.
- You spot a fire on the dock or on another ship nearby.
- The ship begins to drift away from the dock or the mooring lines become excessively slack.
- A mooring line parts.
- You smell smoke.
- Another vessel approaches too closely.
- Any other situation that develops which could prove hazardous.

Good practices

Watch the pressure. Pressure in the cargo system is usually low at the start of loading; in fact it may not register on the pressure gauges at all. As tanks fill up, pressure tends to rise slightly. This should be kept within established limits for the vessel.

Cargo pressure while loading is proportional to the number of open tank valves. Close a valve, the pressure rises; open one, it falls. It is thus possible to decrease the flow of oil into a full or nearly full tank by opening one or more empty tanks.

This technique is particularly helpful when topping off, since it slows down loading rate to a safe limit. In fact it is often possible to stop the flow completely and gravitate cargo from a full tank to an empty one while still loading.

Never close off against shore pressure. Keep at least one tank open at all times or you will run the risk of a broken hose and a bad spill.

Watch the mooring lines. As a ship fills with cargo, she sinks lower in the water. At most docks this causes the mooring lines to become slack. In conjunction with a falling tide, this tendency may cause the ship to drift rapidly away from the dock, with resultant risk of broken hoses and loading arms.

Two men on deck. Practices vary, but is generally a good idea to keep at least two men on deck during cargo operation.

Closing valves. Make sure you and your watch use the proper method of closing valves. After closing, open one or two turns to flush the sediment from the valve seat; then close firmly, taking care not to jam.

Two-valve separation. On ships carrying refined products, it is extremely important to keep the various systems separated, so that incompatible products cannot mix. Considering the time, effort and expenses involved in the refining process, it is not surprising that tanker companies.

Ullages. Remember that ullages are measured from an above deck datum.

Hoses and loading arms. Check for proper alignment and support. Remember that hoses and loading arms form a fragile bond between ship and shore. They are easily broken.

Heating coils. Certain cargoes (heavy fuel oils) must be heated during the voyage to the discharge port.

Inert gas system. On ships fitted with inert gas systems, tanks are inerted before loading commences. As inert gas is displaced by cargo, the inert gas leaves the tank through the vent system. Monitoring equipment in the cargo control room indicates the oxygen content in the tanks, in most cases should remain below 5%.

Logbook entries. The logbook is an important document. Tanker companies rely on it as a vital source of information, and officers can be certain their entries receive careful scrutiny in the main office. Include the following times: connection and disconnection of hoses, start and completion of each product, delays and their causes.

Smoking. Make sure crewmembers smoke in authorized areas only. Be particularly wary of visitors and workers from ashore.

Vessel security has become an important consideration in recent years. Be careful not to allow unauthorized individuals aboard, and stay alert for suspicious activities.

Line displacement

During the final phase of loading, the terminal may want to fill their pipeline with another product, possibly in preparation for the next ship due to the dock. This is called a line displacement.

For example, if the pipeline from shore tank holds 3,000 barrels, the terminal will ask to be notified when the ship gauges indicate 3,000 barrels to go. At this point they will stop their pumps and switch tanks. By the time loading is completed, 3,000 barrels of new product will displace the old product and push it aboard ship.

Loading to final draft

Unlike some types of merchant ships, tankers –most notably crude carriers-frequently load to the maximum draft permitted by law.

When the chief mate draws up his cargo plan, he calculates the exact number of barrels (or tons) to be loaded in order to submerge the ship to her marks. He must, however, work with information which may not be completely accurate. For example, the values of API or temperature maybe slightly off, or the Chief Engineer may have more bunker in his tanks as estimated.

With these potential inaccuracies in mind, it would not be surprising for the final draft to differ by several centimeter (inches) from the calculated value. Such discrepancy causes one of two things; an overloaded ship which is illegal or underloaded one which is less profitable to the company.

To avoid these pitfalls, it is necessary to monitor the draft from the dock during the final minutes of loading, signaling the terminal to shut down just as the ship submerges to her marks. As a rule, the Chief Mate does this, while one officer attends to the tank.

Trimming the ship

Trim is often a vital consideration on tankers. For example, the Master may want his ship flat for crossing a shallow bar. Then again anticipating a large burn-off from a long voyage, he may want to have several centimeters (inches) of trim.

In most cases, the Chief Mate's calculations for trim are accurate. However, he must anticipate some variation, just as he did in loading to the draft. It maybe necessary to adjust the final trim, in one of several ways 1) by loading more cargo forward or aft, 2) by shifting cargo when loading has finished, 3) by shifting bunkers, 4) by ballasting.

The latter method would not be used on a fully loaded ship, but it can be used in the case of a partial load. In most situations, the second method of shifting cargo is the easiest. This can often be done by gravitation, a technique which uses the natural tendency of oil to flow from a full tank to an empty or slack tank.

After loading

When the tank has been topped-off and secured, the vessel is ready for sea. Hoses and loading arms are drained and disconnected. Cargo tanks are ullaged, and temperatures taken. PV valves are closed, and ullage plugs are pinned shut.

VI.3. Ballasting

An empty tanker rides high in the water and is vulnerable to the attacks of an angry sea. Instead of slicing through the swells, the bow tends to bounce along the top of them. This action creates dangerous stresses on the ship's structure. The ship is also less maneuverable.

Ballast – seawater – must take the place of the missing cargo. Seawater is the logical choice because it is abundant and readily available. Seawater ballast has traditionally been carried in empty cargo tanks. However, two things have changed significantly over the years 1) the method of cleaning tanks before ballasting; and 2) the method of deballasting and slop disposal. For many years, tankers disposed of dirty ballast and slops simply by pumping them into sea. This is no longer the case – on the contrary, discharges of oil at sea are now strictly limited.

Segregated ballast tanks (SBT) are now required on virtually all new tankers. A separate pump and pipeline are provided for ballast – thus keeping oil out of ballast and (in theory) seawater out of the cargo system.

Planning the ballast load

Ballasting involves more than just filling tanks with seawater; it must be carefully planned. The following factors must be considered when planning the distribution of ballast:

Stress. Generally speaking, ballast must be spread evenly through the tanks, taking care not to concentrate it on the middle or at the ends. Since more tanks are left empty when ballasting than when loading cargo, these empty tanks must be distributed carefully. Additional empty tanks increase the possibility of creating a dangerous hog or sag condition. Stress should therefore be calculated for each ballast plan used.

Draft. A ballasted ship normally draws much less water than a loaded ship. The draft calculation is sometimes critical, however, as when crossing a shallow bar at low tide.

Trim. During the ballast passage, trim must be kept within acceptable limits. When cleaning tanks, a certain minimum amount of trim is required for stripping (slops do not drain properly if the ship is "too flat"). A trim for 4 metres is required for a 50,000-ton crude carrier.

Propeller immersion. A ship's propeller must remain submerged to operate at full efficiency.

Weather expected on the ballast passage. Weather is a vital consideration in ballast planning. Bad weather can force a tanker to take on as much water as 60% of her loaded deadweight in ballast.

Tank cleaning. Whenever repairs or inspections must be made inside the tanks, they must first be cleaned and gas-freed. This operation is a routine part of a ballast passage. Tanks to be cleaned must, of course, be empty when cleaning is performed. When more than a few tanks are to be cleaned, it is usually necessary to shift or discharge ballast from some of the ballasted tanks.

Ballast handling techniques

Many older ships do not fall under the requirement for SBT. These ships must use special techniques to avoid accumulating large amounts of slops and dirty ballast. These techniques include Crude Oil Washing (COW) and Load on Top (LOT).

Loading dirty ballast requires all the precautions which would normally be devoted to loading cargo. A spill involving dirty ballast is no less serious than one involving cargo; in addition, risk of fire and explosion are as great, if not greater, with dirty ballast as they are with cargo.

Sea valves. Seawater is introduced into the cargo system by opening the sea valves (or sea suction). This is a critical operation because it exposes the cargo system directly to the sea. If done incorrectly it can result in a bad spill; there is always a risk that oil will flow out instead of the sea water flowing in. Normally one sea valve is located on each side of the pumproom, port and starboard. These valves sit right at the skin of the ship. When taking on ballast, only one of these valves need to be opened in most cases. Before opening the sea valve, however, it is important to check the lineup carefully. Make sure each tank valve is open in the tanks designated to receive ballast.

When ballasting through the cargo system, the main object is to prevent oil from escaping as the sea valve is opened. Therefore always start the pump first, before opening the sea valve. This creates a vacuum which immediately draws seawater into the line as the valve is opened. Consequently, no oil is allowed to escape. Because sea valves are located at the bottom of the pumproom and the pump controls are often located elsewhere, a communication system must be devised between the valve operator and the pump operator.

Ballast is sometimes loaded by gravity without using the pumps. Tanks cannot be topped off in this manner, however, since water will stop flowing into the tanks when it reaches the level of the water surrounding the vessel.

In any event, whether ballasting with the pumps or by gravity, **the sea valve should the last valve opened and the first valve closed.**

Load on Top (LOT) is a ballast handling technique – first introduced in the 1960s – which has proven extremely effective in reducing the amount of slops generated during the ballast passage.

If a ship is fitted with crude oil washing (COW) system, ballast preparations begin during the discharge as each designated ballast tank is washed with crude oil **(on ships fitted with COW, any cargo tank to receive ballast must first be crude washed).**

After the departure ballast have been crude washed and stripped, they are filled with sea water. This is considered **"dirty ballast".** Certain designated "clean ballast tanks" are also crude washed during the discharge. These tanks will not be ballasted until later.

The ship departs the discharge port and begins the ballast passage. It is now necessary to prepare the clean ballast tank (i.e. arrival ballast tank) for clean ballast. Each of these tanks is washed with seawater and stripped carefully. The slops are transferred to the slop tank, and the tanks are filled with clean sea water. This is considered **"clean ballast".**

In the meantime, the dirty ballast has had time to settle – i.e. oil residues have floated to the surface. The clean bottom water is pumped overboard, and the remaining oil-water mixture is stripped to the slop tank. In the same manner, the slop tank is allowed to settle; then the clean bottom portion is carefully pumped overboard. This process is most effective on ships using multi-stage slop tanks.

It is important to note that the clean bottom water from dirty ballast and slop tanks should not be pumped overboard in a prohibited zone.

By following the load on top procedure carefully, our ship arrives at the loading port with nothing but clean ballast in her tanks.

VI.4. Discharging procedure

There are as many ways to discharge a tanker as there are to load one, and no step by step instruction can be given. However, certain principles apply to all discharging watches.

Get the bow up. It is usually best to start the discharge in the forward tanks. This lifts the bow and provides a better suction to the pumps. With increased trim, the tanks drain more effectively while stripping.

Strip residual oil into a single tank. Stripping pumps are not powerful enough to move cargo against the high pressure of large centrifugal pumps. Therefore, instead of trying to strip ashore against the main line pressure, it is standard practice to accumulate stripped oil in one tank on board the ship. Thus accumulated, most of it can be discharged with the main cargo pumps. The last few barrels can be stripped ashore after the main pumps shut down. Often, the aftermost center tank (which adjoions the pumproom) is used for this purpose. A special filling line runs from the stripping system into the tank.

Check pumproom frequently. Make regular inspections of the pumproom, checking for leaks and excessive vapour accumulation. A gassy pumproom can kill you. Before entering, always make sure ventilation system is operating. Have a man standby by topside while you're below, in case you should be overcome by vapors.

Two-valve separation. If possible, try to keep at least two closed valves between systems containing unlike cargoes.

Watch the pressure. While discharging, pressure on the cargo system is normally much higher than while loading. Pressure should be monitored carefully, because it tends to change, sometimes appreciably, as topped off in the terminal. Be prepared to change pump speed or place additional or fewer pumps on the line.

Chief Mate's discharging orders. The chief mate generally writes a set of discharging orders detailing sequence, pumps to use, maximum pressure, key valves to open or close, and anything else he thinks important. Study these orders carefully before taking charge of the deck.

Logbook entries. Pay the same scrupolous attention to logbook entries as you would while loading.

When in doubt shutdown. Learn the location of the emergency shut-down switches, or similar controls, for each pump – and don't be afraid to use them.

Tape floats. After the discharge of heavy or sticky products such as bunker fuel, ullage tape floats tend to stick to tank bottoms. If your ship is fitted with a tape-float system – and you suspect the floats may stick – have the pumpman or another crewmember roll up the tapes.

Heating coils. To avoid damage to the heating coils, turn off the steam (or mineral oil) to individual tanks well before each is empty.

Mooring lines. At most docks, mooring lines tend to tighten as the ship rises. A rapidly rising tide combined with a fast discharge could easily part one or more lines.

Stress. Plan the discharge carefully to avoid excessive stresses on the hull. When starting the discharge most of the cargo will come from the forward tanks, but don't overdo it. A certain amount should be pumped from the aft and midship section as well.

Booster pumps. When a shore tank is located at a great distance from the ship, or on top of a hill, an additional pump or pumps are frequently put into use along the shore line. This helps to reduce pressure and increase the rate of discharge.

Whenever a booster pump is to be used, be sure to start the discharge slowly. Watch the pressure; it should drop sharply within a few minutes, indicating the booster pump is on line. It is now safe to increase the discharging rate by speeding up the ship's pump or placing more pumps in service.

List. Control of list is essential during the discharge, especially while stripping. When a ship is allowed to list excessively, residual oil pools may form on the low side of the tanks, where it may not drain properly. To avoid such pitfalls, list must be carefully controlled.

Inert gas systems. During the discharge the inert gas system operates continously. As cargo leaves each tank, an equal amount of inert gas must take its place, otherwise a vacuum will form, drawing air into the tanks.

VI.5. Crude oil washing (COW)

Many crude carriers have adopted a tank cleaning technique which greatly reduces the amount of slop accumulated. Tanks are washed with **crude oil spray** drawn from the ship's cargo and delivered with the fixed tank cleaning machines.

This method takes advantage of the solvent properties of crude oil, which are greatly augmented by delivery in a high pressure spray. Crude oil washing is particularly effective against built-up sludge on tank surfaces, and it significantly reduces the need for manual mucking. It also increases the amount of crude recovered during the discharge, by as much as 1% of the total load, which be left clinging on the surface.

COW is normally used only while a tanker is discharging her cargo. Crude is routed from the discharge side of the cargo system into a special line which carries it to the tank cleaning machines. The cargo pumps supply the necessary pressure and no special pump is required. A pressure of 10kg/cm2 (142 psi) might be considered typical – although this may vary considerably, even on the same ship. It is important to note that the COW technique requires a certain minimum pressure (as specified in each COW manual) in order to operate effectively. At some discharging ports it is necessary to "pinch down" the manifold valves to achieve the desired pressure on the system.

Prerequisites for using COW. In order to use COW, several conditions must first be met. First of all, only ships with inert gas systems, properly operating, may use this technique. The tank cleaning machines must be permanently mounted and of a type suitable for crude oil washing. In addition, not all types of crude oil are adaptable to COW – therefore, the type of crude oil on board must be taken into consideration. A positive means must also be provided to check tank bottoms and confirm that they are clean and dry. Finally, because COW usually lengthens the total discharge time, an allowance must be made for this extra time when planning a vessel's stay in port.

Stripping is of vital importance when crude oil washing. The purpose of COW is to reduce residues left on board the ship – therefore, if stripping is not done carefully the process is a waste of time. Discharge and suction piping must be drained and stripped, and the COW lines on deck must be drained as well. This is done by opening a COW nozzle at the forward end of the ship and another at the aft end. The line then drains into the aft tank by gravity.

The initial crude oil wash can be followed by a water rinse, if necessary. This is done e.g., when a tank id needed for clean ballast or when crew members must enter the tank for inspection or repairs.

Which tanks, and how often? The IMO requires the following on ships using COW:

1) no ballast maybe pumped into a cargo tank unless the tank has first been crude washed; and 2) all tanks must be crude washed periodically for sludge control. The basic requirement is that enough tanks be crude washed to permit adequate ballasting during the ballast passage, taking into account normal weather, draft and trim requirements. Of the remaining tanks

approximately 25% must be crude washed each voyage on a rotating basis – although an individual tank need not be washed more than once every four months.

Hectic, but effective. The addition of COW and inert gas system to crude carriers has increased the complexity of ship operation tremendously. To say that the average discharge is hectic is an understatement. It is not uncommon to discharge, crude oil wash, and ballast – all simultaneously.

Great pressure is put on ship's officers – the chief mate in particular – to keep the systems operating efficiently and in accordance with the plethora of regulations currently provided by local, national and international authorities. A system failure often results in costly delays.

Despite these difficulties, crude oil washing has proven to be an effective technique. Cargo recovery is improved; less slops are accumulated; sludge is controlled. But to achieve these results, sincere and careful effort is required of the ship's officers and crew.

Single nozzle machines are deck-mounted and programmable. Tanks are washed in stages. As the tank level drops, the arc of cleaning spray is varied to "follow" the oil level downward. If selective arc machines are being used, the operation can begin as soon as the cargo level is below the wash head. With less sophisticated machines, the process usually begins with a top wash when the tank is about 60% empty.

The bottom wash begins when the tank is almost completely empty. This step is important, because the largest amount of sludge, wax and sediments tend to accumulate on the bottom. Strategically located twin-nozzle machines, mounted near the tank bottom, are often called into play at this point. These machines are used to wash trouble spots or "shadow areas" behind beams, platforms, etc. which are missed by deck mounted machines.

Twin nozzle machines. In order to wash tanks with crude oil, only fixed machines specifically designed for crude oil washing may be used. These may either be twin-nozzle or single nozzle machines. Both work effectively, but require different methods of operation. Twin-nozzle machines are non-programmable; i.e. no specific arc can be selected. They run through a complete cycle, washing all tanks surfaces in a given period of time. For this reason, crude oil washing with this type of machine is not started until the tank is nearly empty. In this manner no time is wasted "washing" the surface of the cargo.

VI.6. Inert gas system

Inert gas systems are now required on many tankers. Generally speaking, most tankers of 20,000 DWT and above must have inert gas system. The actual regulations are fairly complex, and the rules for ships calling in US ports are slightly different from the IMO requirements.

Tankers operated without IG systems; this meant, of course, that tanks were vented directly to the atmosphere. As a result, air was drawn into the tanks and allowed to mix with cargo vapours. The obvious problem is that air contains 21% oxygen. When oxygen is mixed with hydrocarbon vapours in the right in the proportions, the result is a very dangerous mixture indeed.

Inert gas systems remedy this situation by forming a closed system from which air is entirely excluded. Instead of air, a different mixture of gasses is introduced into the tanks. This mixture must be effectively inert – i.e. it must not promote combustion. On most tankers, the boiler flue gasses are used for this purpose. These gasses generally contain less that 5% oxygen. Some tankers use a special inert gas generator instead of flue gasses. This might be the case where gas of high purity is needed, as on a special product carrier or chemical carrier. In either case the "inert" portion of the gas consists mainly of nitrogen and carbon dioxide.

To get a general idea of how a typical system works, let's follow the route of the inert gas from the ship's boiler to the cargo tanks. Flue gas is drawn from the uptake via an uptake valve. It passes through a scrubber where it is cooled and cleansed of impurities such as soot and sulphur oxides. It is next drawn through a demister, where excess water is removed. It then passes through a fan, which is situated on the "clean" side of the scrubber and demister. This fan provides the positive pressure which makes the system work. From the fan, the gas passes through a pressure control valve which, as the name implies, is used to regulate the pressure of inert gas entering the tanks.

From the pressure control valve the gas leaves the non-hazardous area and enters the hazardous area – i.e. that part of the system where hydrocarbon gas is encountered. Separating these two areas is a deck water seal, which is designed to prevent the backflow of hydrocarbon vapours in the non-hazardous area. From the deck seal, the gas passes through a non-return valve which serves as a back-up to the deck seal. From here the gas passes through the deck isolating valve. This valve is used to isolate the main line to the tanks when the IG system is secured. From the main line the gas enters the tanks via the various branch lines.

Purging

When starting with an empty tank containing 21% oxygen, it is not enough merely to pump inert gas into the tank. In order to achieve a properly inerted mixture, it is necessary to remove air from the tank. This is done by dilution or displacement.

With the **dilution method, inert gas is introduced at high velocity** into the tanks. By this method, it is usually necessary to change the tank atmosphere 3 to 5 times before the tank is fully inerted.

The **displacement method**, on the other hand, is quite different. Gas is **introduced at low velocity.** An interface is formed between incoming inert gas and outgoing air. As inert gas settles into the tank, the outgoing air forced out of the tank through a purge pipe. This method normally requires about 1 1/2 atmosphere changes.

It is important to emphasize that the method used must suit the ship. Depending on the particular equipment and piping, only one or the other is suitable. Regardless of the method used, oxygen readings must be taken at various levels in the tank to ensure that the atmosphere has been properly inerted. These readings must fall consistently below 8% before the tank can be considered inerted.

After discharging cargo or cleaning tanks, the tanks are often **purged** with inert gas in order to remove hydrocarbon vapours. Purging is necessary because in the event of a collision hydrocarbon vapours would rapidly form an explosive mixture with oxygen introduced through damaged bulkheads, decks, etc.

In order to gas-free a tank, the same procedure is used when purging with inert gas. However, in this case air is blown into the tanks and inert gas is vented from the purge pipes.

It is important to note that only a limited number of tanks can be purged at one time. If the velocity of inert gas (or air) entering the tanks is too low, pockets of vapour may be left in the tanks. When too many tanks are purged at once, the pressure drops – and so does the exit velocity. As a result hydrocarbon vapours can accumulate around the main deck.

Loading

Prior to loading, the cargo tanks should, if necessary, be purged until the oxygen level is below 8% in each tanks. At this point, unless the ship will be loading and deballasting simultaneously, the deck isolating valve is closed and the IG system secured.

As cargo is loaded, the inert gas is vented to the atmosphere. Depending on vessel design, the gas will follow one of two routes: 1) up the mast riser; or 2) directly to the atmosphere via high velocity PV valves at each tank. In either case, the idea is to allow the gas to disperse well above the main deck.

If the ship is loading and deballasting at the same time, the situation becomes more complicated. For example, if the deballasting rate exceeds the loading rate, a vacuum will develop into the tanks. As a result, air will be drawn into the system through the PV valves. Therefore in this situation, inert gas must be supplied to the tanks, and pressure must be maintained on the IG system until deballasting is finished. The deck isolating valve can then be closed and the IG system secured until loading is completed.

Loaded passage

After loading is finished, the mast riser bypass valve and/or PV valves are closed. The IG system is started, and the deck isolating valve is opened slowly. After the tanks have been pressurised sufficiently, the system can in most cases be secured.

During the passage to the discharge port the inert gas pressure should be watched carefully. A low pressure alarm is provided for this purpose. A vacuum must not be allowed to develop in the system; otherwise air will be drawn into the tanks. This situation might be expected to occur when passing into a region of colder sea temperatures, causing cargo to cool and contract. At any rate, the pressure should be watched carefully throughout the passage and, if necessary, the system should be restarted and brought back up to pressure.

Discharging

Upon arrival at the discharging port, the inert gas system is turned on. It is kept operating throughout the discharge. A steady supply of inert gas is needed to replace the cargo as it leaves the tanks. During the discharge, always watch the IG pressure carefully. Even when the system is running at full capacity, the pressure may start to drop – indicating that the cargo pumps are getting ahead of the inert gas system. When this happens, the pumping rate must be reduced until the IG system builds back up to a sufficient pressure.

Many crude carriers now wash their tanks with crude oil while discharging cargo. This does not particularly affect the operation of the inert gas system, but it offers an additional reason to operate the system carefully. By law, ships using COW must be properly inerted.

After discharging has been completed, it is a common practice to purge tanks of hydrocarbon vapors. But before doing so, check local regulations – it is prohibited in some ports. While purging with inert gas, readings are taken with a combustible gas indicator.

Tank cleaning

Prior to cleaning tanks, an oxygen reading is obtained at several levels in each tank. If necessary, tanks must be purged with inert gas to bring the readings to below 8%.

Pressure is maintained continuously while tanks are being cleaned. Unless the ship is simultaneously discharging – as when using COW – very little gas will actually move through the lines. The inert gas fans are fitted with recirculating lines to prevent overheating in this situation. The practice on some ships is to crack the mast riser bypass valve a few turns to allow a continuous flow of gas through the line. This increases the efficiency of the system and decreases the absorption of oxygen from the scrubber cooling water.

Gas freeing

Before a tank is gas freed it should first be purged of hydrocarbon vapors. There is a good reason for this precaution. If air is introduced into a tank containing a mixture of hydrocarbon vapours and inert gas, there is a good chance that at some point in the process the vapours and air will form an explosive mixture. At this point, the percentage of hydrocarbon vapours and oxygen will both be right to promote and explosion.

Gas freeing the entire ship is very similar to purging. The only difference is that fresh air is supplied instead of inert gas. The regular IG fans and deck lines are used. The inert gas is allowed to vent from the purge pipes, stand pipes, or high velocity PV valves in the usual manner.

Gas freeing an individual tank must normally be carried out with portable blowers mounted in openings on the main deck. Before the deck plates are removed, the tank is isolated from the rest of the IG system and the pressure is carefully vented. The blowers should supply as high a volume of air as possible. This will ensure a thorough purging of all parts of the tank, and it will also eject the inert gas from the purge pipes at high velocity.

VI.7. Cargo heating

Heavy fractions, such as fuel oil become very thick and sluggish when cold, and, in order that such oils can be loaded and discharged without delay, it is necessary to keep them heated.

Today the oil trade is so vast and wide spread, that the average oil tankers may be trading in the tropics one voyage, and in Arctic conditions the next. It is therefore necessary that cargo heating systems be designed to cope with extreme conditions.

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

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

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

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

The wing tank insulate the center tanks on both sides, while they are subject themselves to the cooling action of the sea, not only through the bottom plating, but through the ship's side. It is therefore advisable to set the steam valves so that the wing tanks obtain a larger share of the steam than the center tanks.

Heavy fuel oils are generally required to be kept at a temperature ranging between 120 F and 135 F. Within this temperature range, they are easy to handle. In ships carrying heavy lubricating oils which require heating, the coils are generally ordinary steel pipe, but vessels carrying crude oils which have to be heated, are now equipped with cast iron or alloy coils. The reason for this is that the heating surfaces are subjected to excessive corrosion from lighter in the crude, and ordinary steel pipes do not stand up to the corrosive action so well as the other materials mentioned.

Special tank cleaning procedures

After the carriage of certain products, tanks can only be adequately cleansed by steaming, or by addition of certain tank cleaning chemicals or additives to the wash water.

Steaming may only be carried out in tanks which have been either inerted or water-washed and gas freed. The concentration of flammable gas should not exceed 10% of the LFL prior to steaming. Precautions should be taken to avoid the build-up of steam pressure within the tank.

If tank cleaning chemicals are to be used, it is important to understand that certain products may introduce a toxicity hazard. Personnel should be aware of the TLV (Threshold Limit Value) of the product. Personnel entering tanks should wear breathing apparatus and appropriate protective clothing. All other tank precautions must be observed. Detector tubes are particularly useful for detecting the presence of specific gases and vapours in tanks.

Tank cleaning chemicals capable of producing a flammable atmosphere should normally only be used when the tank has been inerted. However, such products may be used to clean tank walls in a localised area (wiping down) in vessels not fitted with inert gas system provided the amount of tank cleaning chemical used is small and the personnel entering the tank observe all enclosed space entry requirements.