

DISSERTATION
TANKER SHIP SAFETY SYSTEMS
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**ΑΚΑΔΗΜΙΑ ΕΜΠΟΡΙΚΟΥ ΝΑΥΤΙΚΟΥ
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**ΕΠΙΒΛΕΠΟΥΣΑ ΚΑΘΗΓΗΤΡΙΑ: ΠΑΠΑΛΕΩΝΙΑ
ΠΑΡΑΣΚΕΥΗ**

**ΘΕΜΑ
«TANKERSHIP SAFETY SYSTEMS»**

**ΤΟΥ ΣΠΟΥΔΑΣΤΗ: ΝΑΤΗ ΠΑΣΧΑΛΗ
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ABSTRACT

The purpose of this research aims to show a panoramic vision of the most important safety systems we usually meet in oil tankers. The first part of this research involves a description of inert gas system and a thorough description of all safety systems/mechanisms we meet in an oil tanker for the prevention of over and underpressure, during evaporation of cargo and keep the tanks in all respects safe during voyage and during loading/unloading operations. Afterwards I refer to the nitrogen generator system and its characteristics. Furthermore I analyze the hazards of toxic gases and the gas detection systems we use to detect these gases. Moreover I describe the tank high level and overfill alarm system which help us to avoid pollution of oil. Additionally I make a reference to static electricity and the use of the vapour line. The final part of this research involves some general precautions onboard oil tankers.

INTRODUCTION

During investigations by the major oil companies following a number of serious explosion on tanker ships, particularly during tank washing, it was established that three factors were responsible.

- A) The hydrocarbon gas given off by the cargo.
- B) The oxygen content of the tank atmosphere.
- C) The sources of ignition

It is impossible to prevent the formation of hydrocarbon gas, and the sources of ignition are diverse and not fully understood. However, by introducing an inert gas (e.g. nitrogen, carbon dioxide or helium) into the cargo tank atmosphere, the effective oxygen content can be reduced to a level too low to support combustion. The oxygen concentration must be kept below 10 %. To provide adequate safety margin, a figure of between 3 % and 5 % must be aimed for in practice. Provide that such an atmosphere is maintained, crude oil washing and other operating procedures can be carried out safely without risk that the cargo tank mixtures pass through the flammable range.

It is important that the inert gas system is correctly operated and maintained and it must be remembered that accepted safety procedures must not be relaxed.

Studies have led to the recommendations of IMO and the regulations put forward by Lloyd's, ABS and DNV for the installation of inert gas system, by controlling the oxygen content of the tank atmosphere, largely reduces the potential danger and allows crude oil washing and other cargo handling procedures to be carried out with safety.

In addition to its main function of ensuring safety during tanker operations, the following advantages are also provided by the inert gas system:

- a. The reduction of the oxygen content in the cargo tank atmosphere causes a reduction in corrosion.
- b. The slight pressure provided by the introduction of inert gas into the ullage space makes the pumping of volatile and difficult oils easier during cargo discharge.

THE EXPLOSION TRIANGLE

On board vessels carrying cargoes which give off hydrocarbon vapour dangerous situation arises if oxygen, in the correct proportion, enters the cargo tanks. At this stage a potentially flammable environment exists in the tank and if we have a source of ignition, an explosion could occur.

The explosion triangle in figure 1.1 illustrate the three factors which are necessary for an explosion and what actions can be taken to avoid such.

To minimize the risk of explosion, precautions have always been taken to remove known ignition sources. It is, however, possible that unknown ignition sources exist in certain circumstances.

Tests have established that when a cargo tank contains oil, but is not completely filled, flammable gas mixtures can exist in the ullage space. The hydrocarbon gas of such mixtures depends upon several variables: type of crude, season of loading, temperature, method of discharge etc. The hydrocarbon gas content, therefore cannot be controlled. Measurements of hydrocarbon gas can be taken, but are not reliable and are unlikely to be representative of the whole gas volume.

To reduce the risk of explosion, only the oxygen content is controllable. This control is exercised by the installation of an inert gas system for operation by offshore personnel.

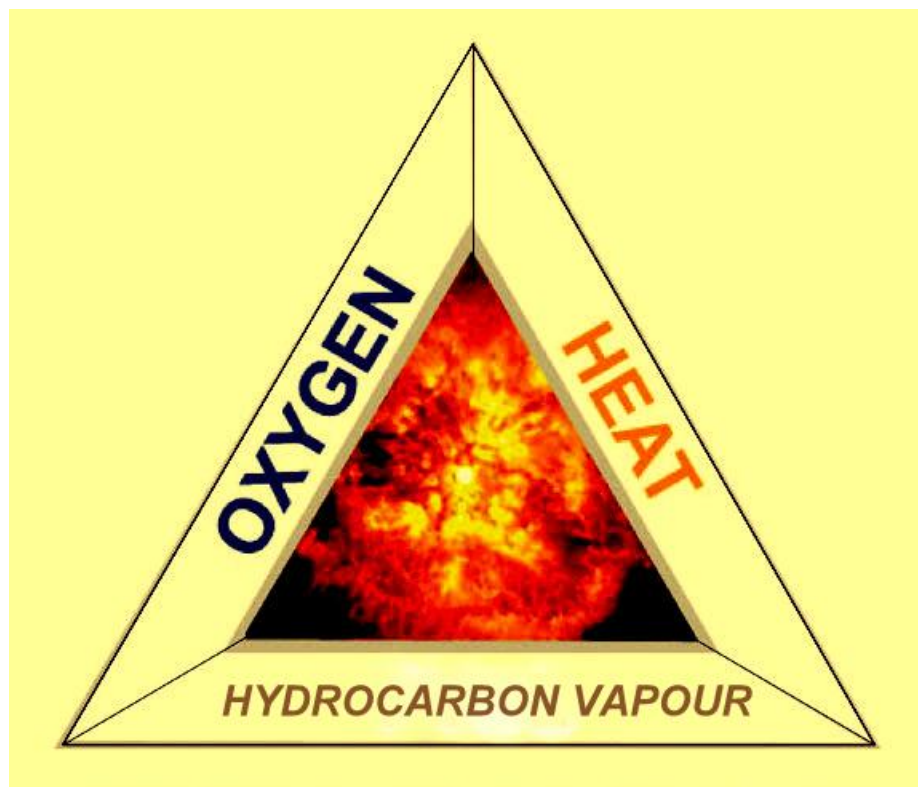


FIGURE 1.1 THE EXPLOSION TRIANGLE

OXYGEN CONTENT OF ULLAGE GAS

A diagram can be drawn for the range of oxygen/hydrocarbon gas proportions which can be expected in the ullage space of a cargo of crude oil, showing the area in which the properties constitute a flammable mixture. The upper and lower flammable limits are represented by UFL and LFL respectively.

Point A corresponds to the oxygen content of air. The line AB represents the oxygen content of a mixture containing only air and hydrocarbon gas. Any mixture represented by coordinates below this line will also contain an inert gas.

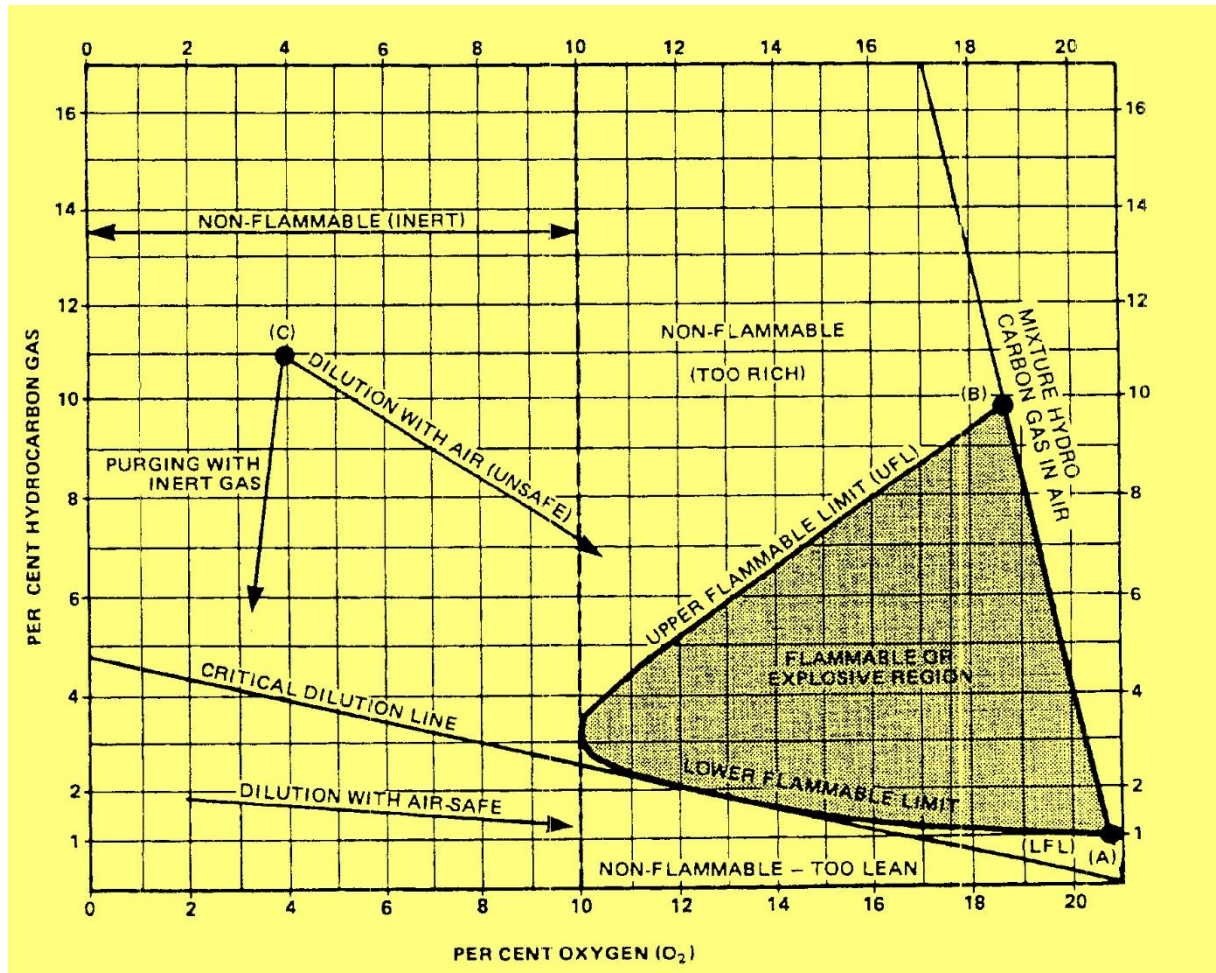


FIGURE 1.2 ULLAGE GAS FLAMMABILITY

It will be seen from the diagram that as the oxygen content is reduced by replacing the air with inert gas, the range of hydrocarbon gas content over which the mixture is flammable is reduced.

When the oxygen level is low enough, below point C, the mixture will not be flammable irrespective of the hydrocarbon gas content.

It must be emphasized that the diagram is approximate and is based upon perfect mixing of the gases, nevertheless it can be used as a guide to operating procedures.

1. DISCRPTION OF INERT GAS SYSTEM

A. PURPOSE

The international conference on tanker safety and pollution prevention held in February 1978 passed resolution 5 recommending that the international maritime organization develop guidelines to supplement the requirements of amended the

arduous operating conditions of inert gas systems and the need to maintain them to a satisfactory standard. In addition regulation 62.1 requires that an inert gas should be designed, constructed and tested to the satisfaction of the administration. These guidelines have accordingly been developed to supplement and complement the convention requirements for inert gas systems. They are offered to administrations to assist them in determining appropriate design and constructional parameters and in formulating suitable operational procedures when inert gas systems are installed in ships flying their flag of their state.

APPLICATION

The status of these guidelines is advisory. They are intended to cover the design and operation of:

1. Inert gas systems that are required on new tankers by regulation 60 of chapter II-2 of the 1978 SOLAS protocol and in accordance with regulation 62.
2. Inert gas systems that are required on existing tankers by regulation 60 of chapter II-2 of the 1978 SOLAS protocol and in accordance with regulation 62.
3. Inert gas systems which are fitted but not required to comply with the requirements of regulation 60 of chapter II-2 of the 1978 SOLAS protocol.

However, for existing inert gas systems the guidelines are directed primarily at operational procedures and are not intended to be interpreted as requiring modifications to existing equipment other than those which are required on ships to which regulation 62.20 applies.

The content of these guidelines is based on current general practice used in the design and operation of inert gas systems using flue gas from the uptake from the ships main or auxiliary boilers and installed on crude oil tankers and combination carriers. The guidelines do not exclude other sources of inert gas, such as systems incorporating independent inert gas generators, other designs, materials or operational procedures. All such divergences should be carefully assessed to ensure that they achieve the objectives of these guidelines.

B. DEFINITIONS

1. Inert gas means a gas or a mixture of gases, such as flue gas, containing insufficient oxygen to support the combustion of hydrocarbons.
2. Inert condition means a condition in which the oxygen content throughout the atmosphere of a tank has been reduced to 8% or less by volume by addition of inert gas .
3. Inertgas plant means all equipment especially fitted to supply, cool, clean, pressurize, monitor and control delivery of inert gas to cargo tank systems.
4. Inert gas distribution system means all piping, valves, and associated fitting to distribute inert gas from the inert gas plant to cargo tanks, to vent gases to atmosphere and to protect tanks against excessive pressure or vacuum.

5. Inert gas system means an inert gas plant and inert gas distribution system together with means for preventing backflow of cargo gases to the machinery spaces, fixed and portable measuring instruments and control devices.
6. Inerting means the introduction of inert gas into a tank with the object of attaining the inert condition defined in No2.
7. Gas-Freeing means the introduction of fresh air into a tank with the object of removing toxic, flammable and inert gases and increasing the oxygen content to 21% by volume.
8. Purging means the introduction of inert gas into a tank already in the inert condition with the object of:
 - a. Further reducing the existing oxygen content and/or
 - b. Reducing the existing hydrocarbon gas content to a level below which combustion cannot be supported if air is subsequently introduced into the tank.
9. Topping up means the introduction of inert gas into a tank which is already in the inert condition with the object of raising the tank pressure to prevent any ingress of air.

C.SOURCES

Possible sources of inert gas on tankers including combination carriers are:

1. The uptake from the ships main or auxiliary boilers
2. An independent inert gas generator, or
3. A gas turbine plant when equipped with an afterburner

D. METHODS OF GAS REPLACEMENT

There are three operations which involve replacement of gas in cargo tanks, namely:

1. Inerting
2. Purging
3. Gas-Freeing

In each of these replacement operations, one of two processes can predominate:

1. Dilution, which is a mixing process
2. Displacement, which is a layering process

These two processes have a marked effect on the method of monitoring the tank atmosphere and the interpretation of the results. Figures 3 and 5 show that an understanding of the nature of the gas replacement process actually taking place within the tank is necessary for the correct interpretation of the reading shown on the appropriate gas sampling instrument.

The dilution theory assumes that the incoming gas mixtures with the original gases to form a homogeneous mixture throughout the tank. The result is that the concentration of the original gases decreases exponentially. In practice the actual rate of gas replacement depends upon the volume flow of the incoming gas, its entry velocity and the dimensions of the tank. For complete gas replacement it is important that the entry velocity of the incoming gas is high enough for the jet to reach the bottom of the tank.

It is therefore important to confirm the ability of every installation using this principle to achieve the required degree of gas replacement throughout the tank.

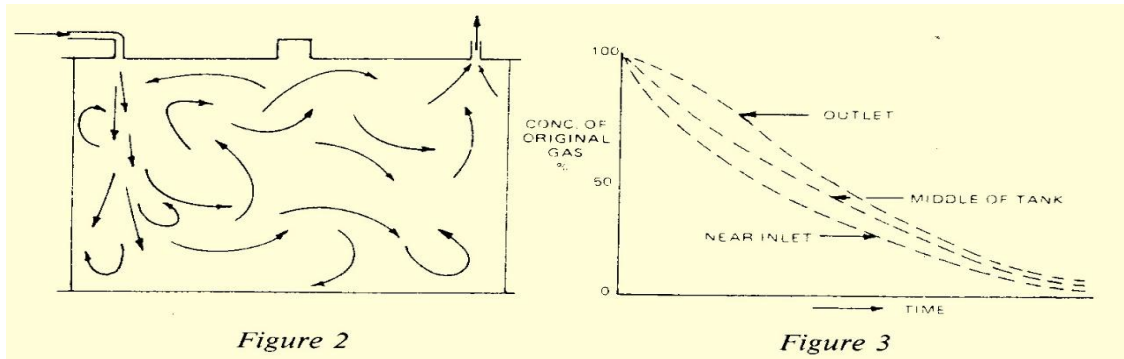


Figure 2 shows an inlet and outlet configuration for the dilution process and illustrates turbulent nature of the gas flow within the tank. Figure 3 typical curves of gas concentration against time for three different sampling positions. Ideal replacement requires a stable horizontal interface between the lighter gas entering at the top of the tank and the heavier gas being displaced from the bottom of the tank through some suitable piping arrangement. This method requires a relatively low entry velocity of gas and in practice more than one volume change is necessary. It is therefore important to confirm the ability of every installation using this principle to achieve the required degree of gas replacement throughout the tank.

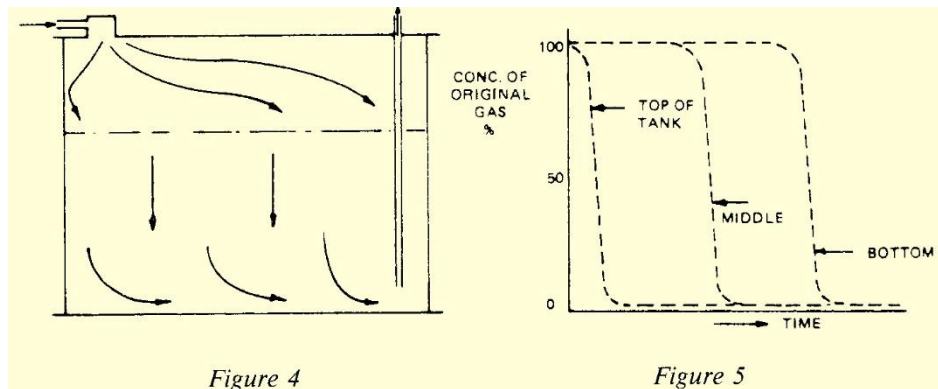


Figure 4 shows an inlet and outlet configuration for the displacement process, and indicates the interface between the incoming and outgoing gases.

Figure 5 shows typical curves of gas concentration against time for three different sampling levels.

ARRANGEMENT	INLET POINT	OUTLET POINT	PRINCIPLE
1	TOP	TOP	DILUTION
2	BOTTOM	TOP	DILUTION
3	TOP	TOP	DISPLACEMENT OR DILUTION

E. GENERAL POLICY OF CARGO TANK ATMOSPHERE CONTROL

Tankers fitted with an inert gas system should have their cargo tanks kept in a nonflammable condition at all times. It follows that:

1. Tanks should be kept in the inert condition whenever they contain cargo residues or ballast. The oxygen content should be kept at 8% or less by volume with a positive gas pressure in all the cargo tanks.
2. The atmosphere within the tank should make the transition from the inert condition to the gas-free condition without passing through the flammable condition. In practice this means that before any tank is gas-freed, it would be purged with inert gas until the hydrocarbon content of the tank atmosphere is below the critical dilution line.
3. When a ship is in a gas free condition before arrival at a loading port, tanks should be inerted prior to loading.

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

1. Inert empty cargo tanks
2. Be operated during cargo discharge, deballasting and necessary in-tank operations
3. Purge tanks prior to gas-freeing
4. Top up pressure in the cargo tanks when necessary, during other stages of the voyage.

F. TANK ATMOSPHERE

On most existing vessels it is not possible to prevent air from entering the cargo tanks, particularly during cargo discharge. However, by installing an inert gas system it is possible to introduce suitably treated flue gas into the cargo tank. This inert gas is supplied at slight pressure displaces any air present in the cargo tanks. The cargo tank is thus slightly above atmospheric pressure, so that ingress of further air is prevented and consequently a safe atmosphere is maintained.

G. INERT GAS SUPPLY

The greater demand for inert gas occurs during cargo discharge, at which time the supply of inert gas must at least equal the cargo discharge rate. The rated capacity of centrifugal cargo pumps is related to a specified discharge head. When discharging against a lower head, it is possible to exceed the rated capacity. To accommodate this and ensure that the inert gas is supplied at a positive pressure, the inert gas system must be capable of supplying inert gas at a rate greater than at which the cargo is being discharged. A factor of 1.25 of inert gas capacity over nominal cargo pump capacity is generally acceptable.

INERT GAS SYSTEM

The inert gas system must provide, within the cargo tanks, an atmosphere which will not support combustion, will not contaminate the cargo and is available in volume and

pressure to suit all operating conditions. The system has two basic groups of equipment:

A) A production plant to produce inert gas and deliver it under pressure, by means of blower, to the cargo tanks.

B) A distribution system to control the passage of inert gas into the appropriate cargo tanks at the required time. The inert gas is distributed to the cargo tanks by branch pipes connected to the inert gas deck main. Each branch pipe contains a valve so that any tank can be isolated.

H. FLOW DIAGRAM

Flue gas from the boilers forms the basis for inert gas production. From the boiler uptakes the hot and dirty gases are drawn via flue gas isolating valve to the scrubber unit. A 100 psi steam cleaning arrangement is fitted for the flue gas isolating valve.

In the scrubber unit the gas is cooled, cleaned and dried before being piped via scrubber isolating valve to the motordriven inert gas blowers. They are mounted on rubber vibration absorbers and isolated by rubber expansion bellows.

Regulation of gas quantity delivered to deck is taken care of by the gas control valves. They have both got valve positioners in addition to pneumatic actuators. Valve leads to the deck main valve to the blow off line to atmosphere. A pneumatic controller is incorporated to measure the deck pressure, compare it to the controller set point and given out the resulting 3-15 psi signal to the valve positioners. If the deck pressure is lower than the set point, the output signal will be raised. Valve No1 thereby travels to a more open position, valve No2 to a less open position. Thus more gas will be delivered to deck and the deck pressure will reach the set point the soonest possible way.

Before entering the deck line the gas must pass the deck water seal. Together with the subsequent non-return valve a means of automatically preventing the backflow of cargo gasses is formed. After plant shutdown the inert gas relief valve opens to balance built-up deck water seal pressure.

The plant may also be used for cargo tank gas-freeing. The blind flange of fresh air intake must then be removed. At this mode of operation neither scrubber isolating valve nor gas control valve can be opened.

I. IG ALARM SYSTEM

The alarm central is located in the main panel. The alarm list give detail information for alarm locations and functions, including shutdown functions. In case of alarms which might give rise to dangerous situations, the alarm logic automatically shuts down the inert gas system in addition to giving visual and audible alarm annunciation. Any inert gas system alarm will activate the engine alarm as well.

After EMERGENCY STOP, the alarm can only be reset by pulling the pushbutton back to normal position. All the other alarms require resetting from main panel. STOP HORN pushbuttons are fitted in panel as well. The closed-circuit principle applies

throughout the system. In the event of failure in the control voltage supply the power failure alarm will be energized by an auxiliary supply.

J. DESCRIPTION OF INERT FLUE GAS SYSTEM

A typical arrangement for an inert flue gas system is shown in figure 6. It consists of flue gas isolating valves located at the boiler uptake points through which pass hot, dirty gases to the scrubber and demister. Here the gas is cooled and cleaned before being piped to blowers which deliver the gas through the deck water seal, the nonreturn valve, and the deck isolating valve to the cargo tanks. A gas pressure regulating valve is fitted downstream of the blowers to regulate the flow of the gases to the cargo tank. A liquid-filled pressure/vacuum breaker is fitted to prevent excessive pressure or vacuum from causing structural damage to cargo tanks. A vent is fitted between the deck isolating/nonreturn valve and the gas pressure regulating valve to vent any leakage when the plant is shut down.

For delivering inert gas to the cargo tanks during cargo discharge, deballasting, tank cleaning and for topping up the pressure of gas in the tank during other phases of the voyage, an inert gas deck main runs forward from the deck isolating valve for the length of the cargo deck. From this inert gas main, inert gas branch lines lead to the top of each cargo tank.

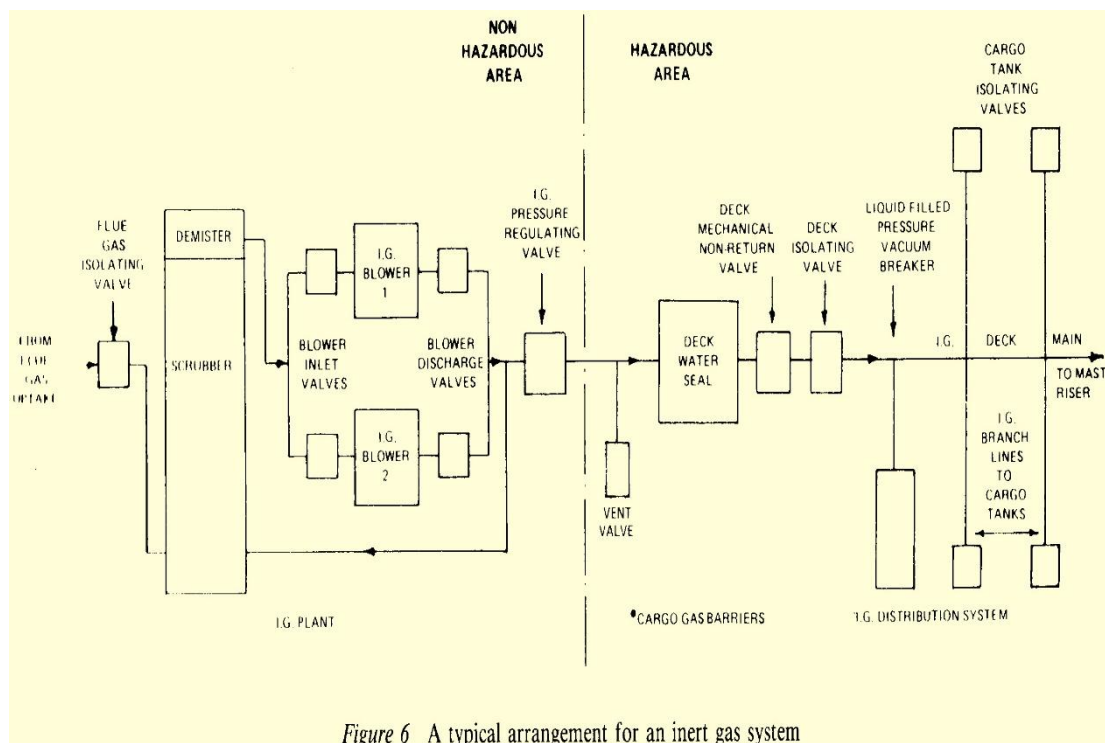


Figure 6 A typical arrangement for an inert gas system

K. SCRUBBER UNIT

The purpose of the scrubber unit is:

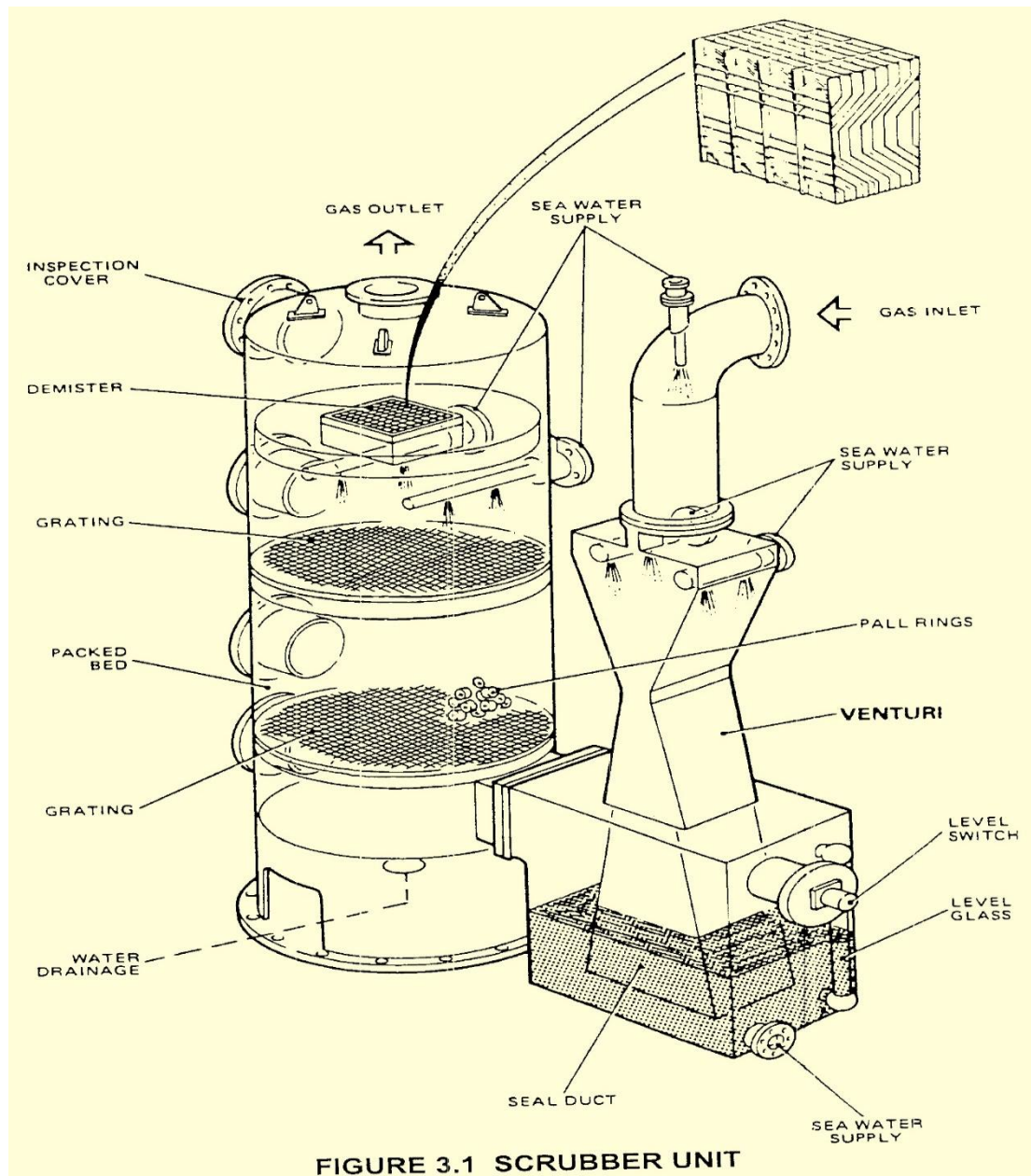
1. To cool the flue gas
2. To remove suspended solid particles from the gas
3. To remove the sulphureous gases
4. To dry the flue gas

In order that these functions can be carried out in the most efficient manner, the scrubber unit has been designed and built in three sections:

1. PRECOOLER
2. VENTOURI
3. SCRUBBER UNIT

PRECOOLER

Hot gas, drawn from the boiler uptake, enters the precooler where sea water is sprayed from a single nozzle into the gas flow, causing a rapid drop in the temperature of the gas. From the precooler, the gas enters the venturi.



VENTURI

Soot removal takes place in the venturi, the efficiency of which depends mainly on the velocity of the gas flow through the venturi. This velocity results in a pressure drop through the venturi, causing the suspended water droplets and soot particles to be deposited on the walls of the venturi. The water droplets run down the sides of the venturi and wash the deposited soot particles to the lower part of the scrubber, from where the resultant slurry is discharged overboard. The nozzle holes must then point vertically downwards. 98.5% of the soot particles of 1 micrometer and above are effectively removed.

The pressure drop across the venturi is adjusted by varying the amount of sea water sprayed through the two nozzles mounted in the venturi upper part. The amount of sea water entering the venturi is controlled by the venturi adjusting valve placed upstream of the nozzles.

The venturi pressure drop can be measured by connecting the ends of an approx. 4 m long transparent plastic hose to the two test gauge connection holes. Let the hose water columns hang vertically and read the pressure drop by measuring the vertical distance between the two water levels.

The pressure drop should be minimum 600 mmWG (600 mm vertical difference between the two water levels) for maximum soot removal in the venturi. This can be achieved by adjusting the stroke limiters of the valve. Pressure drop below 600 mmWG requires adjustment of the valve to more open position.

The scrubber seal, located in the venturi bottom, should at all times be kept filled with sea water. During normal plant operation it will be filled by water from the precooler and venturi nozzles.

SCRUBBER TOWER

After leaving the venturi, the gas enters the base of the scrubber tower and is drawn upwards through a package bed of pall rings against a downflow of sea water sprayed from four nozzles positioned above the packaged bed. The pall rings a large contact surface area between the gas and water. This is an essential feature for the effective absorption of the Sulphur dioxide. The efficiency of the SO₂ absorption depends on the flow rate, temperature and salinity of the sea water, and varies between 95 % and 98 %. The design efficiency is based upon a sea water temperature of 30° C and flowrate given by a spray nozzle pressure of 1 bar. The efficiency increases as the sea temperature is lowered and the flowrate is increased. SO₂ absorption is reduced in fresh water.

The rising gas then passes through a demister (droplet eliminator), which prevents the water droplets from being drawn into the inert gas blowers. The demister consists of a series of individual flow channels through which the gas flow deviates. The resultant loss of inertia in the gas flow causes the water droplets to be deposited on the walls of the flow channels. The water droplets gather to form larger droplets, which flow back to the scrubber tower bottom.

Manholes are provided in both the packed bed section and the section above the eliminator. An inspection window is placed in the nozzle section.

The scrubber is manufactured from mild steel and is glass flaked with polyester coating to protect the steel shell from the corrosive effects of sea water and Sulphur dioxide. The pall rings are made of polypropylene and the grating upon which the rest is made from glass-fibre reinforced plastic. All internal nuts and bolts are made from stainless steel.

The precooler, venturi upper part and venturi intermediate part are manufactured from stainless steel. The venturi lower part is manufactured from mild steel and is internally glass flaked with polyester coating.

DESIGN CONSIDERATIONS FOR INERT GAS SCRUBBER

1. The scrubber should be of a design related to the type of tanker, cargoes and combustion control equipment of the inert gas supply source and be capable of dealing with the quantity of inert gas required by regulation 62 at the designed pressure differential of the system.
2. The performance of the scrubber at full gas flow should be such as to remove at least 90% of sulphur dioxide and to remove solids effectively. In product carriers more stringent requirements may be needed for product quality.
3. The internal parts of the scrubber should be constructed in corrosion-resistant materials in respect of the corrosive effect of the gas. Alternatively, the internal parts may be lined with rubber, glass fibre epoxy resin or other equivalent material, in which case the flue gases may require to be cooled before they are introduced into the lined sections of the scrubber.
4. Adequate openings and sight glasses should be provided in the shell for inspection, cleaning and observational purposes. The sight glasses should be reinforced to withstand impact and be of a heat resisting type. This may be achieved by the use of double glazing.
5. The design should be such that under normal conditions of trim and list the scrubber efficiency will not fall by more than 3%, nor will the temperature rise at the gas outlet exceed the designed gas outlet temperature by more than 3° C.
6. The location of the scrubber above the load waterline should be such that the drainage of the effluent is not impaired when the ship is in the fully loaded condition.

L. INERT GAS BLOWERS

Blowers are used to deliver the scrubber flue gas to the cargo tanks. Regulation 62.3.1 requires that at least two blowers shall be provided which together shall be capable of delivering inert gas to the cargo tanks at a rate of at least 125% of the maximum rate of discharge capacity of the ship expressed as a volume.

In practice installations vary from these which have one large blower and one small blower, whose combined total capacity complies with regulation 62, to those in which each blower can meet this requirement. The advantage claimed for the former is that it is convenient to use a small capacity blower when topping up the gas pressure in the cargo tanks at sea, the advantage claimed for the latter is that if either blower is defective the other one is capable of maintaining a positive gas pressure in the cargo tanks without extending the duration of the cargo discharge.

The inert gas system is normally fitted with three combustion air blowers. Each blower is designed to carry 50% of plant capacity, and the blowers are driven by an ABB electric motor. Blower and motor are mounted on a joint framework. The units are resiliently mounted with flexible connections.

The blower is of the single-stage centrifugal type with overhung impeller. The drive shaft is fitted with a seal to prevent air leakage. Periodical checking of the seal is necessary to keep it in shape.

The blower casing is fabricated in mild steel and is internally flakelined for operation in a corrosive and erosive environment. It is designed to permit removal of the shaft and impeller with a minimum of dismantling.

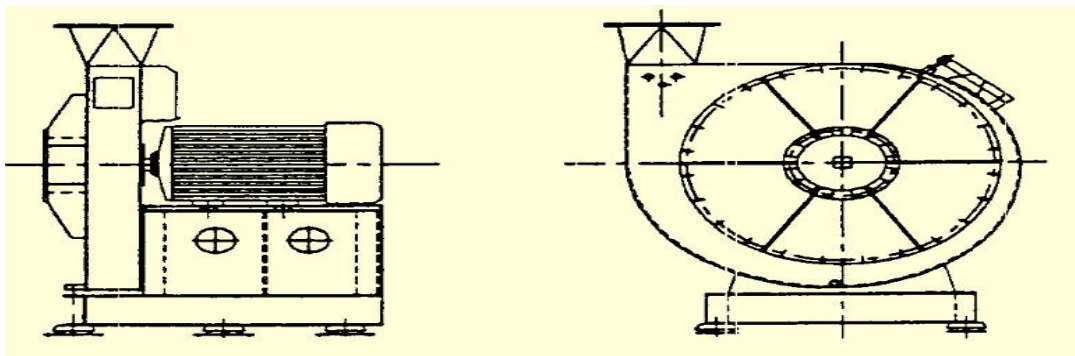


FIGURE 3.2 INERT GAS BLOWERS

DESIGN CONSIDERATIONS FOR INERT GAS BLOWERS

1. The blower casing should be constructed in corrosion-resistant material or alternatively of mild steel but then its internal surfaces should be stove-coated, or lined with rubber or glass fibre epoxy resin or other equivalent material to protect it from the corrosive effect of the gas.
2. The impellers should be manufactured in a corrosion resistant material. Aluminium bronze impellers should be stress-relieved after welding. All impellers should be tested by overspeeding to 20% above the design running speed of the electric motor or 10% above the speed at which the overspeed trip of the turbine would operate, whichever is applicable.
3. Substantial drains, fitted with adequate water seals, should be provided in the casing to prevent damage by an accumulation of water. The drains should be in accordance with the provisions.
4. Means should be provided such as fresh water washing to remove the build-up of deposits which would cause vibration during blower operation.
5. The casing should be adequately ribbed to prevent painting and should be so designed and arranged as to facilitate the removal of the rotor without disturbing major parts of the inlet and outlet gas connections.
6. Sufficient openings in the casing should be provided to permit inspection.
7. Where separate shafts are provided for the prime mover and the blower, a flexible coupling between these shafts should be provided.
8. When roller or ball bearings are used, due regard should be paid to the problem of brinelling and the method of lubrication. The type of lubrication

chosen, i.e. oil or grease, should have regard to the diameter and rotational speed of the shaft. If sleeve bearings are fitted then resilient mountings are not recommended.

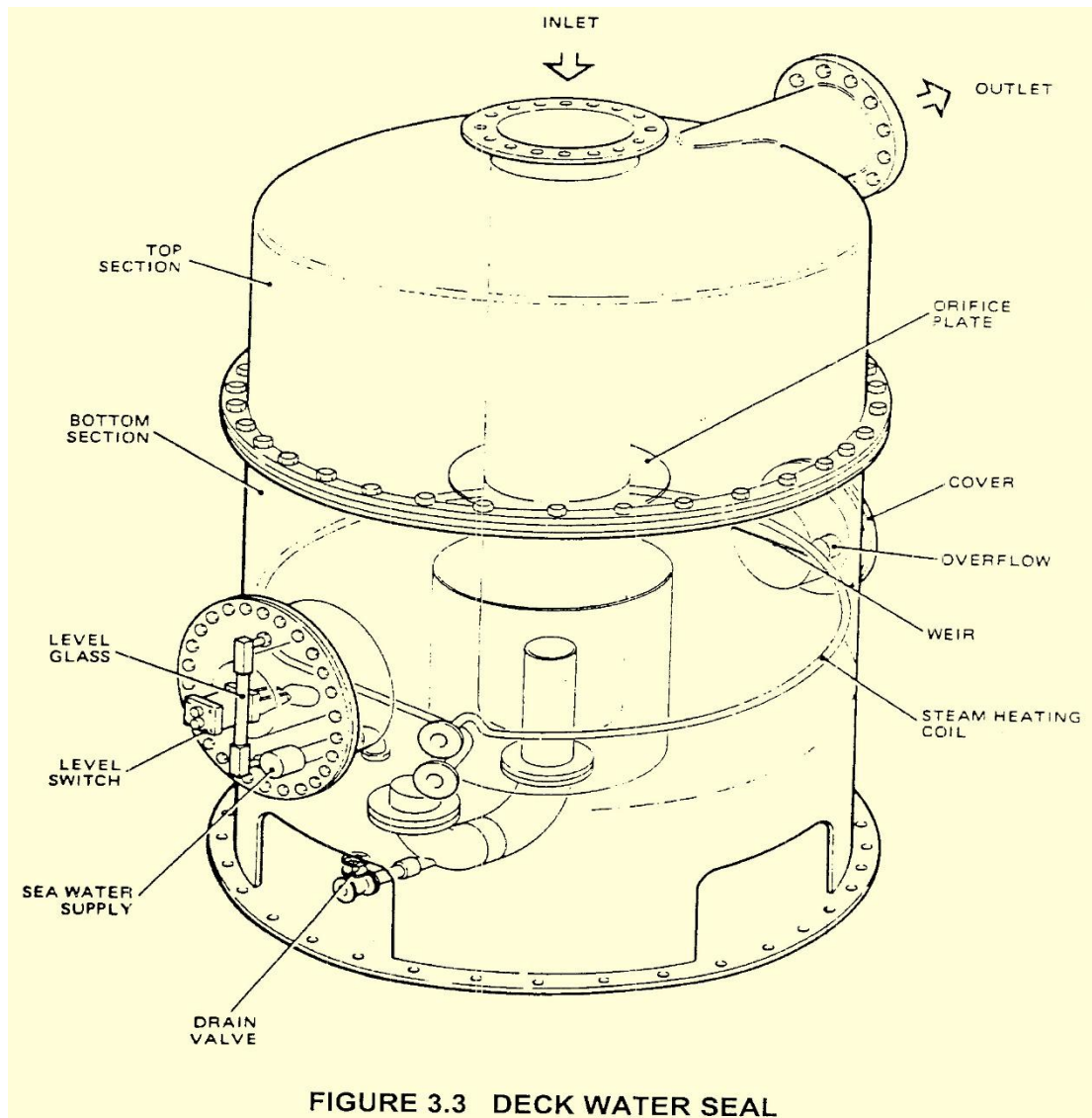
9. The blower pressure/volume characteristics should be matched to the maximum system requirements. The characteristics should be such that in the event of the discharge of any combination of cargo tanks at the discharge rate a minimum pressure of 200 mm water gauge is maintained in any cargo tank after allowing for pressure losses due to :
 - a. The scrubber tower and demister
 - b. The piping conveying the hot gas to the scrubbing tower
 - c. The distribution piping downstream of the scrubber
 - d. The deck water seal
 - e. The length and diameter of the inert gas distribution system.
10. When both blowers are not of equal capacity the pressure/volume characteristics and inlet and outlet piping should be so matched that if both blowers can be run in parallel, they are able to develop their designed outputs. The arrangements should be such as to prevent the blower on load from motoring the blower that is stopped or has tripped out.
11. If the prime mover is an electric motor then it should be of sufficient power to ensure that it will not be overloading under all possible operating conditions of the blower. The overload power requirement should be based on the blower inlet conditions of -5°C at -400 mm water gauge and outlet conditions of 0°C and atmospheric pressure. Arrangements should be provided, if necessary, to maintain the windings in a dry condition during the inoperative period.

M. DECK WATER SEAL

The purpose of the deck water seal is to prevent feedback of hydrocarbon gases from the cargo tanks via the inert gas deck main to the engine room and boiler uptake. A small leakage of hydrocarbon gas can build up to a dangerous concentration over a period of time. Since a mechanical nonreturn valve will permit a very slight leakage, it is necessary to provide a liquid seal. The deck water seal is manufactured in mild steel and is internally coated with glassflake.



A low level alarm facility is provided. A pressure switch, fitted in the sea water supply line to the deck water seal, initiates a low water pressure alarm and shuts down the inert gas system in the event of water supply failure. The deck water seal is fitted with a steam heating coil to prevent freezing of the water in cold conditions. The heating coil has two zink anodes for anti-corrosion which should be regularly inspected. There is also provided a drain valve. A manhole allows inspection of the deck water seal. An externally mounted level glass enables the water level in the deck water seal to be checked. Water loss due to evaporation and as a result of water carryover during start up is made up by means of the seal pump as required.



There are different designs but one of three principal types may be adopted:

1. WET TYPE

This is the simplest type of water seal. When the inert gas plant is operating, the gas bubbles through the water from the submerged inert gas inlet pipe, but if the tank pressure exceeds the pressure in the inert gas inlet line the water is pressed up into this inlet pipe and thus prevents backflow. The drawback of this type of water seal is that water droplets may be carried over with the inert gas which, although it does not impair the quality of the inert gas, could increase corrosion. A demister should, therefore, be fitted in the gas outlet from the water seal to reduce any carry-over. Figure 7 shows an example of this type.

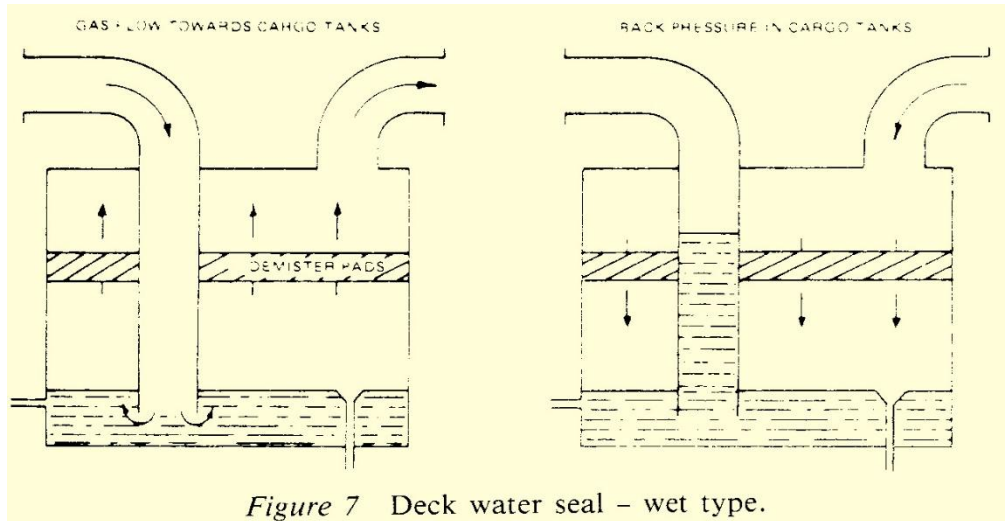


Figure 7 Deck water seal – wet type.

2. SEMI-DRY TYPE

Instead of bubbling through the water trap the inert gas flow draws the sealing water into a separate holding chamber by venturi action thus avoiding or at least reducing the amount of water droplets being carried over. Otherwise it is functionally the same as wet type. Figure 8 shows an example of this type.

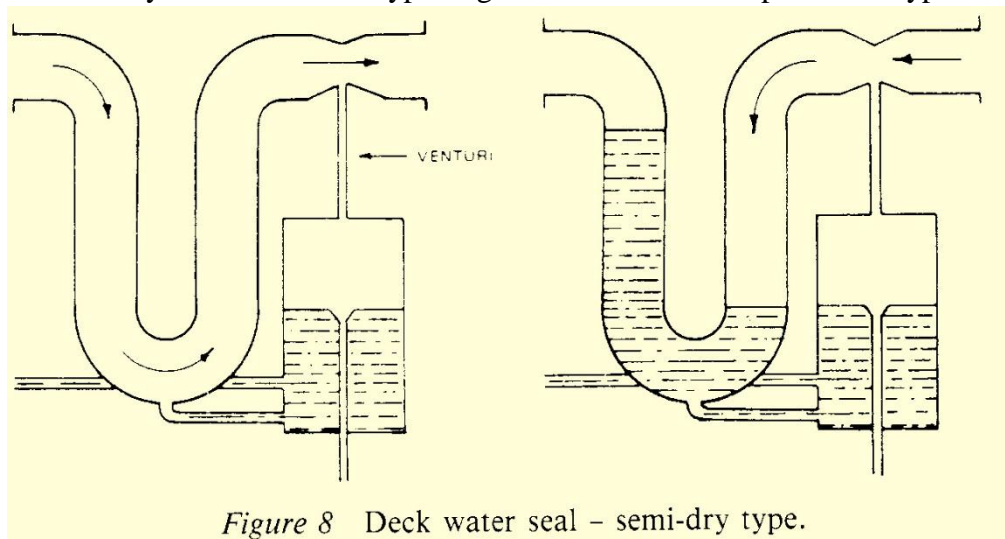


Figure 8 Deck water seal – semi-dry type.

3. DRY TYPE

In this type the water is drained when the inert gas plant is in operation (gas flowing to the tanks) and filled with water when the inert gas plant is either shut down or the tank pressure exceeds the inert gas blower discharge pressure. Filling and drainage are performed by automatically operated valves controlled by the levels in the water seal and drop tanks and by the operating state of the blowers. The advantage of this type is that water carry-over is prevented. The drawback could be the risk of failure of the automatically controlled valves which may render the water seal ineffective. Figure 9 shows an example of this type.

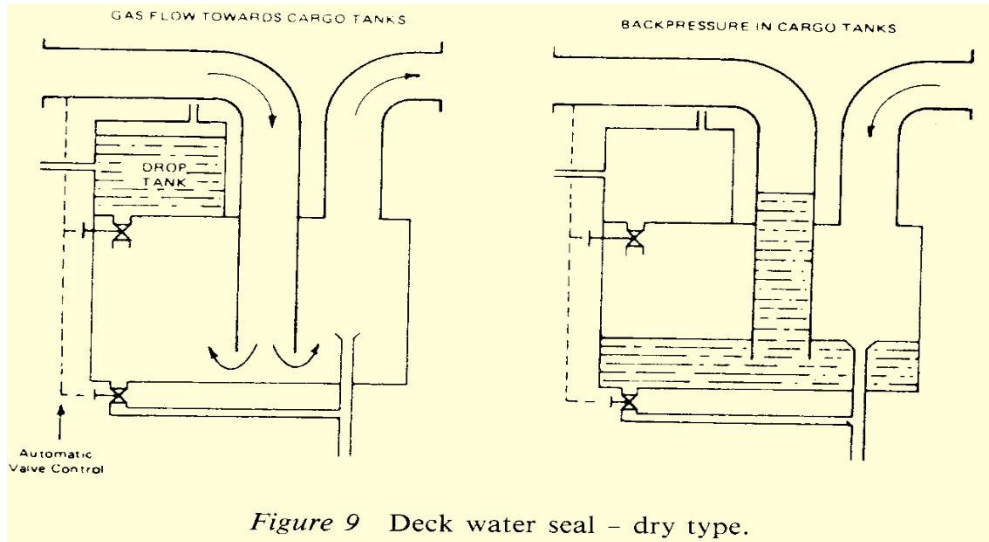
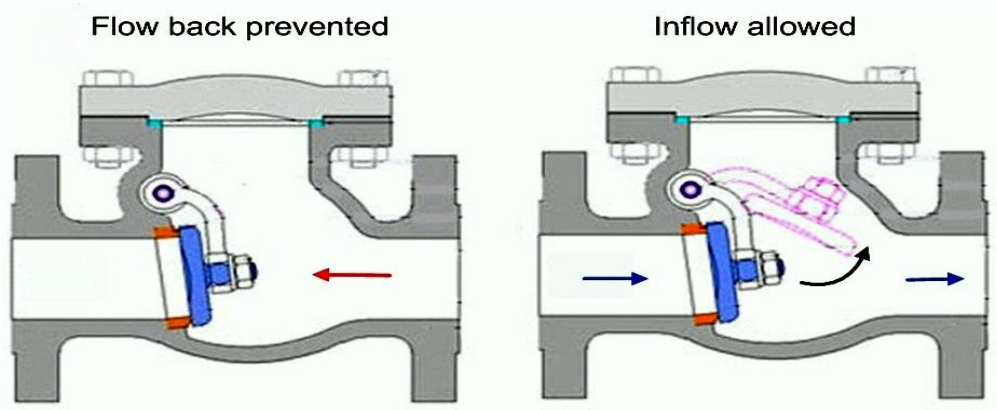


Figure 9 Deck water seal – dry type.

N. NON-RETURN DEVICES

As a further precaution against any backflow of gas from the cargo tanks and any backflow of liquid that may enter the inert gas main if the cargo tanks are overfilled, a mechanical non-return valve, or equivalent is required. This should be fitted forward of the deck water seal and should operate automatically at all times. The valve should be provided with a positive means of closure or, alternatively, a separate deck isolating valve fitted forward of the non-return valve, so that the inert gas deck main may be isolated from the non-return devices. The separate isolating valve has the advantage of facilitating maintenance work on the non-return valve.

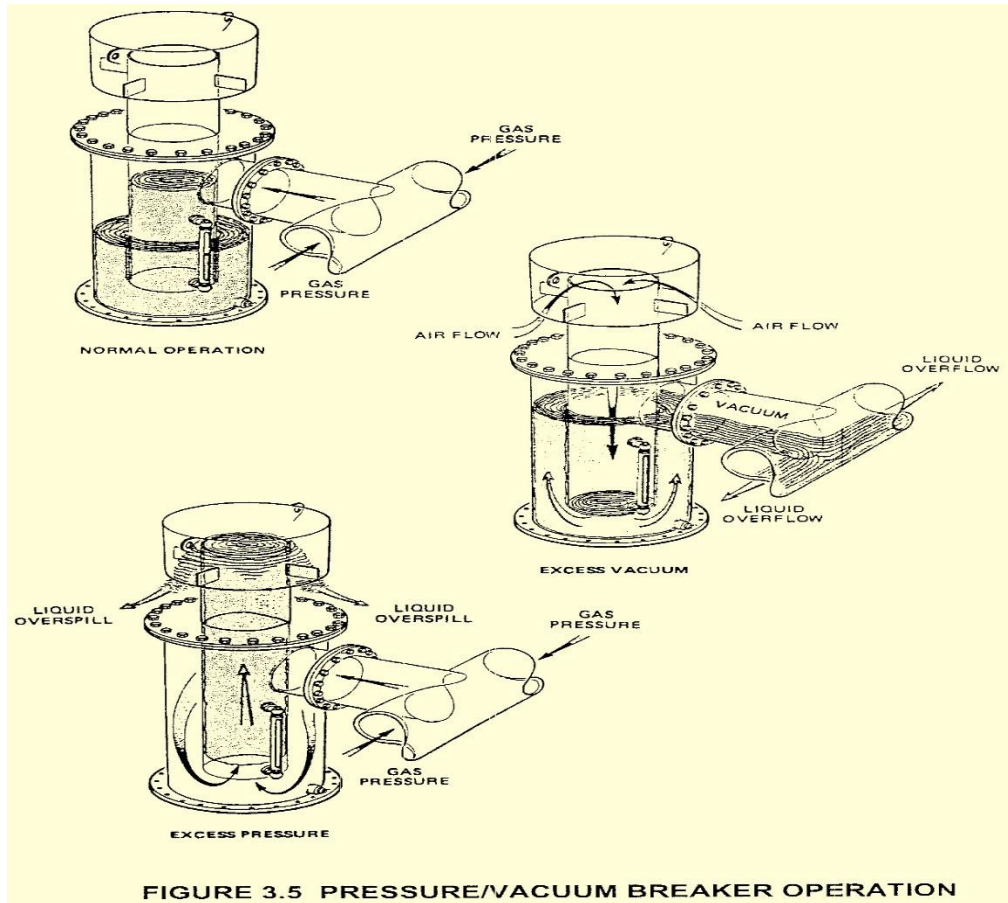
At least two non-return devices, one of which is to be a deck water seal, are to be fitted in the inert gas supply main line in order to prevent the return of hydrocarbon vapor to the machinery space uptakes or to any gas safe space under all normal conditions of trim, list and motion of the vessel. They are to be located between the gas regulating valves required by 2/1.21. The material used in the construction of the non-return devices should be resistant to fire and to corrosive attack from acids formed by the gas. Alternatively, low carbon steel protected by a rubber lining or coated with glass fibre epoxy resin or equivalent material may be used. Particular attention should be paid to the gas inlet pipe to the water seal.



O. LIQUID FILLED PRESSURE VACUUM BREAKER

The pressure/vacuum breaker is fitted to a branch line off the inert gas deck main line. The purpose of the pressure/vacuum breaker is to safeguard against overpressurisation or underpressurisation of the cargo tanks. The pressure/vacuum breaker operates normally at a line pressure of (1800) mmWG and a vacuum of (700) mmWG. The pressure/vacuum breaker is the final backup for any of the pressure/vacuum valves and consists essentially of two concentric tubes. The inner tube acts as a weir over which the water is displaced by excess backpressure. By excess vacuum, the inert gas main connecting pipe acts as a weir over which the water is displaced. After installation onboard the breaker should be kept filled with fresh water. In cold sea water, 20% of the water should be replaced by glycol (CH₂OH) or other antifreeze additive. Total liquid quantity required is given on design specification and p/v breaker drawing. These devices require little maintenance, but will operate at the required pressure only if they are filled to the correct level with liquid of the correct density, either a suitable oil or a freshwater/glycol mixture should be used to prevent freezing in cold weather, evaporation, ingress of seawater, condensation and corrosion should be taken into consideration and adequately compensated for.





P. MAST RISER

The mast riser is normally used during loading for tank vapour pressure control. Its exit location, being at least 6 meters above the deck, allows for the free flow of the vapours displaced from the cargo tanks by the incoming liquid crude oil at the rate of loading of the cargo. The rate of displacement of VOC (Volatile Organic Compounds) vapours from the cargo tank system will be the same as the loading rate but the concentration of VOC vapours in the displaced stream will be greater dependent upon the extent and rate of evolution of VOC vapours from the incoming cargo that would add to the volume of gas/vapour mixture already existent in the cargo tank prior to loading.



Q. HIGH VELOCITY PRESSURE VACUUM VALVE



According to the definition of ISO 15364 3.5, the high velocity pressure / vacuum valve is a device to prevent the passage of flame consisting of a mechanical valve which adjusts the opening available for flow in accordance with the pressure at the inlet of the valve in such that the efflux velocity cannot be less than 30 m/s (98 ft. /sec) under all flow rates and the actual condition of installation. Also, according to the definition of ISO 15364 3-6, this valve is pressure vacuum valve, device to prevent the occurrence of over- or underpressure in a closed container. The purpose of this valve is to provide automatic control of the pressure conditions during loading, unloading, voyage and ballasting without any manual operation on cargo tank.

As aforementioned, the purpose of using this valve is to protect the cargo tank from the damage due to overor under- pressure exceeding design pressure

of cargo tank. The conditions such as loading, unloading and thermal variation brings about over- or under- pressure at a cargo tank. In above condition, this valve plays an important role in relieving of excessive pressure at a tank. For two excessive pressures, the valve functions as follows:

1. Loading condition

By loading into the tank, the pressure inside the valve becomes increased. When the pressure reach to the setting pressure of the valve, pressure disc start lifting (or opening). During lifting of pressure disc, excessive pressure is relieved. When the pressure becomes below the setting pressure of the valve, pressure disc will be close. Generally, closing pressure of the valve is lower than the setting pressure for pressure disc.

2. Unloading condition

By discharging from the tank, the pressure inside the valve becomes decreased below atmosphere pressure. When the pressure decreases until the setting pressure of the valve, vacuum disc start lifting (or opening). During lifting of vacuum disc, negatively excessive pressure is relieved. When the pressure becomes below the setting vacuum of the valve, vacuum disc will be close.

INSPECTION

Inspection should be carried out to check possibility of malfunctioning of the valve. Such possibility contains clogging due to condensate residue, sticking of contact surface between disc and seat and so on. An operator can find out such symptom by check lifting. The check lift handle operated freely in normal condition, but free operation of the handle will be interrupted and an operator will feel tightness or friction when any condensate residue or vapour condensate exists inside the valve. It is very important that operator distinguish normal friction from abnormal friction.

INSTALLATION

The valve should be arranged in such a way that the vent height above the deck or, where relevant, above the fore and aft gangway comply with the requirements of the classification society rules, IMO and SOLAS Regulations.

DESIGN

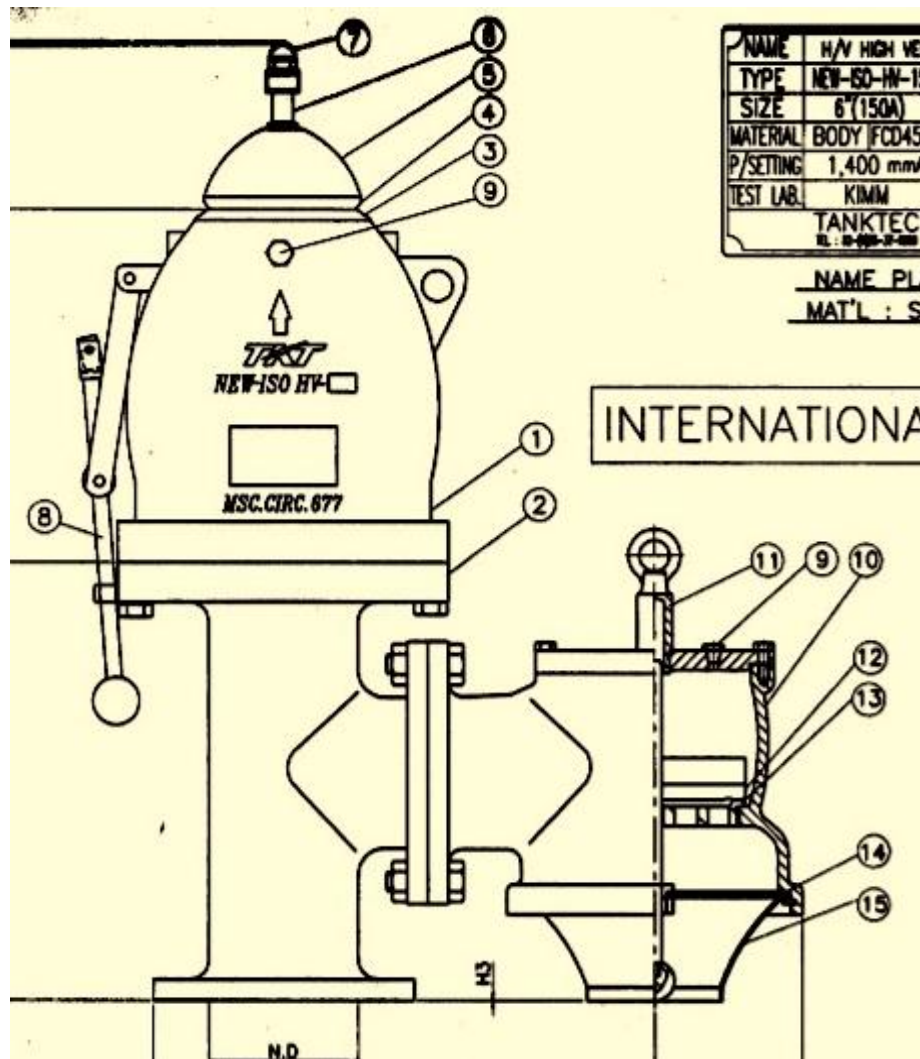
P/V is designed as weight load type that its opening pressure is concluded by preset deadweight and consists of valve upper and lower body with a pressure and vacuum disc, stem pressure and vacuum weight, pad and flame screen. This valve is designed in accordance with ISO 15364. It was designed to allow for inspection, cleaning, repair or removal of internal elements for replacement without removing the entire device from the system, and also it should be correctly reassembled following disassembly for inspection, cleaning or repair. It is designed such that condensed vapour drains from itself and does not impair its efficiency. Its design prevents the accumulation of water inside the device and subsequent

blockage due to freezing. It is designed and constructed to minimize the effect of fouling under normal operating conditions and its design can be examined for any build-up of residue due to vapour condensation that might impair its operation. A manual mean, check lift handle is provided to verify that all moving parts lift easily and cannot remain in the open position because of self-closing function.

MAINTENANCE

The maintenance work of the valve contains regular inspection, cleaning, service repair, replacement and so on. Check lifting should be carried out before each cargo loading, discharging and ballasting in accordance with SOLAS requirement. Frequency of regular inspection and cleaning an operator could conclude when cleaning is carried out by check lifting and regular cleaning program. During check lifting, if check lifting handle is not operated freely, conduct the cleaning of inside parts properly. Also regular cleaning should be carried out without omission as follows:

1. Contact surface between the disc and seat : every 6 month or when gas leakage
2. Internal portion through flushing port: before loading other kind of cargo or when sticking of internal parts
3. Disassembling of upper housing: when permanent sticking of internal moving parts.
4. Flame screen : every 6 month
5. External body: as required



2. INERT GAS OPERATIONS

A. RESPONSIBILITY

The Chief Officer is in charge and shall supervise as the person in charge of the Tank Cleaning, Hydrocarbon Gas (HC) purging, gas Freeing & Re-Inerting operations. He shall ensure that all activities carried out during such operations are in compliance with the latest edition ICS/OCIMF International Safety Guide for Oil Tankers and Terminals (ISGOTT).

B. SAFETY PRECAUTIONS

For the operations to be followed, (Tank cleaning, HC Gas Purging, Gas Freeing and Re-Inerting), the Chief Officer shall carry out the following precautions. Detailed

guidance on preparations and safety precautions are also described within relevant sections of ISGOTT. Have persons engaged in the operations observe the necessary precautions as described in this section and the “Precautions during Gas-freeing Operations” Complete the necessary sections of “Tank Cleaning, Purging and Gas Freeing Checklist” to confirm safety strictly at the appropriate time. Tank Preparation and Atmosphere Control during Operations

C. GAS-FREEING FOR CARGO TANK ENTRY

Cargo Tank entry shall not be permitted unless the Oxygen Content is 21% and the hydrocarbon vapor content is less than 1% of the Lower Flammable Level (LFL). Follow company’s “Procedure for Entry into Enclosed Spaces” with related permits. If the previous cargo contains Hydrogen Sulfide (H₂S) or other toxic contaminants which could evolve toxic gases (e.g. benzene, toluene, Mercaptans, etc.), the tank should be checked for such gases. Refer to “Guidelines for Toxic Gases Hazards”

After cargo discharge / tank cleaning, whenever it is necessary to gas free an empty tank containing hydrocarbon gas mixtures or a mixture of IG + HC gases, it shall first be purged, using inert gas, until the HC (hydrocarbon) content reaches to below the critical dilution line or HC concentration in the tank atmosphere is less than 2% by volume. This is done so that during the subsequent gas freeing no portion of the tank atmosphere is brought within the flammable range. Inert gas used for purging shall contain Oxygen, less than 5% by volume, to ensure the above. The replacement of a tank atmosphere by inert gas can be achieved by either Inerting or Purging. In each of these methods one of two distinct processes, Dilution or displacement, will predominate.

1. Before starting to Gas free, the tank should be isolated from other tanks.
2. Do not commence forced air ventilation (Gas free) until it has been confirmed that the oxygen level is less than 8% and the hydrocarbon vapor content is less than 2% by Volume.
3. To ensure the dilution of the toxic components of inert gas to below their Threshold Limit Values (TLV), Gas freeing should continue until tests with an oxygen analyzer show a steady oxygen reading of 21% by volume and tests with a flammable gas indicator show not more than 1% LFL.
4. If the presence of a toxic gas such as benzene or hydrogen sulfide is suspected, Gas freeing should be continued until tests indicate that its concentration is below its TLV.

D. PRECAUTIONS DURING GAS-FREEING OPERATIONS

It is generally recognized that Tank cleaning and Gas freeing is the most hazardous period of tanker operations. This is true whether washing for clean ballast tanks, Gas freeing for entry, or Gas freeing for hot work. The additional risk from the Toxic effect of petroleum gas during this period cannot be over-emphasized and must be impressed on all concerned. It is therefore essential that the greatest possible care is exercised in all operations connected with tank cleaning and gas freeing. Refer to ISGOTT regarding the various hazards involved. Also, follow the check items as described in Tank Cleaning, Purging and Gas

Freeing Checklist. Precautions below mentioned shall be considered to Hazard identification and Risk control In due course of a Risk management.

E. PREVENT HUMAN INJURY

The chief officer is the responsible person for such operation and shall brief all crew regarding the safety measures to be followed on deck.

1. During gas freeing operations only personnel directly involved in the Gas freeing operations should be allowed on the main deck. Tank openings shall be guarded.
2. The proposed duration and Job / Watch schedule
3. All crew involved in the Gas freeing operations must wear appropriate clothing. Antistatic precautions must be observed on deck.
4. The covers of all tank openings should be kept closed until actual ventilation of the individual tank is about to commence.
5. If small crafts are alongside the tanker, their personnel should also be notified. The atmosphere in the operations area should be monitored for explosive hydrocarbon vapors during such conditions.

F. PREVENTION OF GAS ENTER INTO ACCOMODATION AREA

1. To prevent hydrocarbon vapors to accumulate in the accommodation areas, it may be necessary to change course during Gas freeing operations.
2. The presence of Sparks / Hot soot emanating from the funnel stacks should be considered.
3. If gas freeing is taking place while the vessel is at anchor, it may be necessary to suspend operation during periods with calm or no winds (local regulations regarding port permissions / emissions shall be complied with).
4. Intakes of central air conditioning or mechanical ventilating systems should be adjusted to prevent the entry of petroleum gas, if possible by Partial recirculation of air within the spaces, but should be maintained Positive pressure in accommodation.
5. If at any time it is suspected that gas is being drawn into the accommodation, central air conditioning and mechanical ventilating systems should be stopped and the intakes covered or closed.

G. GAS FREE EQUIPMENT

1. Portable fans or blowers should only be used if they are hydraulically, pneumatically, water or steam driven. Their construction material should be such that no hazard of incendiary sparking arises if, for any reason, the impeller touches the inside of the casing.
2. Portable fans, where used, should be placed in such positions and the ventilation openings so arranged that all parts of the tank being ventilated are equally and effectively gas freed. Ventilation outlets (discharged gas) should generally be as remote as possible from the fans.

3. Portable fans, where used, should be so connected to the deck that an effective electrical bond exists between the fan and the deck.
4. Where cargo tanks are gas freed by the permanently installed blowers, all connections between the cargo tank system and the blowers should be blanked except when the blowers are in use. (i.e. blower outlets / inlets)
5. Before putting such a system into service, the cargo piping system, including crossovers and discharge lines, should be flushed through with sea water and the tanks stripped.
6. Fixed Gas freeing equipment may be used to gas free more than one tank simultaneously but must not be used for this purpose if the system is being used to ventilate another tank in which washing is in progress.

H. PURGING WITH INERT GAS

For reduction in hydrocarbon (HC) content in tank atmosphere for Cargo / Vapor contamination reasons:

1. After tank cleaning operations the cargo tanks may be purged with inert gas to reduce the concentration of the hydrocarbon gas inside the tank atmosphere.
2. Follow the procedures as laid out in the operation and equipment manual.
3. Purge pipes, with proper flame screens shall be fitted, where provided.
4. Carry out the operations of replacing the tank atmosphere by introducing IG of which oxygen content is 5% by Volume or less into the tanks.
5. Go on with purging by IG until the hydrocarbon content reduces to the required / desired level.

Since the main purpose of HC gas purging is displacement HC gas with IG, the procedure first priority shall be supply IG with full capacity of IG Blowers. Under the procedure, Oxygen content in Inert Gas for purging may be permitted by 8% by Volume or less.

I. COMPLETION OF WORK & INERTING CARGO TANKS

After completion of man entry or repair work (in dry docks / lay-up berth) Cargo tanks shall be prepared for loading as follows:

1. An Officer shall confirm each tank free of waste & material used in maintenance & inspection. Related pipelines and supports, including hydraulically operated valves, H.P. pipes and flanges are all in place and tightly secured.
2. All personnel out of tank & close tank dome or access, only keep designated vent ports open. Inert tanks to 8% of Oxygen level.
3. Replace the tank's atmosphere by an inerted atmosphere, using IG with the oxygen content of less than 5% by Volume. This gas replacement should

continue, until the average measured oxygen content in the tanks drops to below 8% by Volume.

J. MEASURES AGAINST INERT GAS SYSTEM IN TROUBLES

In case that proper IG cannot be supplied, which could cause the oxygen content in tanks to exceeds 8% by Volume, or making it difficult to keep the internal pressure of tanks positive due to troubles in the IG system or other reasons during tank cleaning or hydrocarbon gas purging operations, suspend the operations immediately, and do not restart the operations until proper supply of IG is secured. Provided that the atmosphere in tanks is not under control, do not put improper IG (the oxygen content of which exceeds 8%). If the recovery of the IG system is difficult, notify the Technical Superintendent in charge for consultation.

K. INERT WBT(WATER BALLAST TANKS)

The system is to be capable of:

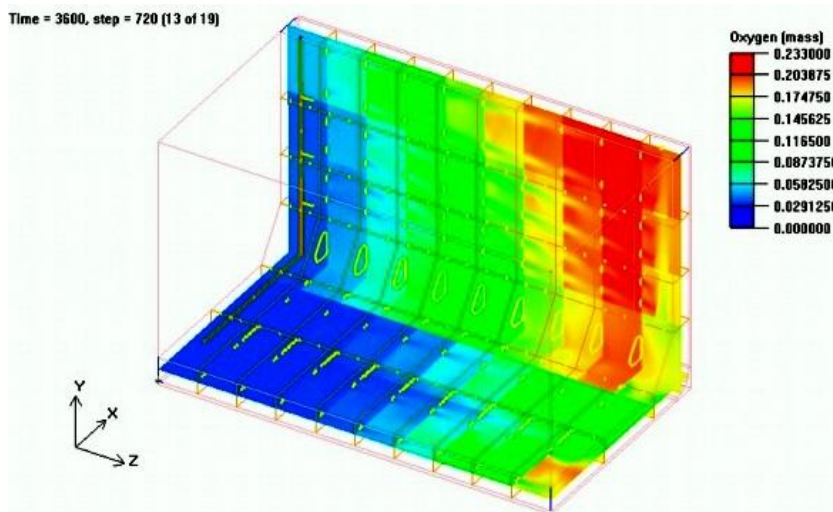
1. Inerting ballast tanks by reducing the oxygen content in any part of any ballast tank to 5% by volume of the atmosphere in each tank.
2. Maintaining the atmosphere in any part of any ballast tank at the 5% by volume oxygen content level and at a positive pressure at all times in port and at sea, except when it is necessary for such a tank to be gas free
3. Eliminating the need for air to enter a tank during normal operations, except when it is necessary for such a tank to be gas free.
4. Purging empty ballast tanks of hydrocarbon gas, should a cargo leak occur, so that subsequent gas freeing operations will at no time create a flammable atmosphere within the ballast tanks.

The objective of this Guide is to provide requirements which will:

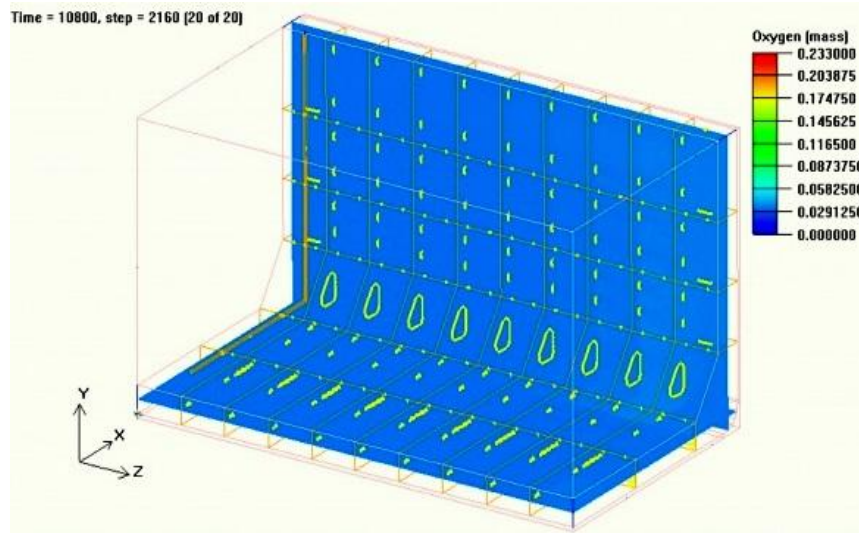
1. Prevent the risk of explosion in ballast tanks caused by the ignition of hydrocarbon gas leaking in from adjacent cargo tanks.
2. Reduce corrosion in ballast tanks.

This is achieved by means of replacing the atmospheric content of the tanks with a gas such as nitrogen, or a mixture of gases such as flue gas, containing reduced levels of oxygen. The venting systems are to be designed so as to maintain the inert condition in the ballast tanks, except when the tanks are required to be gas free. The venting systems of inerted ballast tanks are to be entirely distinct from the vent pipes of the other compartments of the vessel. The arrangements and position of openings in the ballast tank deck from which emission of inert gas can occur are to be such as to minimize the possibility of gases being admitted to enclosed spaces, or collecting in the vicinity of deck machinery and equipment, which may constitute a hazard during operation. The IMO Guidelines for Inert Gas Systems (1990 Edition) proposes two theories regarding the replacement of the atmosphere in a cargo tank: dilution theory and replacement theory. The dilution theory assumes that the incoming gas mixes with the original gas to form a homogeneous mixture throughout the tank, resulting in the concentration of the original gas decreasing exponentially. The replacement theory requires a stable

horizontal interface between lighter gas entering at the top of the tank and heavier gas at the bottom, and results in the heavier gas being displaced from the bottom of the tank through some suitable piping arrangement. However, a ballast tank structure is unlike a cargo tank in that it is subdivided into smaller interconnected compartments by the transverse webs and longitudinal girders in the double bottom, and stringer platforms in the sides. This complex arrangement makes the theories proposed by IMO inappropriate. The purpose of the analysis required by 2/1.29 of this Guide is to establish the time required to effectively inert or gas-free the ballast tanks. Gas-freeing, for example, should be carried out when it is necessary for personnel entry into a ballast tank, and it should be certain that 21% oxygen by volume is achieved throughout the tank. Any pockets of gaseous mixtures with an oxygen level below 21% by volume should be removed. One method that may be used to confirm the effectiveness of Inerting or gas freeing as required by 2/1.29 is to apply numerical simulation using the principles of fluid dynamics, heat and mass transfer with proper approximations. The example analysis investigates gas replacement inside a typical ballast tank, and estimates the required number of atmosphere changes for satisfactory Inerting and gas-freeing, including the removal of any air or inert gas pockets. There are a number of commercially available computational fluid dynamics (CFD) software packages that may be used to predict the distribution of multiple gas species (i.e. oxygen, carbon dioxide and nitrogen) inside of a ballast tank.



INERTING WBT AFTER 1 HOUR, 0.67 ATMOSPHERE CHANGES



INERTING WBT AFTER 3 HOURS, 2.0 ATMOSPHERE CHANGES

3. NITROGEN GENERATOR SYSTEM

The unique design is based on experience from thousands of installations of inert gas systems of all kinds. The first conventional inert gas systems were delivered in the 1960's, the first nitrogen system in 1994. High efficiency, low maintenance costs, safe and easy operation combined with minimum space requirements are important features of the Moss design. The Moss Nitrogen Generators use state of the art membrane technology. Membranes separate gases by the principle of selective permeation across the hollow-fibre membrane wall. Ambient air is compressed, rigorously filtered, and temperature controlled before entering one or more membrane modules (see fig.), each containing thousands of hollow fibres. Within these fibres, the separation of air takes place producing nitrogen gas under pressure. The resulting nitrogen is dry and depleted of carbon dioxides. Main purposes.

1. Inerting purposes where a dry, clean inert gas is required.
2. Purging and padding of cargo tanks, piping and valves.
3. Compressor sealing.
4. Insulation protection on gas carriers



A. SPECIAL FEATURES

The Moss membrane selection and assembly:

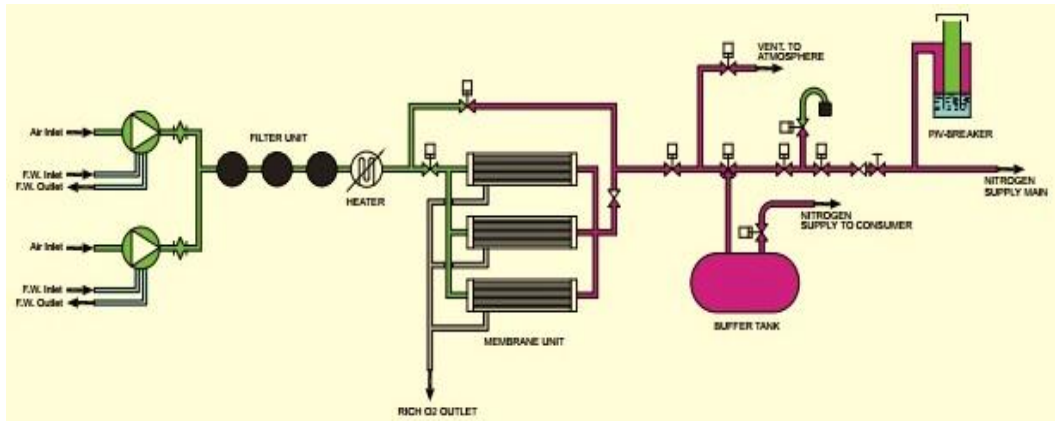
Hamworthy Moss choose membranes based on the intended purpose of nitrogen. Different polymers have different characteristics for high pressure or high purity solutions. The required numbers of membranes are assembled in handy cabinets or racks. The design caters for low space requirement as well as easy installation and maintenance. The Moss filter and heater assembly. The various components are normally on a skid, either a separate filter skid or on one common unit. For smaller systems the components might also be installed in a cabinet.

B. CONTROL SYSTEM

The control system is based on a Programmable Logical Control (PLC). The control panel is of the touch screen type. Several mimic flow diagrams are implemented as well as the controls required for safe and easy operation with a minimum of operator supervision. Additional functions like user manuals and condition monitoring can also be included. On chemical/product carriers a double block and bleed system or Moss pressure/vacuum breaker may be provided. On board LNG/LPG carriers the consumer is normally a buffer tank. A design based on tailor made systems for each project result in cost efficient solutions with optimal performance. The design is compact, yet flexible, with open design to ease maintenance. The Moss Nitrogen Generator system offers valuable savings in space and installation costs both for new buildings and for retrofitting on existing vessels.

C. PERFORMANCE DATA

- Produced Nitrogen purity: Up to 99,9%.
- Product capacity: 10 to 6 000 Nm³/h or more.
- Ambient temperature: +2 to +45°C (possible +55°C, special design).
- Product dew point: Down to -70°C (Atmospheric pressure) depending on application and capacity.
- Product CO₂: Less than 5 ppm.
- Delivery pressure: Up to 11,5 bar g, using 13 barg compressor(s).
- Nominal el. power consumption: Approx. 0,3 kW/Nm³ /h gas at 95% N₂ (excluding water pump).
- Nominal sea/fresh water consumption: 11,5 l/Nm³ gas at 95% N₂



D. MEMBRANE SEPARATION PRINCIPLE

Each Membrane Separator Module contains thousands of polymer hollow fibres bundled together. Air fed at specified optimal pressure and temperature to one side of the membrane, dissolves and diffuses across the fibre material and desorbs as permeate at the low pressure side of the membrane. As the air comprises different constituents, each component dissolves in the matrix to a different extent and permeates at a different rate. The more rapidly permeating components such as oxygen, carbon dioxide and water vapor are enriched in the low-pressure stream, which is safely vented to the atmosphere. The slower permeating components like nitrogen and argon are retained in the high-pressure stream and further removed from the membrane module as the nitrogen gas product.

4. TOXIC GASES HAZARDS

Oil tankers operations at sea and while at port requires some basic safety procedure to be observed. Prior entering a space which contained or has a risk of the presence of any Toxic gases such as benzene, H₂S, etc., the MSDS (Marine Safety Data Sheets) and other relevant information and precautions for Toxic gases as listed in ISGOTT should be referred to. Thorough gas checks using suitable Toxic gas detector tubes need to be carried out.

A. MATERIAL SAFETY DATA SHEETS (MSDS)

It is the responsibility of the supplier to provide any tanker that is to load a cargo or bunker fuel that is likely to contain a toxic component, with a Material Data Safety Sheet (MSDS) before loading commences. The MSDS should indicate the type and probable concentrations of toxic components, amongst all of the constituents in the cargo or bunkers to be loaded. Provision of an MSDS does not guarantee that all of the toxic components of the particular cargo or bunkers being loaded have been identified or documented. Absence of an MSDS should not be taken to indicate the absence of toxic components. Operators should have procedures in place to determine if any toxic components are present in cargoes that they anticipate may contain them. It is the ship's responsibility to advise the

receiver of any toxic component(s) in the cargo to be discharged. The ship must also advise the terminal and any tank inspectors or surveyors if the previous cargo contained any toxic substances.

B. HYDROCARBON VAPORS

1. Hydrocarbon gases are heavier than air (1.5 to 3 times), and tend to accumulate in the vicinity of the area where they are generated. A large amount of gas might exist sometimes in unpredictable locations. The bottom of the pump room is a typical example.
2. Gases flow to the leeward side, and are dangerous in that they may cause explosion at spaces other than where they are generated.
3. The explosion limits or flammable limits (LEL / UEL or LFL / UFL) varies according to the type of Hydrocarbon gas in question. Their proportionate mixtures present in the petroleum vapor in question. This is generally around 1.8% Vol. in Air (Min.) to 9.5% Vol. in Air (Max); whereas International Chamber of Shipping recommends a range of 1.0% to 10.0 Vol. %, to assume safer standards.
4. The danger for explosion is far greater in a lightly laden ship, while loading / unloading cargo, during ballasting operations or during tank cleaning, rather than when fully laden. This is because on a loaded vessel, the tank atmosphere contains hydrocarbons concentrations of well over above UFL.
5. The Company permits limit of Hydrocarbon (petroleum) gas mixture in air conducting man-entry as 1.0 % LFL as measured with suitable approved type gas detector.

TOXIC HAZARDS OF HC VAPOURS

1. Petroleum gas is noxious and harmful to the body. The table K-01-D-1 shows the concentration of petroleum gas and its effects on the human body.
2. Toxicity can be greatly influenced by the presence of some minor components such as aromatic hydrocarbons (e.g. Benzene and Hydrogen Sulfide i.e. H₂S).
3. Even if a tank is empty, gases might be regenerated from sludge in the tank. Precautions are also necessary when working in tanks because Petroleum Gas or Inert Gas from other tanks might enter the tank due to leakage from valves.

HC GAS CONCENTRATION (Volumetric Proportion in Air) Effects on the Human body:

- 0.02% 300ppm Industry Permissible concentration
- (TLV-TWA for 8 Hrs.) or 2% LEL
- 0.1% 1,000ppm Irritation in the eyes within an hour.
- 0.2% 2,000ppm Irritation in the eyes, nose or throat within 30 minutes, dizziness and unsteadiness.
- 0.7% 7,000ppm Signs of giddiness within 15 minutes.
- 1.0% 10,000ppm sudden giddiness occurs and if the body is exposed to the same conditions continuously, unconsciousness results, and can sometimes lead to death.
- 2.0% 20,000ppm sudden giddiness, unconsciousness, resulting in death.

C. HYDROGEN SULFIDE (H₂S)

Characteristic of Hydrogen Sulfide (H₂S):

1. H₂S is a highly toxic, corrosive and flammable gas that in low levels will smell like rotten eggs.
2. It may be present in bunkers in dissolved state or as a gas. It may also be found in certain Natural gases, Crude oils and certain refined products such as Naphtha.
3. It is Colorless and Heavier than Air, having relative vapor density of 1.189
4. Exposure to high levels of H₂S can be fatal after a very short period of time.
5. H₂S is a liquid soluble gas and produces vapor when the liquid is agitated or heated. It is not possible to predict the likely H₂S vapor concentration present above a liquid in a tank, from any given liquid concentration but, as an example, an oil containing 70 “ppm by weight” as concentration of H₂S in liquid has been shown to produce 7000 “ppm by volume”.

H₂S GAS CONCENTRATION (ppm by Vol. in air) Effects on the Human body:

- 0.5 ppm First Detected by smell.
 - 10 ppm May cause some nausea, minimal eye irritation.
 - 25 ppm Eye and respiratory tract irritation. Strong odour.
 - 50 – 100 ppm Human sense of smell starts to break down. Prolonged exposure to concentrations at 100 ppm induces a gradual increase in the severity of these symptoms and death may occur after 4 – 48 hours of exposure.
 - 150 ppm Loss of sense of smell in 2 – 5 minutes
 - 350 ppm could be fatal after 30 minutes of inhalation 700 ppm RAPIDLY induces consciousness (few minutes) and death. Causes seizures, loss of control of bowel and bladder. Breathing will stop and death will result, if not rescued promptly.
 - >700 ppm IMMEDIATELY FATAL.
1. In cases where H₂S concentrations are known to be greater than 100 ppm in the vapor space and likely to be present in the atmosphere, Emergency escape Breathing Apparatus shall be made available to personnel working in the hazardous area, who, should already have a Personal (pocket-able) H₂S gas monitoring alarm / instrument.
 2. The presence of H₂S in bunkers should not be ruled out. Empty bunkers tanks shall be tested for the presence of H₂S prior to bunkering.
If new to be supplied bunkers contains H₂S the DPA shall be informed immediately.

D. PYROPHORIC OXIDATION

In an oxygen-free atmosphere where hydrogen sulphide gas is present or, specifically, where the concentration of hydrogen sulphide exceeds that of the oxygen, iron oxide is converted to iron sulphide. When the iron

sulphide is subsequently exposed to air, it is oxidized back to iron oxide and either free sulphur or sulphur dioxide gas is formed. This oxidation can be accompanied by the generation of considerable heat so that individual particles may become incandescent. Rapid exothermic oxidation with incandescence is termed pyrophoric oxidation.

As described above, the formation of pyrophors is dependent on three factors:

1. Presence of iron oxide (rust).
2. Presence of hydrogen sulphide gas.
3. Lack of oxygen.

As long as the cargo tanks remain inerted, there is no danger of ignition from a pyrophoric exothermic reaction. However, it is imperative that the atmosphere in the tank is not allowed to become flammable. Flammable atmospheres would inevitably arise if the tanks are discharged while the inert gas plant is inoperable.

E. BENZENE

Health Concerns in connection with Benzene:

1. Benzene is present in varying concentrations in some crude oils and the MSDS shall be consulted each time before cargo handling.
2. Benzene gas has poor warning qualities, as its odour threshold is well above the TLV-TWA limits. Exposure to concentrations in excess of 1000 ppm can lead to unconsciousness and death. Benzene can also be absorbed through the skin and becomes toxic when ingested.
3. If there is evidence that dissolved benzene is present in the liquid cargo in quantities of 0.5% by volume or more, respiratory protection is required when conducting tank “de-mucking” or standing up wind from tanks containing benzene are being vented.

TLV (Threshold Limit Value) – TWA (Time Weighted Average): The airborne concentration of a Toxic substance averaged over an 8 hours Period, usually expressed in parts per million (ppm)

TLV - STEL (Short Term Exposure Limit): The airborne concentration of a Toxic substance averaged over any 15 minute period, usually expressed in parts per million.

Gas IACS RECOMMENDATION: Limit 8 Hour work shift (ppm) (STEL) Limit 15 min working (ppm) Benzene (C₆H₆) 1-5 , Hydrogen Sulfide (H₂S) 5-20 , Carbon Dioxide (CO₂) 5-30 , Carbon Monoxide (CO) 25-50 , Nitrogen Dioxide (NO₂) 1-3 , Nitrogen Monoxide (NO) 25-50 , Sulphur Dioxide (SO₂) 2-5.

F. MERCAPTANS (THIOL)

1. Mercaptans are colorless gas, having a smell similar to rotting cabbage.
2. They are generated by the de-gradation of natural organisms.
3. They can be detected by smell at concentrations below 0.5 ppm, although health effects are not experienced until the concentrations are several times higher than this.

4. The initial effects of Mercaptans on persons are similar to those caused by H₂S exposure.
5. Mercaptans may be found in the following conditions:
 - They may occur on ships where sea water has remained beneath oil or where oil residues are left in tanks that contain water. (Such as dirty ballast tank, after it has been completely drained).
 - They may also be found in water treatment plants and ballast treatment facilities.
 - Are also present in vapors of pentane plus cargoes and in some crude oils.
 - Are also used as an odorizing agent in natural gas

G. COMPOSITE OF INERT GAS

After efficient scrubbing of the inert gas (to reduce the content of sulfur dioxide), the typical constituents of a flue gas are as showing the Table:

- Nitrogen N 83%
- Carbon Dioxide CO₂: 12-14%
- Oxygen O₂: 2-4%
- Sulfur Dioxide SO₂: 50 ppm
- Carbon Monoxide CO: Trace
- Nitrogen Oxides NO_x: 200 ppm
- Water Vapor H₂O: Trace (high, if not effectively dried)
- Ash and Soot C: Traces
- Density: 1.044 (heavier than air)

H. HEALTH CONCERNS OF INERT GAS

1. The main hazard of inert gas is its low oxygen content.
2. The subsequent hazards such as the presence of traces of toxic gases in Inert Gas, inside cargo tanks and spaces of such encountering are reduced and controlled, by following the company's designated "Procedures for Entry into Enclosed Spaces".
3. By Gas freeing from a "Purged condition (HC=2% VOL)" to the "Gas free condition(HC=1% LEL)", sufficient dilution of such toxic gases to below their TLV-TWA limits will have been achieved.

I. OXYGEN DEFICIENT ATMOSPHERE

1. The health effects and consequences because of lack of oxygen are listed in the table.
2. These effects will take place without any warning such as odour or physical symptoms.
3. In tanks and/or voids of complicated geometry with high possibility of "pockets of atmosphere" with low O₂-content, and where rescue operations may be difficult, the use of a portable oxygen meter with audible alarm is strongly recommended.

Health effects from lack of oxygen:

- 22 % Oxygen enriched atmosphere
- 20.8% Normal level ($\pm 0.2\%$)
- 19.5% Oxygen deficient atmosphere
- 16% Impaired judgment and breathing
- 14% Rapid fatigue and faulty judgment
- 11% Difficult breathing and death in a few minutes

5. GAS DETECTION SYSTEMS

A. FIXED GAS DETECTION SYSTEM

In addition to the requirements in paragraphs 5.7.1 and 5.7.2, oil tankers of 20,000 dwt and above, constructed on or after [date], shall be provided with a fixed hydrocarbon gas detection system complying with the International Code for Fire Safety Systems for measuring hydrocarbon gas concentrations in all ballast tanks and void spaces of double-hull and double-bottom spaces adjacent to the cargo tanks, including the forepeak tank and any other tanks and spaces under bulkhead deck adjacent to cargo tanks. Gas detection equipment is required for ensuring spaces are safe for entry, work or other operations. Their uses include the detection of:

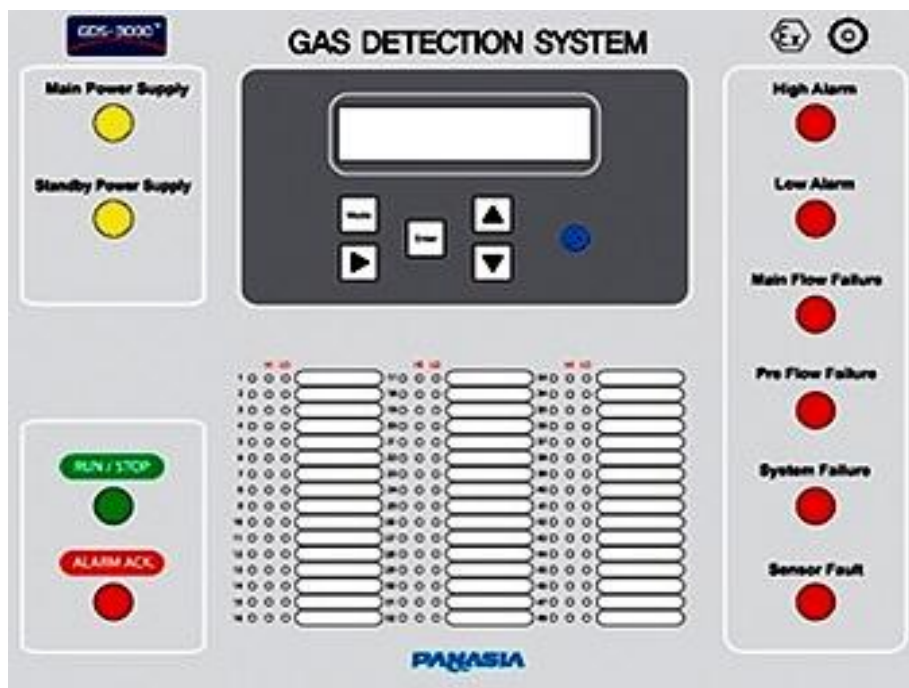
1. Cargo vapour in air, inert gas or the vapour of another cargo.
2. Concentrations of gas in or near the flammable range.
3. Concentrations of oxygen in inert gas, cargo vapour or enclosed spaces.
4. Toxic gases

Personnel must fully understand the purpose and limitations of vapour detection equipment, whether fixed or portable. Maintenance records for all gas detection equipment onboard are to be maintained by the Chief Officer. Onboard calibration records and shore records are to be maintained together for each meter and are to be updated on each occasion that the instrument is tested or checked. The importance of careful calibration cannot be over emphasized as the gas detection or analyzing equipment will only give accurate readings if calibration is carried out strictly in compliance with the manufacturer's instructions and using the correct calibration gases. Where calibration is carried out ashore or by shore technicians, a certificate is to be issued and retained onboard. Instruments must always be checked, zeroed and spanned where applicable before every use as per the manufacturer's instructions. Where calibration is required by the manufacturer's instructions to be carried out ashore or by shore technicians, this must be recorded within the vessel's PMS and all certification issued. In such circumstances at least one unit for each measurement function should remain onboard available for use at all times. Where calibration is carried out ashore or by shore technicians, a certificate is to be issued and retained onboard. The system is designed to extract a gas sample from each sample point via sample piping to the analyzing unit where the flammable and hydrogen sulphide gas

content is measured. By using solenoid valves, the unit provides an effective way of sampling multiple locations using only one sensor for gas detection. The system utilizes a heavy-duty sample pump to extract a sample of gas from each of the sample point locations. The extraction circuit incorporates a flow sensing device to annunciate a flow failure if the pump ceases to operate or sample lines become blocked. Solenoid valves are used to select each sampling line for analysis in a sequential or pre-programmed sampling sequence. Furthermore, the system is extendable by adding additional valves, which are automatically recognised and activated. Flame arresters are installed on all sample lines in accordance with class regulations. The system can supply information to the vessels AMS system via a communications protocol which allows for a real time flow of information including the current location being sampled and the gas concentration level at this location.



FIXED GAS DETECTION SYSTEM



FIXED GAS DETECTION SYSTEM PANEL

LCD DISPLAY: The LCD is a 41line 40-character screen that displays information for each channel. (Locations name, gas concentrations, alarms and time and date).

HIGH ALARM LAMP: Indicates that the concentration of gas at a particular location has exceeded the high alarm set point. The system buzzer will also sound on this alarm condition. The alarm signal is latched and can only be cleared if the gas hazard disappears.

LOW ALARM LAMP: Indicates that the concentration of gas at a particular location has exceeded the Low alarm set point. The system buzzer will also sound on this alarm condition. The alarm signal is latched and can only be cleared if the gas hazard disappears.

SYSTEM FAILURE LAMP: Indicates electronics failure and is on if a fault on the system has occurred. The system buzzer will also sound on this alarm condition. The alarm signal is latched and can only be cleared if the system fail condition is rectified.

MAIN/PRE FLOW FAILURE LAMP: Indicates that a blocked line has been detected or that the pump has failed. The system buzzer will also sound on this alarm condition. The alarm signal is latched and can only be cleared if the flow fail condition disappears, pressing the Alarm ACK. key will clear the flow fail signal. On resetting this alarm, always check to ensure that flow is received from other sample lines to confirm correct operation of the pump.

SENSOR FAULT LAMP: Indicates a sensor has failed. The system buzzer will also sound on this alarm condition. The alarm signal is latched and can only be cleared if the system fail condition is rectified. The Lamp will light if the system does not receive a signal from the sensor or the sensor signal has exceeded the over range.

STBY MAIN POWER SUPPLY: The lamp will indicate the source of power the system is currently operating on.

B. PORTABLE MULTI GAS DETECTORS

FLAMMABLE GAS MONITORS (EXPLOSIMETER):



The Explosimeter is the name normally associated with the instrument for measuring hydrocarbon gas in air at concentrations below the Lower Flammable Limit. Its full name is a Catalytic Filament Combustible Gas Indicator. A full understanding of the construction and principle of an Explosimeter is essential for its safe and efficient use and it is essential that any person using this instrument carefully studies the operating manual. There is also a detailed explanation in the ISGOTT carried on tankers. The Explosimeter measures from 0 to 100% of the Lower Explosive Limit (1.4% by volume). If the gas to air mixture is above the upper explosive limit (6% by volume) the meter reading will initially rise to give a reading of 100% or above, but will rapidly fall towards zero because the mixture of gas and air in the combustion chamber is too 'rich' to sustain combustion. The meter must therefore be constantly observed for this phenomenon, as an apparently safe reading may be obtained when the atmosphere is in fact highly dangerous. Calibration checks must be carried out at two monthly intervals and when a filament has been changed in accordance with manufacturers' instructions. Note that, in general, an explosimeter may be calibrated by different gases. It is essential that the correct gas is used otherwise an error may result. Explosimeters will not read hydrocarbon levels in an inert atmosphere. Modern instruments have a poison resistant flammable pellistor as the sensing element. Pellistor rely on the presence of Oxygen (minimum 11% by volume) to operate efficiently and for this reason Explosimeters must not be used for measuring hydrocarbon gas in inert atmospheres. Unlike in early Explosimeters, the pellistor unit balances the voltage and zeros the display automatically when the instrument is switched on in fresh air. In general, it takes about 30 seconds for the pellistor to reach its operating temperature. However, the operator should always refer to the

manufacturer's instructions for the startup procedure. A gas sample may be taken in several ways:

- Diffusion.
- Hose and aspirator bulb (1 squeeze equates to about 1 meter of hose length).
- Motorized pump (either internal or external).

Flammable vapours are drawn through a sintered filter (flash back arrestor) into the pellistor combustion chamber. Within the chamber are two elements, the 'Detector' and the 'Compensator' this pair of elements is heated to between 400 and 600° C. When no gas is present, the resistances of the two elements are balanced and the bridge will produce a stable baseline signal. Combustible gases will catalytically oxidize on the detector head causing its temperature to rise. This oxidization can only take place if there is sufficient oxygen present. The reading is taken when the display is stable. Care should be taken to ensure that liquid is not drawn into the instrument. The use of an inline water trap and a float probe fitted to the end of the aspirator hose should prevent this occurrence. Most manufacturers offer these items as accessories. Modern units will indicate on the display when the gas sample has exceeded the LFL. An explosimeter does not give a reliable reading with atmospheres deficient in oxygen, such as those present in inerted or partially inerted tanks. The meter must not be used for measuring hydrocarbon concentrations in inerted atmospheres. An Explosimeter is not a precision instrument and it can only indicate the presence of all flammable vapours in the atmosphere being tested. The instrument will indicate a value representing the mixture of hydrocarbon vapours present. The only time the instrument is accurate is when it is measuring the same gas with which it has been calibrated. Older instruments are fitted with flashback arresters in the inlet and outlet of the detector filament chamber. The arresters are essential to prevent the possibility of flame propagation from the combustible chamber and a check should always be made to ensure that they are in place and fitted properly. Modern pellistor type instrument have sintered filters usually built into the pellistor body. Some authorities require, as a condition of their approval, that PVC covers be fitted around meters with aluminium cases to avoid the risk of incentive sparking if the case impacts on rusty steel.

TANKSCOPE (NON-CATALYTIC HEATED FILAMENT GAS INDICATOR):



Although similar to the Explosimeter, the 'Tankscope' (or Non-Catalytic Heated Filament Gas Indicator) measures hydrocarbons in an inert atmosphere. It indicates their presence as a percentage proportion of the whole atmosphere. The instrument is especially useful during purging with inert gas. It will indicate when the proportion of hydrocarbons has fallen to a level whereby the atmosphere will remain below the Lower Explosive Limit (LEL) on the introduction of fresh air. Calibration checks must be carried out at two monthly intervals. The sensing element of this instrument is usually a non-catalytic hot filament. The composition of the surrounding gas determines the rate of loss of heat from the filament, and hence its temperature and resistance. Only cotton filters should be used to remove solid particles or liquid from the gas sample when hydrocarbons are being measured. Water traps may be used to protect the instrument where the sampled gas may be very wet. Guidelines on the use of filters and traps will be found in the operating manual for the instrument. The sensor filament forms one arm of a Wheatstone bridge. The initial zeroing operation balances the bridge and establishes the correct voltage across the filament, thus ensuring the correct operating temperature. During zeroing, the sensor filament is purged with air or inert gas free from hydrocarbons. As in the Explosimeter, there is a second identical filament in another arm of the bridge which is kept permanently in contact with air and acts as a compensator filament. The presence of hydrocarbon changes the resistance of the sensor filament and this is shown by a deflection on the bridge meter. The rate of heat loss from the filament is a non-linear function of hydrocarbon concentration and the meter scale reflects this nonlinearity. The meter gives a direct reading of % volume hydrocarbons. In taking a measurement, the manufacturer's detailed instructions should be followed. After the instrument has been initially set at zero with fresh air in contact with the sensor filament, a sample is drawn into the meter by means of a rubber aspirator bulb. The bulb should be

operated until the meter pointer comes to rest on the scale (usually within 15-20 squeezes) then aspirating should be stopped and the final reading taken. It is important that the reading should be taken with no flow through the instrument and with the gas at normal atmospheric pressure. The non-catalytic filament is not affected by gas concentrations in excess of its working scale. The instrument reading goes off the scale and remains in this position as long as the filament is exposed to the rich gas mixture.

GAS INDICATOR TUBES:



Probably the most convenient and suitable equipment to use for measuring very low concentrations of toxic gases on board tankers is the chemical indicator tube. These consist of a sealed glass tube containing a proprietary filling which is designed to react with a specific gas and to give a visible indication of the concentration of that gas. To use the device the seals at each end of the glass tube are broken, the tube is inserted in a bellows-type fixed volume displacement hand pump, and a prescribed volume of gas mixture is drawn through the tube at a rate fixed by the rate of expansion of the bellows. A color change occurs along the tube and the length of discoloration, which is a measure of the gas concentration, is read off a scale integral with the tube. In some versions of these instruments, a hand operated injection syringe is used instead of a bellows pump. It is important that all the components used for any measurement should be from the same manufacturer. It is not permissible to use a tube from one manufacturer with a hand pump from another manufacturer. It is also important that the manufacturer's operating instructions are carefully observed. Since the measurement depends on passing a fixed volume of gas through the glass tube, any use of extension hoses should be in strict accordance with manufacturer's instructions. The tubes are designed and intended to measure concentrations of gas in the air. As a result, measurements made in a ventilated tank, in preparation for tank entry, should be reliable. Under some circumstances, errors can occur if several gases are present at the same time, as one gas can interfere with the measurement of

another. The manufacturer's operating instructions should be consulted prior to testing such atmospheres. For each type of tube, the manufacturers must guarantee the standards of accuracy laid down in national standards. Tanker operators should consult the vessel's flag administration for guidance on acceptable equipment.

MULTI GAS INSTRUMENTS:



MULTI GAS DETECTOR

Multi gas instruments are now widely used and are usually capable of housing four different sensors. A typical configuration would comprise of sensors for measuring:

1. Hydrocarbon vapour as a %LFL (Explosimeter function using a pellistor sensor).
2. Hydrocarbon vapour in inert gas as a %Vol (Tankscope function using an infra-red sensor).
3. Oxygen (using an electrochemical sensor).
4. Hydrogen Sulphide (using an electrochemical sensor).

All these monitors should be tested at regular intervals in accordance with manufacturer's instructions. Multi gas instruments may be supplied for gas measurement use and be fitted with a data logging capability, but without an alarm function. Care must be taken when using multi-gas instruments to check for hydrocarbons in an inerted atmosphere under pressure as the pellistor within the instrument could be damaged if subjected to pressure.

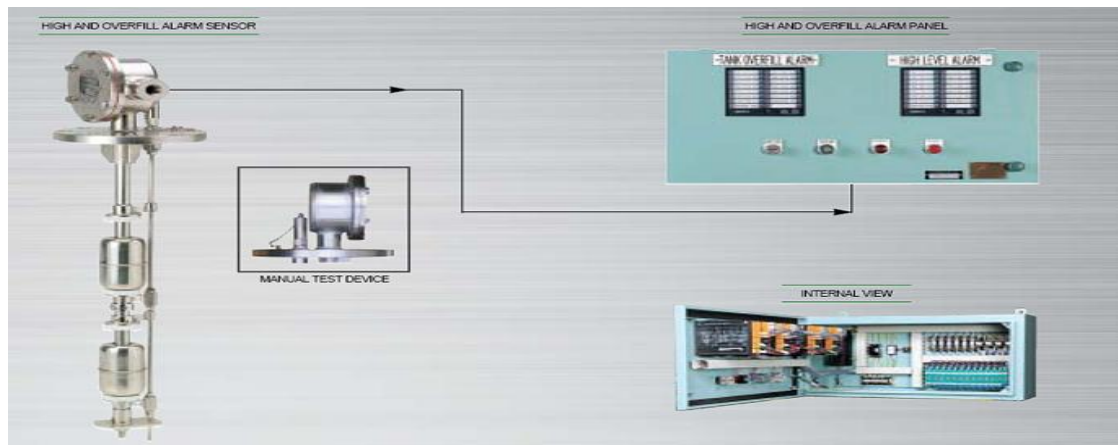
PERSONAL GAS MONITORS:



PERSONAL GAS DETECTOR

Multi gas instruments may also be supplied as compact units fitted with an alarm function for personal protective use during tank entry. These personal monitors are capable of continuously measuring the content of the atmosphere by diffusion. They usually employ up to four electrochemical sensors and should automatically provide an audible and visual alarm when the atmosphere becomes unsafe, thereby giving the wearer adequate warning of unsafe conditions. Disposable personal gas monitors are now available. They usually provide protection against a single gas and are available for low oxygen level, and high concentrations of hydrocarbons and other toxic vapours. The units should provide both audible and visual warning at specified levels of vapour concentration, which should be at or below the TLVSTEL for the monitored vapour. Typically, these monitors weigh less than 100 grams and have a life of about 2 years.

6. TANK HIGH LEVEL/OVERFILL ALARM SYSTEM



Each cargo tank is to be fitted with a high level alarm and an overflow alarm, which are to be independent of each other. The overflow alarm is at least to be independent of the tank gauging system. The alarm systems are to be self-monitoring (or fitted with other means of testing) and provided with alarms for failure of tank level sensor circuits and power supply. All alarms are to have visual and audible signals and are to be given at each cargo transfer control station. In addition, overflow alarms are also to be given in

the cargo deck area in such a way that they can be seen and heard from most locations. The high level alarm is to be set at no less than that corresponding to 95% of tank capacity, and before the overfill alarm level is reached. The overfill alarm is to be set so that it will activate early enough to allow crew in charge of the transfer operations to stop the transfer before the tank overflows. The level alarm system is perfectly separated from temperature and level monitoring system electrically. The level alarm sensor consists of magnetic float and reed switch built in the pipe. When the liquid level reaches a set point, the reed switch is actuated by magnetic float. This signal is connected to alarm unit through safety barrier. At the same time, we can get audible and visible alarm on the main control panel as well as external alarm on the bridge top. The 95% of volume is normally for high alarm and 98% of volume is normal for overfill alarm. When the liquid level reaches a set point, the reed switch is activated and the contact signal generated by level alarm sensor is transmitted to control panel through I.S barrier. After 15-20 sec., the visual and audible alarm is generated by alarm unit, and also the external horn and lighting is activated by external alarm generated from control panel at the same time. The alarm unit is activated when visual and audible alarm, and then rotating unit & external horn activated at the same time. The level alarm switch should be located, whenever possible, at some easily accessible, well lighted place on the vessel. Location should be such that the ambient temperature at the level alarm switch is within the range 0-60⁰ C. The position of alarm switch should be selected according to correct tank name.

Following should be confirmed before operation test:

1. Each cable should be confirmed satisfactory connection polarity(+,-) between each level switch and corresponded tank in monitoring panel,
2. Each float should be positioned at suitable place and no obstruction should be confirmed on guide pipe throughout traveling float.
3. There is no water in the tank to avoid the bad insulation

METHOD OF LIFTING TYPE TEST DEVICE:

1. Open the plug of the test device.
2. Lift the test rod upward until the test rod is not lifted.
3. After 10-15 sec. the alarm will arise on deck alarm and main control panel.
4. After fast testing, the test device returns to normal position.

7. STATIC ELECTRICITY

Static electricity presents fire and explosion hazards during the handling of petroleum and during other tanker operations such as tank cleaning, dipping, ullaging and sampling. Certain operations can give rise to accumulations of electric charge which may be released suddenly in electrostatic discharges with sufficient energy to ignite flammable hydrocarbon gas/air mixtures. There is, of course, no risk of ignition unless a flammable mixture is present. There are three basic stages leading up to a potential static hazard:

1. Charge separation,
2. Charge accumulation and
3. Electrostatic discharge.



Whenever two dissimilar materials come into contact, electrostatic charge occurs at the interface. The interface may be between two solids, between a solid and a liquid or between two immiscible liquids. At the interface, a charge of one sign (say positive) moves from material A to material B so that materials A and B become respectively negatively and positively charged. The charges can be separated by many processes. For example:

- The flow of liquid petroleum through pipes.
- Flow through fine filters (less than 150 microns) which have the ability to charge fuels to a very high level, as a result of all the fuel being brought into intimate contact with the filter surface, where charge separation occurs.
- Contaminants, such as water droplets, rust or other particles, moving relative to oil as a result of turbulence in the oil as it flows through pipes.
- The settling of a solid or an immiscible liquid through a liquid (e.g. water, rust or other particles through petroleum). This process may continue for up to 30 minutes after the tank contents have stopped moving.
- Gas bubbles rising up through a liquid (e.g. air, inert gas introduced into a tank by the blowing of cargo lines or vapour from the liquid itself released when pressure is dropped). This process may also continue for up to 30 minutes after the tank contents have stopped moving.
- Turbulence and splashing in the early stages of loading oil into an empty tank. This is both a problem in the liquid and in the mist that can form above the liquid.
- The ejection of particles or droplets from a nozzle (e.g. during steaming operations).
- The splashing or agitation of a liquid against a solid surface (e.g. water washing operations or the initial stages of filling a tank with oil).
- The vigorous rubbing together and subsequent separation of certain synthetic polymers (e.g. the sliding of a polypropylene rope through gloved hands).

A. PROTECTIVE MEASURES AGAINST ELECTROSTATIC HAZARDS

Measures that must be taken to prevent electrostatic hazards whenever a flammable atmosphere could potentially be present are:

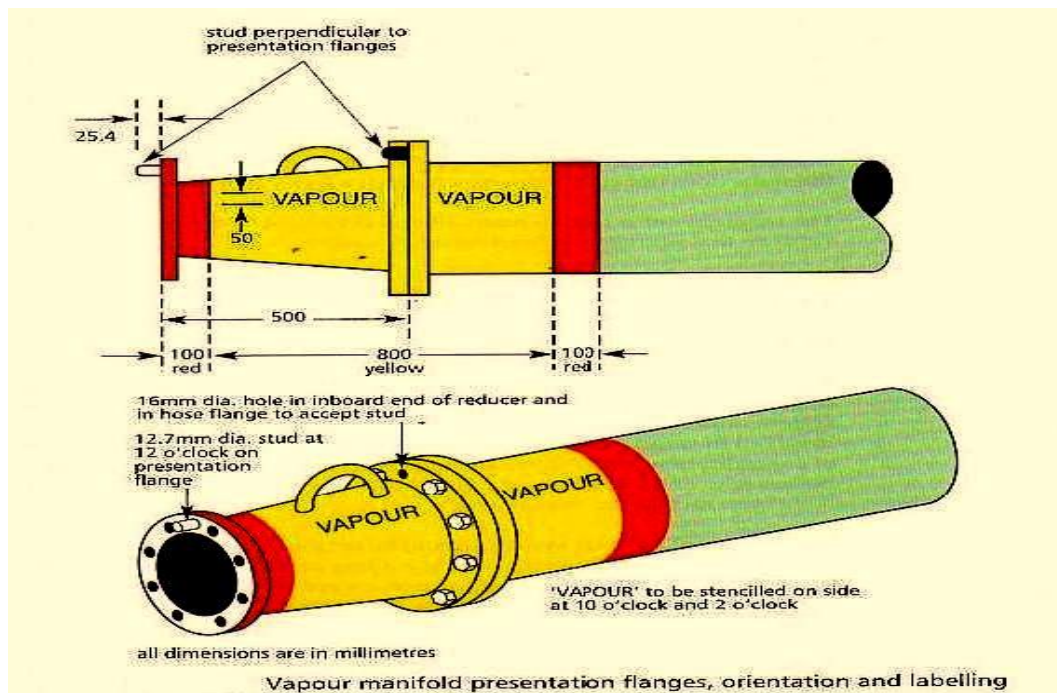
- The bonding of metal objects to the metal structure of the ship to eliminate the risk of spark discharges between metal objects that might be electrically insulated. This includes metallic components of any equipment used for dipping, ullaging and sampling.
- The removal from tanks or other hazardous areas, of any loose conductive objects that cannot be bonded.
- Restricting the linear velocity of the cargo to a maximum of 1 meter per second at the individual tank inlets during the initial stages of loading i.e. until after the bottom structure is covered, all splashing and surface turbulence has ceased, and any water that may have been present is cleared from the lines.
- Banning the use of all metallic equipment and all non-metallic containers of more than 1 liter capacity for dipping, ullaging and sampling during loading and for 30 minutes after completion of loading. After the 30 minute waiting period, metallic equipment may be used for dipping, ullaging and sampling but it must be effectively bonded and securely earthed to the structure of the ship before it is introduced into the tank and must remain earthed until after removal.

Non-metallic containers of less than 1 liter capacity may be used for sampling in tanks provided that they have no conducting components and they are not rubbed prior to sampling. Cleaning with a high conductivity proprietary cleaner, a solvent such as 70:30% IPA: toluene mix, or soapy water is recommended to reduce charge generation. Operations carried out through a correctly designed and installed sounding pipe are permissible at any time. It is not possible for any significant charge to accumulate on the surface of the liquid within the sounding pipe and therefore no waiting time is required. However, the precautions to be observed against introducing charged objects into a tank still apply and, if metallic equipment is used, it should be bonded before being inserted into the sounding pipe.

8. VAPOUR LINE

Venting of cargo tanks during cargo transfer or cargo related operations must be carried out in accordance with applicable international, national, port and terminal regulations. Tank vent system outlets are located at a safe distance from all areas where personnel who are not involved in cargo work may be present, to ensure that toxic vapours are diluted to a safe level of concentration before they can reach such an area. The safe distances specified depend on the severity of the toxic hazard. In all cases the principles described in the IMO Codes will have been met by the ship's design. The cargo tank venting system should be set for the type of operation to be performed. Cargo vapour displaced from tanks during loading or ballasting should be vented through the installed venting system to atmosphere, except when return of the vapour to shore is required. The cargo or ballast loading rate should not exceed a rate of vapour flow within the capacity of the installed system. In the case of ships fitted with a venting system which is common to several tanks, it is important to remember that vapours (or liquid in the event of

overflow) may pass through the venting system from one tank into another, and thereby cause contamination of cargo or tank atmosphere.



A required level of maintenance and inspection will be necessary to ensure the cleanliness of the venting system, and in particular of the P/V valves, high velocity valves and devices to prevent the passage of flame into cargo tanks. Particular attention should be given to the possibility of flame screens becoming blocked by dirt, freezing water, or vapour condensation from certain chemical cargoes - e.g. those with high melting points or liable to polymerize -since blockage can severely jeopardize tank integrity. The IBC Code requires the ship to be able to return vapours of most toxic chemicals to shore. When a tank is connected to a vapour return line, it is important to keep a safe pressure balance between the ship and shore. The vapours should be evacuated fast enough to keep the pressure in the tank below the set opening pressure of any pressure relief valve in the tank venting system. IMO guidelines recommend a maximum tank pressure of 80% of the set pressure. It is thus critically important clearly to agree in advance with the shore terminal management what the liquid loading rate and the pressure at the vapour connection will be, and to plan how they will be controlled. Liquid should not be permitted to enter the vapour return line. If liquid gets into the vapour line it will cause the cross section available for the flow of vapour to be reduced, as a result of which the pressure inside the tank can rise rapidly. Loading should be suspended until the pressure is released, and the presence of liquid dealt with. Connection of hoses intended for vapour transfer to manifold flanges of pipelines for liquid transfer is prevented by a stud permanently fixed between two bolt holes in the presentation flange of the ship's vapour return manifold. The stud will fit into a corresponding additional hole in the flange of the shore vapour hose. Vapour connections should also be identified by painting and stenciling in a standard way.

9. GENERAL PRECAUTIONS ONBOARD OIL TANKERS

The daily operation of oil tankers involved many hazards. There are many check items that should be complied with to ensure a safe working atmosphere. Observance of following precautions by crew are the most common practice that should be complied with.

A. RESTRICTION OF SMOKING, OTHER BURNING ACTIVITIES AND NAKED LIGHTS

Smoking is prohibited except in designated smoking areas. Any violations must be reported to the Master. Such guidelines and controls are to be applied to other sort of burning activities such as incense sticks, pipe tobacco, joss sticks, etc. Safety Matches or fixed electrical cigarette lighters (car type) will be provided in authorized smoking areas. Safety Matches or fixed electrical cigarette lighters (Car type) must not brought in private cabins outside authorized smoking areas and shall under no circumstances be carried on the tank deck or where petroleum gases may collect. During certain special operations, such as Gas freeing or Gas Purging operations, where the presence of inflammable gas can be suspected, then smoking in designated smoking areas is also prohibited. The carriage and Usage of Hand Gas Lighters are prohibited onboard Oil Tankers. Safety Matches are available to use in designated Smoking Area. Notices: Portable and Permanent notices prohibiting smoking and the use of naked lights should be displayed conspicuously at the points of access to the ship and at the exits from the accommodation area. Refer to Warning Signs to be displayed (at Sea/ in Port). The Master shall designate & post suitable notice for smoking areas under the following conditions:

- While alongside a berth or at an off shore marine facility: Officers Smoking Room, Crews Smoking Room and Cargo Control Room.
 - At sea : Officers Smoking Room, Crews Smoking Room, Chart Room, Bridge, Radio Office, Cargo Control Room and Engine Control Room.
1. Smoking on the navigational bridge is prohibited in certain port limits, when pilot or port officials are onboard (e.g. Australian Waters, Panama Canal, etc.)
 2. The designated smoking areas must be provided with self-extinguishing ash trays or filled with water.
 3. The designated smoking areas must be provided with Automatic Gas Detection system and alarm.
 4. Portholes and doors leading to the designated smoking areas must be closed at all times.
 5. Shore facilities regulations must be observed at all times while transit & docked at the facility.

B. PROHIBITION OF USING FIRE EXCEPT IN DESIGNATED AREAS AND CONTROL OF POTENTIAL IGNITION SOURCES

At sea, the use of portable stoves and cooking appliances are to be effectively controlled. Ensure the portholes and doors are closed and confirm the safety and the absence of hydrocarbon gas before the use of fire. Galley stoves: The use of galley stoves or other cooking appliances that employ naked flames are prohibited, while the tanker is at berth. The use of other portable electrical appliances are to be controlled. Steam ranges may be used all the time while the vessel is at berth. In this case, the galley personnel must be instructed and trained in emergency procedures in the safe operation of galley equipment. Oil / Fat fryers are to be fitted with thermostats to cut-off electrical power and so to prevent accidental fires. Fire blankets are to be readily available. Electric heaters in pantries: Electric heaters (hot plates, toasters or the like) must be fixed at limited and designated positions only. Never use them if inflammable gas comes into the accommodation or there is a danger that gas is likely to exist.



C. STANDARDS FOR USE OF PRIVATE ELECTRIC APPLIANCES AND OTHER PORTABLE ELECTRICAL EQUIPMENT

Visitors should be cautioned about the restricted use of Non-Approved Type of portable electrical equipment in the Dangerous Area on the Tanker. Use of Electric appliances in private cabins, other than Entertainment systems, Calculators, Camera equipment and Electric razors are prohibited. Hand Held UHF / VHF portable transceivers must be of intrinsically safe type. Other equipment, including, but not limited to Portable radios, Tape recorders, Electronic calculators, Portable telephones or pagers, etc. unless of Intrinsically Safe Type, shall not be used on the cargo tank deck, or in areas where flammable gas may be present.

D. CLOSING PORTHOLES AND DOORS

With the exception of the designated authorized passage way(s), all portholes and doors leading to/from the accommodation must be closed in port. To further minimize the possibility of gas entering the accommodation during cargo operations, as far as possible the access to accommodation should be limited to the leeward side (opposite to the manifold connection) entrance to accommodation, above the Main / Upper deck level.

E. ATTENTION TO VISITORS

Control of visitors onboard is to be in accordance with the access control and other procedures laid out within the Ship Security Plan. They shall be guided by the notices as displayed at the point of entrance. Only allow authorized visitors onto the vessel upon presentation of photo ID. Instruct visitors to adhere to the vessel's prohibition to bring matches or lighters onboard, and to comply with the vessel's smoking restrictions. All visitors shall be escorted from the gangway to the accommodation entrance. No visitor is permitted to walk around the main deck/cargo area without escort by vessel personnel.



F. PRECAUTIONS WHEN STORING SPONTANEOUSLY COMBUSTIBLE MATERIALS

Materials which may cause spontaneous combustion (saw dust, oily rags, especially oil of vegetable origin, etc.). Must be stored in a well-ventilated area to prevent the accumulation of flammable gases. They are liable to ignite without the external application of heat, as a result of gradual heating within the material produced by oxidation. This effect is further enhanced where material is stored in warm areas, e.g. proximity of hot pipes, etc. Waste rags, saw dust, or any similar absorbent material must not be stowed in the same compartment as oils, paints, etc. They should not be left lying on decks or equipment and should be stored or disposed effectively. Certain chemicals, such as those used for boiler treatment are also oxidizing agents and, although carried in diluted form, are capable of spontaneous combustion if permitted to evaporate. Refer Procedures for Handling Chemicals and Hazardous Wastes. The containers used for storage shall be kept covered and should not be stored together with flammable materials.

G. PRECAUTIONS AGAINST SPARKS FROM FUNNEL

At sea, where sparks / burning soot are observed being emitted from the funnel, measures to avoid such sparks falling on deck such as course alteration, where possible, should be considered. Any special operations such as cargo tank cleaning, purging and gas freeing operations should be ceased and all tank opening closed.

Boiler tubes should be soot blown prior to arrival and after departure from a port. Boiler tubes soot blowing should not be carried out at berth. At sea, the officer of navigational watch should be consulted, prior to such activity, and suitable measures adopted. Duty deck personnel shall watch for sparks or soot emitting from the funnel. If sparks from the funnel are observed, the duty engineer or Chief Engineer must be notified immediately.



BIBLIOGRAPHY

HYUNDAI SAMHO HEAVY INDUSTRIES CO., LTD INSTRUCTION
MANUALS

WEBSITES

- http://www.eagle.org/eagleExternalPortalWEB/ShowProperty/BEA%20Repository/Rules&Guides/Archives/131_InertGasSystemforBallastTanks/Guide
- <http://shipsbusiness.com/tanker.html>
- <https://www.tc.gc.ca/publications/EN/TP4295/PDF/HR/TP4295E.pdf>
- <http://www.hamworthy.com/PageFiles/185/Moss%20Nitrogen%20Generator%20System%20BROCHURE.pdf>
- http://www.bcpetro.com/ballast_water_management_system.html