CHAPTER 11

Shipboard Systems

This chapter describes the main ship systems that are used during cargo and ballast operations in port.

11.1 Fixed Inert Gas systems

This section describes, in general terms, the operation of a fixed IG system that is used to maintain a safe atmosphere within a ship's cargo tanks. It also covers the precautions to be taken to avoid health risks associated with operating IG plants.

Refer to the ship's operations manual, the manufacturer's instructions and the installation drawings, as appropriate, for details on the operation of a particular system. Consult the IMO publication *Guidelines for Inert Gas Systems* for a more detailed explanation of the design and operation of typical IG system.

See OCIMF's information paper *Inert Gas Systems* for guidance on using IG while carrying flammable oil cargoes.

11.1.1 General

Hydrocarbon gas in petroleum tankers cannot burn in an atmosphere containing less than about 11% oxygen by volume. One way to provide protection against fire or explosion is to keep the oxygen level below 11%. This is usually achieved by using a fixed piping arrangement to blow IG into each cargo tank to reduce the air content, i.e. the oxygen content, and render the tank atmosphere non-flammable.

See section 1.2.3 and figure 1.1 for detailed information on IG and flammability.

11.1.2 Sources of Inert Gas

Possible sources of IG on tankers and combination carriers are:

- Uptake gas from the ship's boilers.
- Independent IG generators.
- IG (or nitrogen) supplied from external sources.

11.1.3 Composition and quality of Inert Gas

SOLAS requires IG systems to deliver IG with an oxygen content in the IG main of not more than 5% by volume at any required rate of flow.

SOLAS also requires that IG systems keep positive pressure in the cargo tanks and have an oxygen content of not more than 8% (except when it is necessary for the tank to be gas free).

When using flue gas from a main or auxiliary boiler, an oxygen level of less than 5% can generally be obtained, depending on the quality of combustion control and the load on the boiler.

When an independent IG generator is installed, the oxygen content can be automatically controlled within finer limits, usually between 1.5% to 2.5% by volume.

In certain ports, the maximum oxygen content of IG in the cargo tanks may be set at 5% to meet safety requirements, e.g. the operation of a Vapour Emission Control System (VECS). When such a limitation is in place, the ship should be advised of the requirement in the pre-arrival information exchange.

Efficient scrubbing of the IG is essential, particularly for the reduction of the sulphur dioxide (SO_2) content. High levels of sulphur dioxide increase the acidic characteristic of IG, which may cause accelerated corrosion to the structure of the ship.

11.1.4 Methods of replacing tank atmospheres

If the entire tank atmosphere could be replaced by an equal volume of IG, the resulting tank atmosphere would have the same oxygen level as the incoming IG. In practice, this is impossible to achieve and a volume of IG equal to several tank volumes would need to be introduced into the tank before the desired result could be achieved.

A tank's atmosphere can be replaced with IG either by inerting or purging. These are distinct processes, where the atmosphere will either be diluted or displaced:

- Dilution: when the incoming IG mixes with the original tank atmosphere, the original gas decreases slowly. The incoming IG should have enough velocity to enter the bottom of the tank. Because of this, only one tank should be inerted or purged at a time when using this method.
- Displacement: because IG is slightly lighter than hydrocarbon gas, when the IG enters at the top of the tank the hydrocarbon gas escapes from the bottom. When using this method, it is important that the IG has a very low velocity. This method allows several tanks to be inerted or purged at the same time.

Inerting or purging through a series of tanks is called the cascade method, where the IG enters the first tank and exits to the second tank. Using this method, the tanks are inerted/purged from top to bottom or from bottom to top.

Whichever method is used, it is important that oxygen or gas measurements are taken at different heights and positions within the tank. A mixture of IG and petroleum gas can become flammable.

To achieve the protection of an IG system, it is important that the system is properly operated and maintained.

It is important to follow the safety precautions when petroleum gas is vented. The flame trap of the venting system should be kept in good condition. The purge velocity of IG should be sufficient to minimise the exposure of personnel working on deck. The operation should be stopped before lightning or a thunderstorm.

11.1.5 Cargo tank atmosphere control

11.1.5.1 Inert Gas operations

Tankers using an IG system should maintain their cargo tanks in a non-flammable condition at all times:

- Tanks should be kept in an inert condition at all times, except when it is necessary for them to be gas free for inspection or work, i.e. the oxygen content should be not more than 8% by volume and the atmosphere should be maintained at a positive pressure.
- The atmosphere within the tank should transition from an inert condition to a gas free condition without passing through the flammable condition. In practice, this means that before any tank is gas freed it should be purged with IG until the hydrocarbon content of the tank atmosphere is below the critical dilution line (line GA in figure 1.1).
- When an oil tanker is in a gas free condition before arrival at a loading port, the tanks should be inerted before loading.

To maintain cargo tanks in a non-flammable condition, the IG plant should:

- Inert empty cargo tanks (see section 11.1.6.1).
- Be in operation, or be ready for immediate operation, during cargo discharge, de-ballasting, COW and tank cleaning (see sections 11.1.6.6 and 11.1.6.9).
- Purge tanks before gas freeing (see section 11.1.6.10).
- Top up the pressure in the cargo tanks when necessary during other stages of the voyage (see sections 11.1.6.5 and 11.1.6.7).

11.1.5.2 Inert Gas system maintenance

The deck and engine departments should cooperate closely to ensure the IG system is maintained and operated properly. It is important to make sure that non-return barriers function correctly, especially the deck water seal or block and bleed valves, so that there is no possibility of petroleum gas or liquid petroleum passing back to the machinery spaces.

Dry and semi-dry type deck water seals present a higher risk of backflow. OCIMF's *Inert Gas Systems, Dry Type Deck Water Seals – Prevention of Inert Gas/Hydrocarbon Backflow* and *Inert Gas Systems, Semi-Dry Type Deck Water Seals – Prevention of Inert Gas/Hydrocarbon Backflow* provide guidance on how to reduce the risk of backflow. Operators should be aware of the safety risks and understand the information in these papers when fitting these types of deck water seals.

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

11.1.5.3 Degradation of Inert Gas quality

Tanker personnel should be alert to the possible degradation of the quality of IG in tanks as a result of air being drawn in. This can happen when the IG or cargo systems are operated improperly or when petroleum product in a tank releases oxygen, e.g.:

- Not topping-up the IG promptly if the pressure in the system falls due to temperature changes at night.
- Opening tank apertures for too long when carrying out tank gauging, sampling and dipping.

When water is drained from a non-inerted tank, air will be mixed in with the drainings and released into an inerted slop tank. The volume of air drawn into the slop tank in this manner can be particularly high if an eductor is used to drain cargo tanks back to the slop tanks. When liquid is to be drained to the slop tank, the oxygen content of the IG should be closely monitored.

11.1.6 Use during cargo tank operations

Before the IG system is operated the tests required by the operations manual or the manufacturer's instructions should be carried out. The fixed oxygen analyser and recorder should be tested and proved to be in good order. Portable oxygen and hydrocarbon meters should also be prepared and tested.

11.1.6.1 Inerting empty tanks

When inerting empty tanks that are gas free, IG should be introduced while venting the air in the tank. This operation should continue until the oxygen content throughout the tank is not more than 8% by volume. The oxygen level will not then increase if a positive pressure is maintained by using the IG system to introduce additional IG.

If the tank is not gas free, the precautions against static electricity in section 11.1.6.8 should be followed until the oxygen content of the tank has been reduced to 8% by volume.

When all tanks have been inerted, they should be kept common with the IG main and the system pressurised with a minimum positive pressure of at least 100mm Water Gauge (WG). If individual tanks have to be separated from a common line, e.g. for product integrity, the tanks should have an alternative means of maintaining an IG blanket.

11.1.6.2 Loading cargo or ballast into inert tanks

When loading cargo or ballast, the IG plant should be shut down and the tanks vented through the appropriate venting system. On completion of loading or ballasting, and when all ullaging is completed, the tanks should be closed and the IG system restarted and re-pressurised, if necessary. The system should then be shut down and all safety isolating valves secured.

Local regulations may prohibit venting after COW (see section 12.5.8).

11.1.6.3 Simultaneous cargo operations

When loading and discharging cargo simultaneously, venting to the atmosphere can be minimised or even avoided by interconnecting the tanks through the IG main. Depending on the relative pumping rates, pressure in the tanks may be increased or reduced and it may be necessary to adjust the IG flow to maintain tank pressures within normal limits.

11.1.6.4 Vapour balancing

Vapour balancing is used to avoid the release of gases and to reduce the use of the IG systems when transferring cargo:

- For internal transfer of cargo, the ship's vapour return system (IG valve) will be connected between tanks being discharged and loaded.
- Vapour balancing to the shore or another ship involves a return of vapours to the Vapour Return Line (VRL) to shore or to the other ship using a flexible hose.

To ensure that vapour balancing operation is done safely, and cargo vapours are not accidentally released into atmosphere, the following recommendations should be followed:

Before cargo transfer:

- Use appropriate equipment to monitor the vapour stream. The oxygen analyser and alarms should be tested for proper function before each cargo transfer operation. Where local regulations require, the vapour stream should be monitored continuously, with audible and visual alarms, to ensure that the oxygen does not exceed 8% by volume.
- Before cargo transfer, the vapour space of the discharging facility and receiving tank should be inerted to less than 8% oxygen.
- The VRL pressure alarm setting should be lower than 80% of the P/V valve lowest release setting.
- If it is safe, the vapour transfer hose should be purged and inerted before the vapour transfer.

Do not open the vapour manifold valves until the IG pressure of the receiving ship exceeds that of the discharging ship.

During the cargo transfer:

- The IG system on the discharging ship should be operational and on standby, with the IG main deck isolating valve closed. Use the IG system if the IG pressure in the discharging ship falls below 300mm WG.
- The IG pressure in cargo tanks should be monitored and the information regularly exchanged between two ships or with a terminal.
- Do not let air enter the cargo tanks.
- Stop the transfer if the oxygen content of the vapour stream is above 8% by volume. It is only safe to continue the transfer once the oxygen content is 8% or less by volume.
- The cargo transfer rate should not exceed the designed rate for the vapour balancing hose.

11.1.6.5 Loaded passage

A positive pressure of IG should be maintained in the ullage space at all times during the loaded passage to prevent air from entering (see section 11.1.5.3). If the pressure falls below the low pressure alarm level, it will be necessary to start the IG plant to restore pressure to the system.

Loss of pressure is usually a result of leaks from tanks and low sea or air temperatures. It is important that tanks are always gas-tight. Gas leaks are usually easily detected by their noise. For safety reasons, every effort should be made to eliminate leaks at tank hatches, ullage lids, tank washing machine openings, valves, etc.

Leaks that cannot be eliminated should be marked and recorded, based on the toxicity or hazards created, so that they are sealed quickly and as soon as possible.

Certain oil products, e.g. jet fuel and diesel oil, can absorb oxygen during the refining and storage process. This oxygen can later be released into an oxygen deficient atmosphere, e.g. ullage space of an inerted cargo tank. The cargo tanks should be monitored to maintain the oxygen level below

8%. Purging, or any necessary precautionary measures, should be taken to maintain the oxygen level below 8%.

11.1.6.6 Discharge of cargo or ballast from inert tanks

The IG supply should be maintained throughout cargo discharge or, in exceptional circumstances, e.g. cargo tank ballast discharge operations, to prevent air entering the tanks. If a satisfactory positive IG pressure can be safely maintained without a continuous supply of IG, it is acceptable to recirculate or stop the supply of IG as long as the IG plant is kept ready for immediate operation.

On arrival in port, if the IG has to be de-pressurised for any reason it may be difficult, because of the low boiler load, to re-pressurise with IG that has low enough oxygen content. In this case, it may be necessary to create a load on the boiler by using the main cargo pumps to circulate the cargo around the ship's pipelines until the IG quality is high enough.

Throughout the cargo discharge, particularly when the boiler load is low or fluctuating, the oxygen content of the IG supply should be carefully monitored. The oxygen content and pressure of the IG main should be continuously recorded during discharge. For the action to take if the IG plant fails during discharge from inerted tanks, see section 11.1.12.

In normal operations closed measurements should be taken. However, if hand dipping a tank is necessary, pressure may be reduced while dipping ports are open but care should be taken not to allow a vacuum to develop since this would pull air into the tank. To prevent this, it may be necessary to reduce the cargo pumping rate. Discharge should be stopped immediately if there is a danger of the tanks coming under vacuum.

11.1.6.7 Ballast passage

During a ballast passage, cargo tanks (other than those required to be gas free) should remain inert and under positive pressure to prevent air entering. Whenever pressure falls to the low pressure alarm level (100mm WG minimum), the IG plant should be restarted to restore the pressure. Attention should be paid to the oxygen content of the IG delivered.

11.1.6.8 Static electricity precautions

In normal operations the presence of IG prevents the existence of flammable gas mixtures inside cargo tanks. However, hazards caused by static electricity may arise, mainly in the case of a failure of the IG system. To avoid these hazards, follow the procedures in chapter 3.

11.1.6.9 Tank washing, including Crude Oil Washing

Before a tank is washed, the oxygen content should be checked in two places – one metre below the deck and at the middle level of the ullage space. The oxygen content should never be above 8% by volume. If the tank has a swash bulkhead, the measurement should be taken at similar levels in each section of the tank. The oxygen content and pressure of the IG being delivered during the washing process should be continuously recorded.

If the oxygen content in the tank exceeds 8% by volume or the pressure of the atmosphere in the tanks is no longer positive, washing should be stopped until safe conditions are restored (see section 11.1.12).

11.1.6.10 Purging

When a tank needs to be gas freed after washing it should first be purged with IG to lower the hydrocarbon content to 2% or less by volume. This is to ensure that, during the gas freeing, no part of the tank atmosphere is brought within the flammable range.

The hydrocarbon content should be measured with an instrument specifically designed to measure the percentage of hydrocarbon gas in an oxygen deficient atmosphere.

If the dilution method of purging is used it should be with the IG system set for maximum capacity. This will give maximum turbulence within the tank. If the displacement method is used, the gas inlet velocity should be lowered to prevent undue turbulence (see section 2.1.2.4).

11.1.6.11 Gas freeing

Before starting to gas free, the tank should be isolated from other tanks. When fans connected to the cargo pipeline system are used to introduce air into the tank, the IG inlet should be isolated. If the IG system fan is used to put air into the tank, both the line back to the IG source and the line into each tank being inerted should be isolated (see chapter 3).

11.1.6.12 Preparation for tank entry

To ensure the toxic parts of IG are safely below their Threshold Limit Values (TLVs), gas freeing should continue until tests show a steady oxygen reading of 21% by volume and tests with a flammable gas indicator show not more than 1% of the LFL.

If the presence of a toxic gas such as benzene or H_2S is suspected, gas freeing should continue until tests show that its concentration is below its Occupational Exposure Limit – Time Weighted Average (OEL-TWA) (IMO Resolution A.1050(27) *Revised Recommendations for Entering Enclosed Spaces Aboard Ships*).

Positive, fresh air ventilation should be maintained throughout the time personnel are in a tank. The oxygen, toxic gas and hydrocarbon content of the tank atmosphere should be tested frequently.

When other inert tanks are either next to or connected to the tank being entered, personnel should be alert to the possibility of IG leaking into the gas free tank, e.g. through bulkhead fractures or defective valves. Special precautions should be taken, including monitoring the tank atmosphere while personnel are inside. For advice on entry into enclosed spaces, see chapter 10.

11.1.7 Precautions to be taken to avoid health hazards

11.1.7.1 Inert Gas on deck

Some wind conditions may bring vented gases down onto the deck, even from specially designed vent outlets. If gases are vented at a low level from cargo hatches, ullage ports or other tank apertures, the surrounding areas can contain harmful concentrations of gases and may also be oxygen deficient. In this case, all non-essential work should stop and only essential personnel should remain on deck, taking all necessary precautions.

If the last cargo carried was a sour crude, tests should also be made for H_2S around the deck area. If a level higher than 5ppm is detected, no personnel should be allowed to work on deck unless they are wearing suitable breathing protection (see sections 1.4.6 and 12.1.9).

11.1.7.2 Entry into cargo tanks

Entry into cargo tanks should be permitted only after they have been gas freed, as described in sections 11.1.6.10 and 11.1.6.11. The safety precautions in chapter 10 should be observed, including the carrying of a personal gas detector. If the hydrocarbon and oxygen levels specified in section 11.1.6.12 cannot be achieved, entry should be permitted only in exceptional circumstances and when there is no practicable alternative. A thorough risk assessment should be carried out and appropriate risk mitigation measures put in place. As a minimum, personnel should wear breathing apparatus (see section 10.10 for further details).

11.1.7.3 Scrubber and condensate water

IG scrubber effluent and the condensate formed when the water vapour in the IG condenses inside the IG distribution piping are acidic and corrosive.

Care should be taken to avoid contact with either the effluent or condensate. Appropriate PPE that protects the eyes and skin should be worn.

11.1.8 Cargo tank protection against over/under pressure

Serious accidents have occurred on oil tankers as a result of cargo tanks being severely over or under pressure. Although SOLAS regulations have been modified to require tanks to be fitted with pressure monitors and safety devices, it is still essential that venting systems are thoroughly checked to ensure that they are correctly set for the intended operation. Once operations have started, further checks should be made for any abnormalities, e.g. unusual noises of vapour escaping under pressure or P/V valves lifting. See section 11.2.2 for more information on how to avoid over or under pressurisation.

A ship's personnel should be provided with clear operating procedures for properly managing the venting system and should have a full understanding of its capabilities and limitations.

11.1.8.1 Pressure/Vacuum breakers

P/V breakers provide another safety mechanism to prevent over or under pressurisation. Normally, one breaker is connected to the IG/vent main to protect the cargo tanks. P/V breakers are usually liquid filled and it is important that the correct density liquid is used and the appropriate level maintained. Evaporation, condensation and sea water can all affect P/V breakers. In heavy weather the pressure surge caused by the movement of cargo in tanks may cause a P/V breaker to blow out. In the case of excess vacuum, the liquid overflows to the IG main and is lost. Some types of P/V breaker can recover and reuse the liquid if lost by pressure. The P/V breakers should be marked with their High Pressure (HP) and vacuum opening pressures, the date of the last inspection, the type of anti-freeze and the lowest operating temperature.

11.1.8.2 Pressure/Vacuum valves

P/V valves are required on each tank, to provide for the flow of small volumes of tank atmosphere due to thermal variations, and are set to operate ahead of the P/V breakers. Some systems may also have a small capacity P/V valve fitted in a bypass across the mast riser isolation valve. However, it is common practice to install full flow P/V valves on each tank where only small capacity valves are required.

11.1.8.3 Full flow Pressure/Vacuum venting arrangements

Protection from over or under pressurisation of the cargo tanks may be provided by installing, on each tank, full flow P/V valves rated for 125% of the maximum loading/discharge rate. Where the mast riser is the primary vent, the P/V valve may serve as the secondary protection.

It is common on ships carrying non-homogenous cargoes to use the individual full flow P/V valves as primary venting while loading. These P/V valves are usually the high velocity type, which disperse the tank vapours by partially closing the outlet to increase the velocity of the vapour flow to more than 30m/sec. The high velocity flow means no flame screen is needed at the vapour outlet on this type of valve.

11.1.8.4 Individual tank pressure monitoring and alarm systems

A tank pressure monitoring and alarm system may be used as an alternative to P/V valves for the secondary P/V relief. These systems use individual tank pressure sensors connected to an alarm system that is monitored in the cargo control room or a location where cargo operations are normally carried out.

The set points for non-inerted ships should be 10% over or under the P/V valve settings. For inerted ships the set points should be 10% over the pressure setting and above zero for the low pressure (100mm WG) setting to prevent the tank from taking in air. When using a vapour return line for non-inerted ships, the HP setting will be set to 90% of the pressure valve. The low pressure (vacuum) setting will be set so that the alarm occurs before the vacuum valve relieves.

11.1.9 Product carriers fitted with an Inert Gas system

11.1.9.1 General

The basic principles of inerting for product carriers and crude carriers are similar. However, there are some differences, which are outlined in the following sections.

11.1.9.2 Carrying products with a flashpoint above 60°C

Tankers may carry petroleum products that have a flashpoint above 60°C, e.g. lubricating oils, Heavy Fuel Oils (HFOs), diesel fuels, etc., without needing an IG system fitted or, if fitted, without having to keep the tanks inerted.

However, when cargoes with a flashpoint above 60°C are carried at a cargo temperature higher than their flashpoint less 10°C, e.g. some residual fuel oils, the tanks should be inert because they could become flammable.

If IG systems are fitted the cargo tanks should be inerted where there is a possibility that the headspace atmosphere may become flammable (see section 1.6).

When a non-volatile cargo is carried in a tank that has not been gas freed, the tank should be inert.

11.1.9.3 Additional purging and gas freeing

Gas freeing is required on product carriers more frequently than on crude carriers because of the greater need for tank entry and inspection and for venting the vapours of previous cargoes. On inerted product carriers, purging should be done before gas freeing (see section 11.1.6.10).

Purging is not essential before gas freeing when the hydrocarbon gas content of a tank is below 2% by volume.

11.1.10 Cold weather precautions for Inert Gas systems

An IG system may not work properly in extreme cold weather.

11.1.10.1 Condensation in Inert Gas piping

SOLAS requires that the piping system is designed to prevent accumulation of cargo or water in the pipeline. However, in extreme cold any water in the IG may freeze in the IG main. The system should be operated to minimise residual water and it should be closely monitored.

11.1.10.2 Control air

Air operated control valves, where the control air has a high water vapour content, that are fitted to the IG system outside the engine room may not operate correctly if exposed to extremely low ambient temperatures. Air operated control valves should be exercised/operated regularly to ensure correct operation.

Water separators in control air systems should be drained frequently and the control air dryers should be checked regularly for proper operation.

11.1.10.3 Safety devices

In extremely cold weather, ice may prevent the P/V valves from operating and may block the flame screens on the P/V valves and mast risers.

Water filled P/V breakers should be filled to the appropriate level with anti-freeze liquid.

Deck water seals are fitted with heating coils that should be used before cold weather sets in.

11.1.10.4 Sea chests

To ensure that the water supply to the scrubber and deck seal is maintained in icy conditions at sea or in estuaries, low sea water suctions should be used. This will reduce the probability of ice slurry getting into the sea chest. Steam injection connections to sea chests can be used to help clear sea chests.

11.1.11 Inert Gas system failure

SOLAS requires that each ship fitted with an IG system has detailed instruction manuals covering operations, safety and maintenance requirements and occupational health hazards. The *International Code for Fire Safety Systems (FSS Code)* states, "The manual shall include guidance on procedures to be followed in the event of a fault or failure of the IG system".

11.1.11.1 Action to take should the Inert Gas system fail

If the IG system fails to deliver the required quality and quantity of IG, or to maintain a positive pressure in the cargo tanks and slop tanks, action must be taken immediately to prevent any air going into the tanks. All cargo and/or ballast discharge from inerted tanks must be stopped, the IG deck isolating valve closed, the vent valve between it and the gas pressure regulating valve opened and immediate action taken to repair the IG system.

National and local regulations may require the failure of an IG system to be reported to the harbour authority, terminal operator and to the port and Flag State administrations.

Section 12.8.3.1 gives guidance on special precautions to take if the IG system fails when loading static accumulator oils into inerted cargo tanks.

11.1.11.2 Follow-up action on crude oil tankers

Pyrophoric iron sulphide deposits (pyrophors, see section 1.5.3) may be present in the cargo tanks of crude oil tankers. If a tanker is carrying crude oil, the failed IG system must be repaired and restarted, or another source of IG provided, before discharge from inerted tanks is resumed.

11.1.11.3 Follow-up action on product tankers

Tank coatings usually inhibit the formation of pyrophors in the cargo tanks of product tankers. If it is impracticable to repair the IG system, discharge may be resumed with the written agreement of all interested parties, as long as an external source of IG is provided or detailed procedures are established to ensure the safety. The following precautions should be taken:

- Consult the manual referred to in section 11.1.11.
- Ensure that devices to prevent the passage of flame, or flame screens (as appropriate), are in place and check they are in a satisfactory condition.
- Open the valves on the vent mast risers.
- Permit no free fall of water or slops.
- Introduce no dipping, ullaging, sampling or other equipment into the tank unless essential for the safety of the operation. If it is necessary for such equipment to be introduced into the tank, it should be done after at least 30 minutes after the injection of IG has stopped. See section 11.1.6.8 for static electricity precautions relating to IG, and section 12.8 for static electricity precautions when dipping, ullaging and sampling.
- Ensure that all metal components of any equipment to be introduced into the tank are securely electrically earthed. This restriction should be applied for at least five hours after the injection of IG has stopped.

11.1.12 Emergency Inert Gas supply

SOLAS requires that suitable arrangements are provided to enable the IG system to be connected to an external supply of IG.

These arrangements should consist of a 250mm nominal pipe size bolted flange, isolated from the IG main by a valve and located forward of the Non-Return Valve (NRV). The design of the flange should be compatible with the design of other connections in the ship's cargo piping system.

11.1.13 Inert Gas plant repairs

As IG causes asphyxiation, great care should be taken to avoid the escape of IG into any enclosed or partly enclosed space.

No one should be allowed inside the scrubber or deck water seal until the atmosphere has been tested and an oxygen level of 21% by volume obtained (see chapter 10). While personnel are working inside such spaces the oxygen content of the atmosphere should be continuously monitored and the personnel should be under constant supervision.

Before opening the IG system it should be gas freed and any enclosed space should be ventilated to avoid any risk of oxygen deficiency.

Continuous positive ventilation should be maintained before and during the work.

11.2 Venting systems

11.2.1 General

Venting systems are required to meet SOLAS regulations. Venting systems are necessary for achieving safety on board a tanker and it is essential that they are operated to meet their design requirements and that they are properly maintained.

To ensure hydrocarbon vapours are diluted into the atmosphere clear of the tanker's deck, venting systems allow vapours to be released either at:

- Low velocity high above the deck from a vent riser.
- High velocity from a high velocity valve closer to the deck.

Vents are installed in selected locations to prevent the accumulation of a flammable atmosphere on the tank deck or around any accommodation or engine room housings (see section 2.1.3).

The ship's personnel should be fully trained on the operation and maintenance of the venting system and should be aware of its limitations to prevent over or under pressurisation of tanks (see section 11.2.2).

11.2.2 Tank over pressurisation or under pressurisation

11.2.2.1 General

Over pressurisation of cargo and ballast tanks is caused by compression of the ullage space through the inadequate release of vapour or by overfilling the tank. Under pressurisation can be caused by not allowing IG or air into the tank when liquid is being discharged. The resulting over or under pressure in the tank may result in serious deformation or catastrophic failure of the tank structure and its peripheral bulkheads, which can seriously affect the structural integrity of the ship and could lead to fire, explosion or pollution (see section 11.1.8).

11.2.2.2 Causes of tank over pressurisation

Over pressurisation usually occurs during ballasting, loading or internal transfer of cargo or ballast. It can be caused by one of the following:

- Overfilling the tank with liquid.
- Incorrect setting of the tank's vapour or IG isolating valve to the vapour line or IG line.
- Failure of an isolating valve to the vapour line or IG line.
- Failure of the vent valve or high velocity valve.
- Choked flame trap or screen in a mast riser or vent stack.
- Loading or ballasting the tank to a level greater than its venting capacity (see section 11.3.3.1).
- Ice forming on the vents, freezing of the P/V or high velocity valves or ice on the surface of the ballast (see section 11.1.10.3).
- A restriction in the vapour lines caused by wax, residues or scale.
- Not monitoring the pressure or controlling vent valves during loading.

11.2.2.3 Tank over pressurisation – precautions and corrective actions

The best way to protect against over pressurisation is by following effective procedures:

- A procedure to control the setting of the isolating valves on the vent lines. The procedure should include a method of recording the current position of the isolating valves and a method for preventing them from being incorrectly or casually operated.
- Where isolating valves are fitted to the branch line to each tank, they should be provided with locking arrangements that are under the control of the ship's Responsible Officer.
- A method of recording the status of all valves in the cargo system and preventing them from being incorrectly or casually operated.
- Setting the valves in the correct position and making sure that they remain correctly set.
- Restricting the operation of the valves to authorised personnel only.

Regular maintenance, pre-operational testing and operator awareness of isolating valves, P/V valves or high velocity vents can guard against failure during operation.

To protect over pressurisation through filling tanks too quickly, all ships should have maximum filling rates for each individual tank and these should be available to the ship's personnel (see section 11.3.3). Tank vents should be checked to ensure that they are clear when the operation begins. During freezing weather, they should be inspected regularly throughout the operation.

When over pressurisation of a tank or tanks is suspected, loading or ballasting of the tanks should stop immediately.

11.2.2.4 Tank under pressurisation – causes

The causes of under pressurisation are similar to those of over pressurisation:

- An incorrect setting of the tank's vapour or IG isolating valve to the vapour line or IG line.
- Failure of an isolating valve on the vapour line or IG line.
- Failure to operate the IG fan due to breakdown or other reasons.
- Failure in one of the IG supply valves.
- A choked flame screen on the vapour inlet line.
- Ice forming on the vents of ballast tanks during cold weather.
- Not monitoring and/or controlling vent valves during discharge.

11.2.2.5 Tank under pressurisation – precautions and corrective actions

The precautions to guard against under pressurisation are the same as those relating to over pressurisation (see section 11.2.2.3).

Where under pressurisation of a tank or tanks is suspected, discharge should stop immediately.

To reduce a partial vacuum in tank, the liquid level is raised by pumping into the affected tank, or IG or air is put into the ullage space. However, be careful with the following:

- On a ship with an IG system, it is possible that air leaks may mean the quality of the IG is low.
- Giving IG a high velocity could cause an electrostatic hazard.
- Observe the precautions in section 12.8.3 when measuring and sampling.
- On ships without an IG system where it is not possible to reduce the partial vacuum by raising the liquid level, ensure that the rush of air does not put foreign objects into the tank.

11.3 Cargo and ballast systems

This section describes the pipelines and pumps used for loading and discharging cargo and ballast. For the purpose of this guide, the cargo heating system and COW system are part of the cargo system.

The cargo system is one of the prime areas where a breach of cargo containment may occur and care should be taken not to over pressurise sections of the system or to subject it to shock loads.

Operation of the cargo and ballast systems should only be carried out by personnel who are familiar with the correct operation of the pumps and associated systems, as described in the operation manual.

11.3.1 Operation manual

The ship's crew should have access to up-to-date drawings and information on the cargo and ballast systems as well as an operation manual.

11.3.2 Cargo and ballast system integrity

The cargo and ballast systems are subjected to many conditions that may ultimately lead to a loss of containment. These include:

- Turbulence in the flow, caused by poor pipeline design or excessive flow rates, and abrasion due to solid particulates in the cargo or ballast, can result in local erosion and pitting in the pipelines.
- Main fore and aft pipeline runs are usually located at the bottom of the tanks and on the main deck, where the effects of hogging, sagging and the cyclical motions of a ship in a seaway are most pronounced. These movements may result in damage to pipeline connections and bulkhead penetrations and to local external damage at pipeline supports.
- When handling cargoes that the system has not been designed for, particular care should be taken to prevent damage to cargo valve seals and pump seals that are not suited to aggressive cargoes such as spiked crude oils.
- Corrosion due to rusting when pipe systems are used for both water and oil.

Local corrosion is found where internal coatings have failed and the corrosion is concentrated at a small location. This localised corrosion may be accelerated when water is allowed to lie in the bottom of pipelines, with sulphurous products from cargo or IG, or if electrolytic corrosion cells that are set up when pipeline connections are not securely bonded.

Any latent defect in the cargo system will usually reveal itself when the system is pressurised during the discharge operation. It is good practice to pressure test cargo lines on a periodic basis, depending on the trade of the ship. Although these pressure tests may provide an indication of the system's condition at the time of the test, they should not be considered a substitute for regular external inspection of the pipeline system and periodic internal inspections, particularly at known failure points such as pump discharge bends and stub pipe connections.

Any latent defect in the ballast system will usually reveal itself when the system is being used during the de-ballasting operation. The inability to fully discharge or drain ballast tanks may result in stability problems on double bottom or double hull ships and, in some instances, could result in the ship being in an overloaded condition. Where a single ballast pump is fitted, company procedures should address use of alternative means of ballasting/de-ballasting.

11.3.3 Loading rates

Masters should be provided with information on maximum loading rates for each cargo and ballast tank and, where tanks have a combined venting system, for each group of cargo or ballast tanks. This will ensure that tanks are not over or under pressurised by exceeding the capacity of the venting system, including any installed secondary venting arrangements.

Other considerations will also need to be taken into account when determining maximum loading rates for oil tankers. Precautions against static electricity hazards and pipeline erosion are in section 11.3.3.2.

11.3.3.1 Venting arrangements

Venting capacity is based on the maximum volume of cargo entering a tank, plus a 25% margin for gas evolution (vapour growth).

When loading cargoes with a very high vapour pressure, gas evolution may be excessive and the allowance of 25% may not be enough. To ensure the capacity of the venting system is not exceeded, closely monitor the vapour line pressures on inerted ships and limit loading rates on non-inerted ships. The vapour growth increases when the liquid levels in the tank are above 80%. On inerted ships IG system pressures should be closely monitored, particularly when topping-off during loading operations or when starting COW during discharge operations.

When calculating loading rates a maximum venting line velocity of 36m/sec should be considered. This flow rate should be calculated for each diameter of line used. The volume throughputs may be aggregated where a common vent riser is used, but the maximum flow rate should not be exceeded anywhere within the system.

11.3.3.2 Flow rates in loading lines

Depending on the trade of the tanker, different loading rates need to be determined for each cargo tank. These loading rates depend on the maximum flow rates in the cargo lines for different products and loading operations. In general, the following flow rates may need to be calculated for each section of the cargo system:

- A loading rate based on a linear velocity of 1m/sec at the tank inlet for the initial loading of static accumulator cargoes into non-inerted tanks.
- A loading rate based on a linear velocity of 7m/sec for bulk loading of static accumulator cargoes into non-inerted tanks.
- A loading rate based on a linear velocity of 12m/sec for loading non-static accumulator cargoes and for loading static accumulator cargoes into inerted tanks. This velocity is for guidance only and is generally considered as a rate above which pipeline erosion may occur at pipe joints and bends.

When a number of tanks are loaded through a common manifold, the maximum loading rate may be determined by the flow rate through the manifold or drop lines. For this reason, it is important that a constant check is kept on the number of cargo tank valves that are open at once and that a proper loading rate is determined for the loading operation.

Offshore floating hoses that meet OCIMF guidelines (see bibliography) and have a nominal diameter of less than 400mm are suitable for continuous operation at a flow velocity of 21m/sec. Offshore floating hoses with a diameter greater than 400mm are suitable for continuous operations at a flow velocity of 15m/sec. However, the maximum loading rate may be controlled by the size of the ship's loading line inboard of where the hose is connected.

11.3.3.3 Rate of rise of liquid in the cargo tank

Small tanks, such as slop tanks, may have larger filling or suction valves than their size would normally require in order to accommodate certain operations, such as recirculatory COW from slop tanks. In such instances, the limiting factors of the venting flow rate and the liquid line flow rate may not be suitable for assessing maximum loading rates. It is then also necessary to consider the rate of rise of the liquid in the tank if over-filling is to be avoided.

To exercise control over the rate of liquid rise in any cargo tank, it may be appropriate for the tanker to set the loading rate to limit the rate of rise of liquid in a cargo tank.

11.3.3.4 Loading rates for ballast tanks

Loading rates for ballast tanks should be determined in the same way as cargo tanks, considering the size of vent outlets using a velocity of 36m/sec. Liquid filling rates can be calculated using a pipeline flow rate of 12m/sec and are subject to a similar rate of rise as in section 11.3.3.3.

11.3.4 Monitoring of void and ballast spaces

Void and ballast spaces in the vicinity of the cargo tank deck should be regularly monitored for leaks from adjacent tanks. Monitoring should include regular atmosphere checks for hydrocarbon content and regular sounding/ullaging of the empty spaces (see also chapter 12).

11.4 Power and propulsion systems

While a tanker is berthed at a terminal, its boilers, main engines, steering machinery and other equipment essential for manoeuvring should normally be kept in a condition that will permit the ship to be moved away from the berth in the event of an emergency. See section 21.7.1.1 for advice on planned immobilisation.

A terminal may allow some degree of immobilisation of the propulsion plant while the ship is alongside. However, the tanker should obtain permission from the Terminal Representative or the local authority pre-arrival before taking any action affecting the readiness of the ship to move under its own power.

The terminal should always be notified of any unexpected event that affects operations and their safety.

11.5 Vapour recovery systems

Vapour recovery systems fall into two categories:

- Those systems conforming to IMO guidelines that provide a system for returning cargo vapours to the shore for reclaiming or incinerating. These are known as VECSs (see section 23.7.7).
- Proprietary systems for recovering petroleum liquid or vapour that would otherwise be vented during the loading operation or during the loaded passage. These are known as vapour recovery systems.

Personnel who operate VECSs and vapour recovery systems should be fully trained to use them.

11.6 Volatile Organic Compound recovery systems

During loading, Volatile Organic Compounds (VOCs) are normally vented to the atmosphere unless a VOC recovery system is used to recover them. A VOC recovery system may be based on active or passive technology – see figure 11.1.

VOCs are mixtures of light hydrocarbons, such as methane, ethane, propane and butane, that evaporate within the range of normal atmospheric conditions. VOCs are generated when cargo flashes. The flash produces vapour due to depressurisation in the piping system from the source to the cargo tank and from evaporation from the oil surface inside the cargo oil tanks during and after loading. The level of evaporation depends on the volatility of the cargo loaded. See section 1.1.

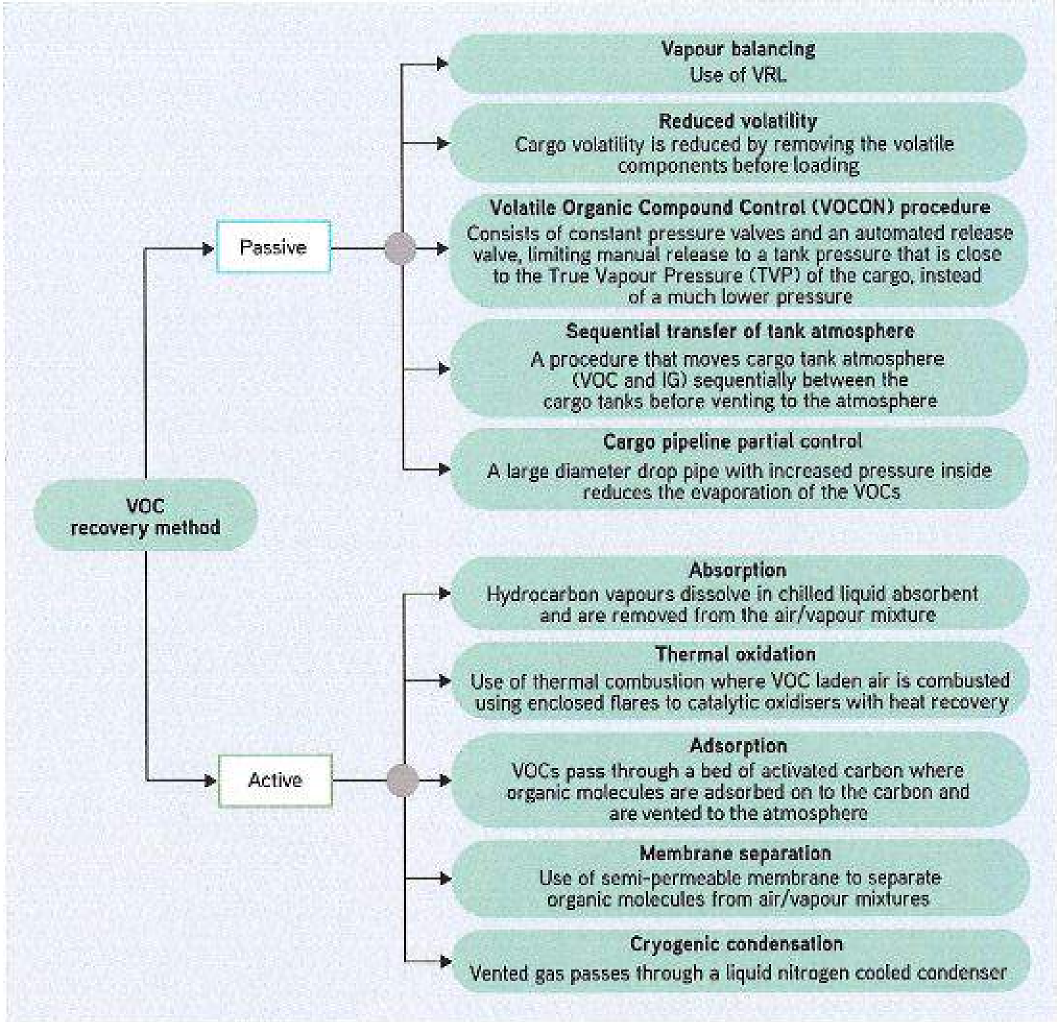

Figure 11.1: Examples of passive and active VOC recovery methods

11.7 Stern loading and discharging arrangements

Using a stern manifold for cargo transfer operations introduces additional hazards and operational concerns. Procedures should address the following:

- The requirement to monitor the stern manifold and the cargo tank deck area at the same time.
- The dangerous area extending at least three metres from the manifold valve should be clearly marked. No unauthorised personnel should be allowed in this area during the entire cargo operation.
- Additional trip hazards from working in a mooring area.
- Spill containment arrangements on the aft deck area.
- Provision of drip trays beneath the stern manifold.
- Elimination of potential sources of ignition from accommodation openings and electrical fittings. Air inlets and doors to enclosed spaces should be kept closed.
- Connection and disconnection of hoses where no lifting gear is available.
- Firefighting equipment should be laid out and ready for use close to the stern manifold.
- Continuous watch by a responsible crew member at the stern throughout the cargo operation.

(See sections 12.1.6.9, 12.1.13.9 and OCIMF's *Guidelines for Offshore Tanker Operations*.)