Storage Tanks

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Sarajevo 2023

Chapter 12 Contents

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Introduction

Crude oil tanks are usually used in the oil fields as intermediate storage tanks for the produced treated clean oil. These tanks are installed upstream of the main booster pump station. They serve as feeder tanks prior to transferring the clean oil by the main oil trunk lines to the farm tanks for sales. Also they are used for crude oil storage at the shipment terminal farm tanks.

Generally, storage tanks have walls with suitable thickness. They are high to eliminate oil spill / fire spreading out as a safety precaution measure in case of a tank burst, oil leakage or fire in the tank. In addition, storage tanks are connected to the plant fire fighting system, so that suitable action can be made in the event of fire in a tank.

12.1 Types of Storage Tanks

There are two common designs:

1- The fixed roof tanks.
2- Floating roof tanks.

12.1.1 The Fixed Roof Tanks

1- They store crude oil near atmospheric pressure (Figure 12.1).

2- The entering oil strikes an expanding plate to assist separation of any remaining gas, which then goes to the low-pressure flare.

3- Oil level is detected by a float inside a guide tube and transmitted to the control room. The level is also checked periodically by dipping.

4- The fire foam inlet is sealed by a thin sheet of glass, which prevents gas escaping, and will shatter if foam arrives behind it.

A major problem experienced with fixed roof tanks is the variation of internal pressure due to temperature changes causing expansion or contraction of the tank contents.

The tank may be subjected to either pressure or vacuum. This is prevented by using a combined pressure / vacuum relief valve installed in the roof as shown in Figure 12.1.

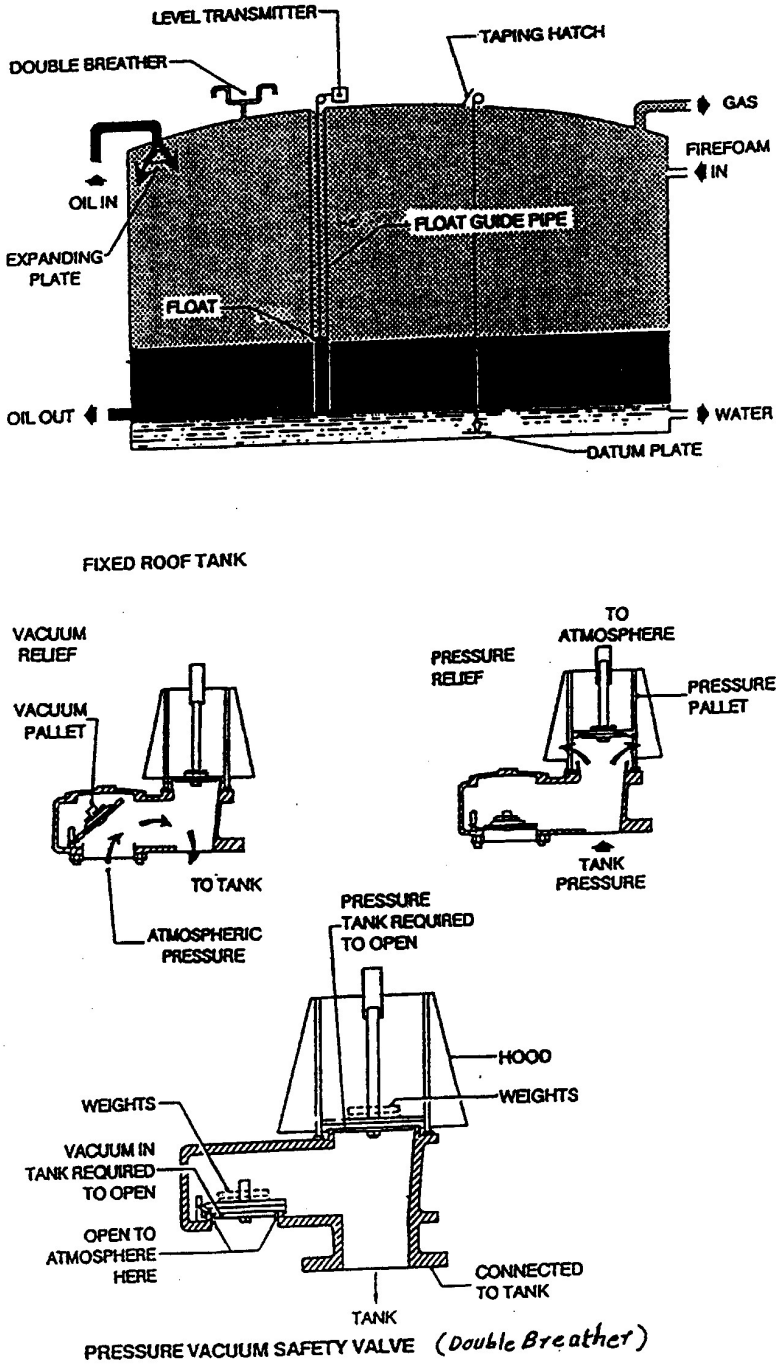

Figure 12.1 Fixed Roof Tank and Accessories

If the tank contents can evaporate under atmospheric conditions, a nitrogen blanket is maintained over the liquid surface. If the liquid does evaporate, the tank will vent nitrogen (gas). Therefore, cooling of crude oil occurs and contraction of the oil takes place. Air will be drawn into the tank but the nitrogen blanket will form a barrier between air and the hydrocarbon thus reducing the fire hazard.

Tanks are equipped with inlet and outlet valves, a level gage, a double breather and a drainage outlet.

Pressure / Vacuum Safety Valve (Double Breather)

The double breather valve shown in Figure 6.1 is specially calibrated to bleed off into the atmosphere when the internal pressure exceeds 20 mm of water. It sucks in air from the atmosphere when a vacuum of 10 mm of water is created inside.

12.1.2 The Floating Roof Tanks

These tanks are so called because the roof floats on the liquid and eliminates the vapour space above the liquid. This allows for storage of higher vapour pressure products such as gasoline, naphtha, etc.

There are two types, the pontoon roof and the hard top pan roof tanks. This type of tanks is extensively used because it reduces costly evaporation losses from tanks.

12.1.2.1 The Pontoon Roof Tanks

The floating roof has an annular ring of pontoon (Figure 12.2) surrounding a single deck centre. The rim of the roof is sealed using shoes held against the sides by weights or springs as shown in Figure 12.3.

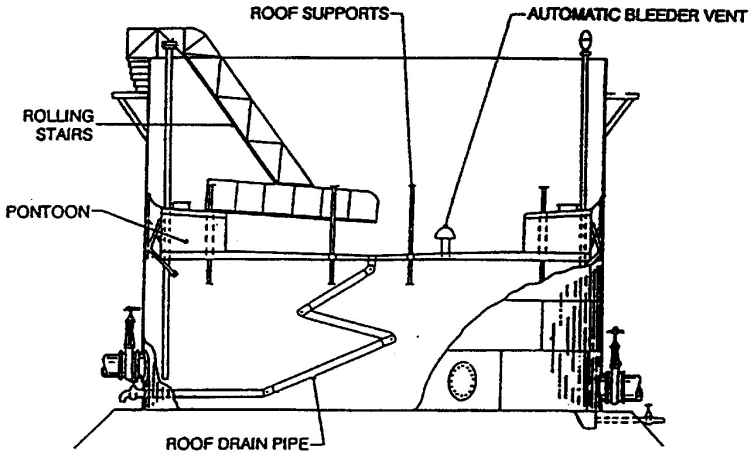

Figure 12.2 Pontoon roof tank

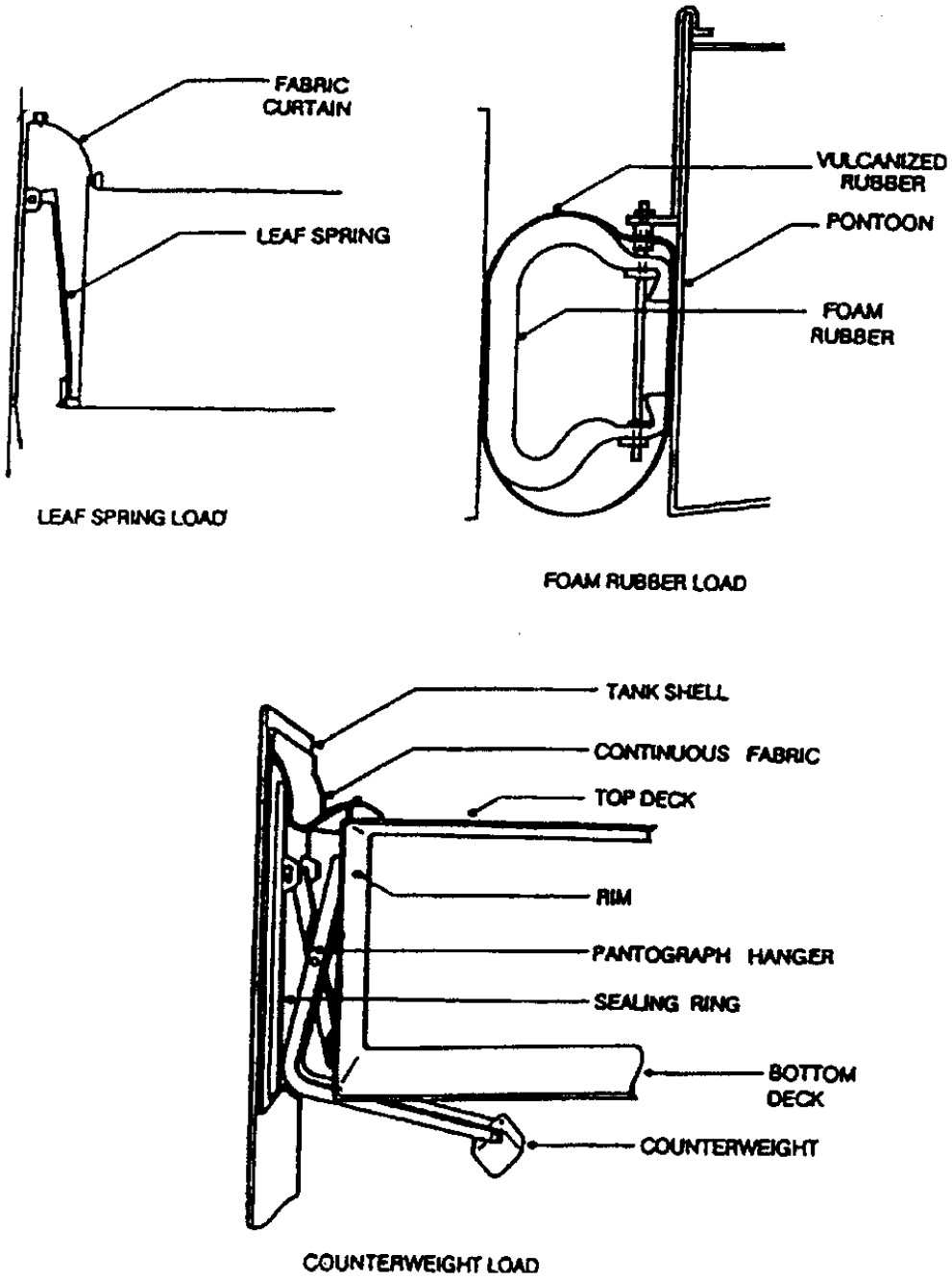

Figure 12.3 Floating Roof Tank Sealing Method

12.1.2.2 The Hard Top Pan Roof Tanks

This type of floating roof shown in Figure 12.4 has all the advantages of the pontoon roof for vapour conservation and better safety against fire. In addition, it has a fixed cone roof, which protects the floating roof elements. The floating roof has no need for roof water drainage. The cost of this type of tanks is generally less where the tank size does not exceed 100 feet in diameter.

The floating roof rests on the liquid and has the form of an inverted shallow pan of single thickness steel. The roof contacts the liquid over its entire surface. Hard top pan roof has automatic vents. Figure 12.4 shows an illustration of a typical hard top pan floating roof sealing method.

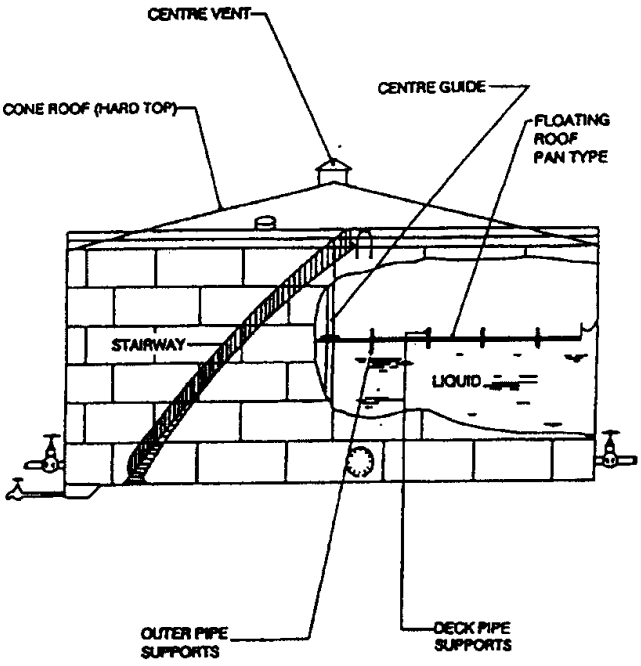

Figure 12.4 Hard Top Pan Floating Tank

12.2 Maintenance of Storage Tanks

12.2.1 Cleaning

Steel tanks should be kept clean and free from spilled oil or other materials. They should be painted to minimize corrosion. All water and accumulated dirt should be removed from the bottom edge of the tanks.

12.2.2 Maintenance

If leaks occur, they have to be repaired temporarily. The leaks should be repaired permanently as soon as possible. Maintenance and inspection of tanks must cover the following on a regular basis:

1- Tank basin and access ways.
2- Tank foundations.
3- Earthing system.
4- Bottom.
5- Shell.
6- Roof.
7- Ladders and gangways.
8- Fire fighting system.
9- Instruments.

The maintenance includes inspection before and after cleaning, suggested repairs, effected repairs and inspection after effected repairs of any or all of the above items.

On the following pages, more details about the tank maintenance and the required safety precaution in different cases.

12.3 Tank Maintenance

Tanks require maintenance, both internally and externally. This includes preventive measures to fight tank corrosion and pipeline connections, accessories, and access ladders and walkways. It also includes repair.

12.3.1 External Maintenance of Tanks

External maintenance consists of the regular inspection and renewal of the protective coating of the tank shells and the proper functioning of the cathodic

protection system. The purpose of cathodic protection of tanks is to supplement bottom exterior coatings by the metal at possible coating voids.

Protective coating is usually formed by one or more layers of paint.
Depending on the type of paint used, however, painting will only extend the service life of the tank when it has a perfect bond to the metal. Therefore to be sure of proper application it is important to follow the instructions of the paint supplier.

In addition to corrosion protection the painting of a tank has a further advantage: white or other light paints reflect heat and stabilize the internal temperature of the tank.

It is difficult to specify how often a tank should be repainted, because the climate is the principal factor in this decision. Humid, salt-bearing air near the coast can make it necessary to repaint as often as every three years, while under favorable conditions, paint coats may last for ten or even fifteen years.

As a rule, a tank should be painted as often as necessary to provide reasonable protection for the tank and its contents.

12.3.1.1 Application of Paint

1- Before any paint is applied, the surface of the plates should be cleaned of scale, rust, dirt, oil, grease and weathered paint to ensure a good bond to the metal. This is done by grit-blasting(sand – blasting), because this method is fast and comparatively safe. There are some points that require attention while grit-blasting;

   a. The grit should be clean and dry and the grit should be of equal size

   b. The compressed air must be as dry as possible. Moist air will result in rapid rusting of the freshly prepared surface. For the same reason grit-blasting (sand – blasting) should not be done during rainy or foggy weather, or when dew is present on the surface.

The presence of scale on the surface increases the time required to obtain bare metal, because of its hardness. Thus it may be advisable to allow the scale to drop off the metal surface by exposure to air for some time.

2- After grit-blasting, dust must be removed from all surfaces, and the plates must be primed as soon as possible to prevent moisture and dirt in the air Settling on the surface. Instead of immediate priming of the surface, a coat of a Positing solution may be applied. This solution provides a good

foundation for all types of primers, and the application of primers may be delayed for as long as 24 hours.

3- Other methods of preparing for painting are:

   a. Wire brushing, either by hand or using pneumatic bushes.

   b. Scraping with special knives or scrapers.

   c. Chipping with hand hammers or pneumatic tools.

   d. Grinding with specially developed surface grinders.

4- Spark resistant tools must be used in explosive areas. Previously painted Surfaces also require some treatment before application of another layer. The Old Paint must be free from oil, grease, dirt, dust, foreign substances and flaking paint. This can be achieved by the use of suitable cleaning fluids, Steam cleaning, high pressure water jets or wire brushing.

5- Optimum conditions require the application of a full coat of priming paint on the prepared surface, followed by a full coat of finish paint. Paint can be applied by brush, roller, airspray or airless spray, in accordance with the manufacturers' recommendations.

Unless explosion proof, power driven spraying **equipment** must NOT be used in explosive areas

12.3.2 Internal Maintenance of Tank

1- Internal maintenance of tanks is mainly concerned with corrosion combat.

2- Internal corrosion occurs on tank bottoms and in the vapour space above the liquid. In this respect sour crudes present a much more serious problem than sweet crudes or refined products.

3- Steel which is wetted frequently by oil is unlikely to corrode quickly. Therefore, vapour zone problems in floating-roof tanks are confined to the small area under the fabric seal.

4- Iron sulphide scale and brine in the basic sediment and water layers can cause serious internal corrosion on tank bottoms. When combined with corrosion products dropping from the tank roof, basic sediment and water can quickly eat away tank bottoms unless protection is provided.

5- Although different coatings are used, preparation of the surface in the vapour zone and on tank bottoms is of utmost importance.

6- In both cases, long life of the coating is directly dependent on the surface preparation. The area to be coated should be free of scale and other foreign materials and completely dry. Sand-blasting is the most common method of cleaning the surfaces. For the most part, these coatings are coal tar paints or enamels with melting temperatures above 60° C (140° F). Proper primers must be used before the application of any type of coating and the primers should be applied within a limited time after the sand-blasting is completed. If rust forms or dirt collects on the steel before the primer is applied, the surface should be re-sand blasted or cleaned.

7- Bottom coatings are usually relatively thick in order to provide maximum protection. Glass reinforcing may be applied between coats. Most bottom coal tar coatings are applied by pouring, rather than by any other method.

   Bottom coatings may extend from 30 cm (1 ft) to 1 m (3 ft) up the interior shell surface and up any roof supports. It is preferable to have the bottom coating applied under roof supports as well as around them. Vapour zone coatings also require a clean, dry surface for proper adherence. Appropriate primers must be used and are specified by the individual paint company.
   Plastics as well as coal tar are used for vapour zone coating.

8- Vapour from oil contains hydrogen (more in sour crude, less in sweet crude) which combines with the iron of the tank roof to form iron sulphide and to free hydrogen. As iron sulphide scale accumulates, galvanic action begins between the scale and the deck material. Flexing of the roof causes pieces of the iron sulphide to break loose. On the tank bottom galvanic action again takes place between the scale and the bottom, often resulting in deep pitting and leaks.

12.3.2.1 Emptying and Blanking off the Tanks

1- Before any work is done which might release vapours, all sources of ignition should be eliminated from the area where flammable vapour may be present or may travel.

2- Roads should be closed and signs posted to keep vehicles and other potential sources of ignition away form the area. Particular attention should be paid to the wind direction in defining the extent of the hazard.

3- Normally, the operations department can be expected to have carried out any initial cleaning steps, such as hot gas oil circulation or treatment with chemicals. Furthermore, the operations department should also empty the

tank to as low a level as possible using the normal system, prior to handing over the tank for cleaning.

4- Further product removal can then be achieved by either connecting a hose to the drain valve and pumping the bottoms to a slops tank, or by raising the oil level by pumping water into the tank and removing the oils through the normal suction line work. The use of water is particularly valuable if the tank is tilting or has an uneven bottom.

5- If water is used with certain products, such as motor gasoline containing an anti-icing additive, aviation fuels or other products with a critical water specification, such products should always be pumped to slops and not to the finished product tanks.

6- The presence of sediment or sludge may greatly hinder liquid removal. This is normally recognized in the initial stages and hot gas -oil or certain chemicals may be used to counter this, but nothing further should be done until the tank is opened after the gas-freeing step.

7- Next, all lines to and from the tank should be cleared and flushed with water or drained.

8- In the water flushing/pumping operations described above, care should be taken to restrict the flow of slops as well as water, to a velocity of I metre per second, in order to avoid static electricity hazards.

9- Swing arms, mixing spiders, and any other internal pipework should be washed through, after which the last remnants of product can be pumped away. At this stage some liquid may be held up in the legs of floating roof tanks because of plugged drain holes. This should be borne in mind later on in the tank cleaning operation, and legs should be checked and emptied if necessary when personnel first enter the tank. Permanent foam connections should also be checked for hydrocarbon content which may result from a burst seal.

10- After the completion of flushing, tank-side valves should then be closed, caution tabs attached to them, and the lines isolated either by disconnecting or blanking. Foam and drain lines are exceptions, and may remain in service until gas-freeing has been carried out.

11- After isolation has been completed, the tank will contain water with a thin film of product on its surface. This remaining liquid should then be drained off until traces of product appear; the remnants either being removed by vacuum truck, pumped by hand into barrels, or allowed to pass into the petroleum interceptor for skimming off.

12- Provisions should also be made for the disposal of sediment and for its removal from the tank compound. Burying of the sediment within the tank compound is not recommended because of possible contamination of groundwater and in the general interests of good housekeeping. If however, the amount of sediment is small, and is not pyrophoric, consideration can be given to disposal within the compound. When the expected amount of sediment is great, consideration may be given to building ramps over bund/fire walls, or using large containers that can be handled by a crane.

12.3.2.2 Gas Freeing

1- Before allowing people without suitable respiratory protection to enter a tank, the tank should be freed from flammable / toxic vapours, and the oxygen level raised to more than 20% v. Gas-freeing is usually done by either natural ventilation, mechanical ventilation, or, in certain cases, by steam. Figure 6.5 shows air ventilation arrangements. To a much lesser degree, inert gas and water displacement methods are used. Raising the oxygen level can of course only be achieved by either natural or forced ventilation.

2- Pure oxygen should never be used for ventilation because it enhances the explosion hazard.

3- If pyrophoric iron sulphide is present, special precautions are necessary during gas-freeing as the introduction of air may cause the deposits to ignite.

12.3.2.3 Tank Cleaning

1- Tank cleaning is usually done with the aid of portable machines. Some tanks that require frequent cleaning may be fitted with fixed cleaning guns. These guns clean the tanks with a rotating high pressure water jet. The water jet rotates in such a way that all pans of the tank are reached. The impact of the water jet loosens all adherent oil and dirt.

2- Oil or chemicals may be used for jetting instead of water. The accumulated oil and water mixture is removed from the tank bottom together with a large part of the basic sediment and water by pumping. The remaining basic sediment and water has to be removed by hand and for this purpose some tanks have a special removable plate in the lower course of the shell plates.

3- After the tank or vessel has been emptied (as far as possible), certified as gas-free and the work permit has been issued, cleaners are allowed to enter that tank and commence work.

4- There are various cleaning methods possible, and a selection or combination of methods may be made depending on each particular case. In most instances, the use of water is widely applicable, and this is used in conjunction with pumps and nozzles, some with hand-held hoses, and others through fixed jets. If the tank cannot be maintained gas-free, (e.g. it still contains a large quantity of sludge), cleaning jets are used.

12.3.2.4 Cleaning of Fixed-Roof Tanks

Cleaning with hand-held fire-hoses and high capacity fixed tank cleaning equipment is unsafe if the tank contains crude, gas oil, or lighter fractions.

This is because high electrostatic space charges may be created by water getting into the product remnants which could lead to incendiary discharges.

Electrostatic charges are high only if oil is present in the mist created by the jet. Hoses therefore may only be used if there are definitely no pools of oil present in the tank. This may be difficult to ensure if large quantities of sludge are present. However by filling the bottom of the tank with water, it may effectively float off any oil present.

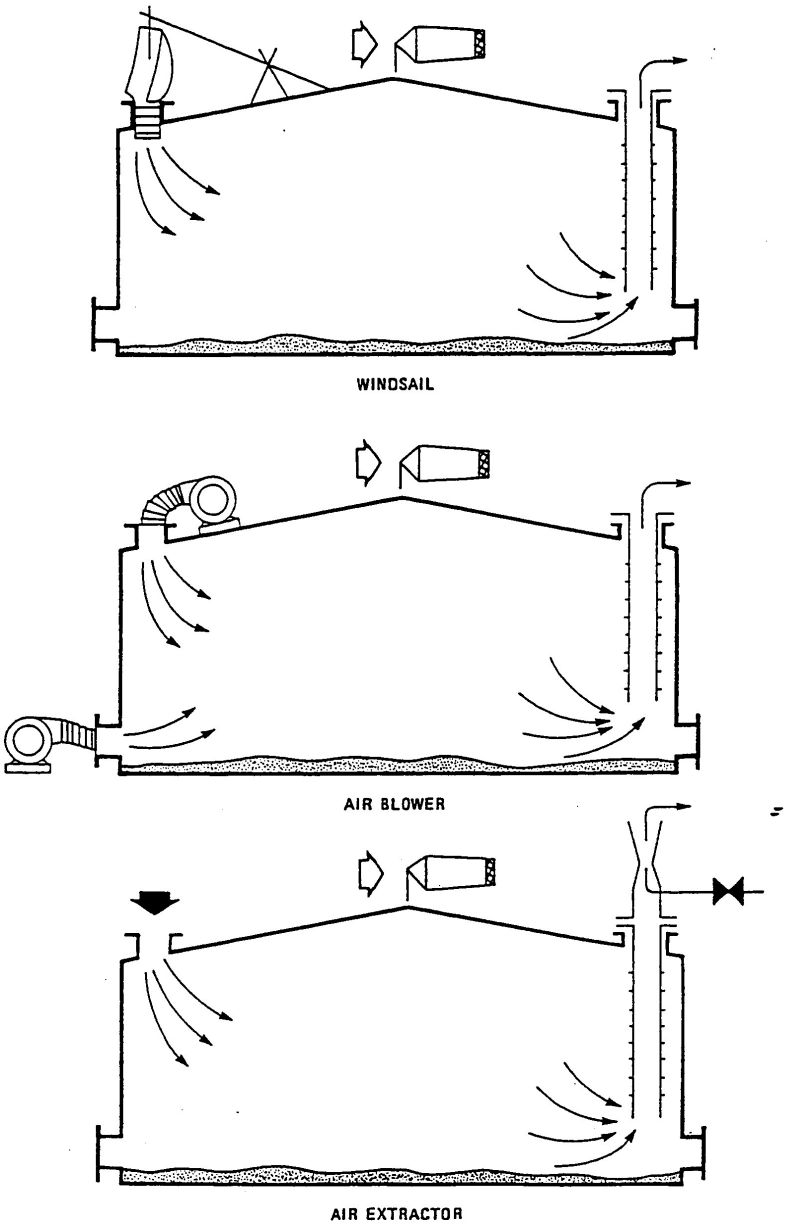

Figure 12.5 Air Ventilation of Tanks

12.3.2.5 Cleaning of Floating-Roof Tanks

1- Cleaning with hand-held fire-hoses and high capacity fixed tank cleaning equipment is safe, provided the roof is settled on its legs, and the leg settings do not exceed 2 metres. The flat pancake shape of the vapour space does not allow space charges to build up to dangerous voltage levels.

2- If the bottom sediment can no longer be pumped, gas oil or any other suitable light oil may be used to make the bottoms less viscous. This can be done by installing a pump (not combustion engine drive) in the tank pit, connecting the suction to a source of light oil, (e.g. a road tanker), and discharging via a rubber hose through a tank manhole**. (Note:** if the tank is not gas-free, any circulation of the oil should follow the rules given previously).

3- When the washing oil becomes fairly viscous, the oil is pumped out via the drain, or via the suction hose of a second pump, (not combustion engine driven) and the process is repeated until further cleaning in this way is no longer effective.

   At this stage, all leg drain holes of floating roof tanks must be checked and cleared if necessary. In addition, if the tank contains heating coils, they should be checked for product in the heating coils and cleared if necessary.

4- If pyrophoric iron is present, the internal surface of the tank should be kept wet to prevent spontaneous ignition.

5- In some cases, large quantities of sludge often remain which defy removal by methods other than manual, and the above process may well be limited in its effect. In practice two possibilities remain, either manual removal, or the use of water hoses from tank manholes which will, break down the sludge further for removal by vacuum truck or sludge pump. Manual removal requires cleaners wearing air-supplied breathing apparatus and equipped with wooden tools, squeegees etc. However, water jetting in a fixed-roof tank can be unsafe because of the following two factors:

   a. The tank vapour space can re-enter the explosive range as a consequence of sludge disturbance;

   b. Pools of liquid hydrocarbons may still be present, and create charged mists capable of causing an incendiary spark.

6- The potential hazards should always be evaluated for each specific case by an experienced operator. The decision to proceed either manually or with water jets can therefore only be taken as a result of a local assessment.

7- If complete oil removal is difficult, do not start to use water hoses until the tank is pronounced gas-free. There should be continuous forced ventilation while jetting, preferably using an air-extractor on a roof manhole with a flexible trunk extending to the bottom part of the tank. The forced ventilation may prevent explosive levels being reached, but vapour concentrations must be continuously monitored at several different places. If vapour concentrations rise to 10% LEL, jetting must stop until the atmosphere is again gas-free.

8- If forced ventilation is difficult, ensure that no pools of oil are present. This may be achieved by flooding the bottom of the tank with water, and pumping away the surface oil to slops. Provided no pools of oil are present, the mist formed by jetting is unlikely to create an explosion hazard.

9- Close attention must be paid to the appearance of the tank floor, and jetting stopped if oil pools re-form. Continuous checking of the tank vapour space is still a necessary safety measure, and work must stop if vapour concentrations rise to 10% LEL.

10- Finally the cleaners should enter the tank, wearing air supplied breathing apparatus, and using wooden tools, push the remaining sludge to the drain, pump suction, or tank manhole. Ventilation should continue during this period and frequent gas tests taken. If the concentration exceeds 10% LEL, consideration should be given to stopping the work because higher concentrations may be present elsewhere in the tank. In any case personnel should leave the tank if the concentration approaches 50% LEL.

    Because of the difficulties in measuring vapour concentrations in such a large space, the levels recommended above should be interpreted with caution. In practice, any sign of gas should be considered a hazard and the source investigated.

11- Heating coils, roof supports and other internals should then be cleaned by hosing with gas oil.

12- The next step is further cleaning of tank walls, bottom and internals with water jets. The washing is usually done with a 10 bar water stream. Because of static hazards, this procedure may be unsafe if there is a possibility of vapour release creating an explosive atmosphere as a result

of disturbing any remaining sludge. Special care is therefore still required at this stage to ensure that the tank vapour concentration is checked and kept gas-free. The scale or sediment will contain a high proportion of rust, and will have to be collected and removed.

This is usually done manually after the water has been discharged into the drainage system. Care should be taken that any pyrophoric iron is keptavet during removal.

13- Where vacuum trucks are available for general cleaning duties such as cleaning small tanks, oil-catchers, oil-sewers, etc., such vehicles can also be used for sludge removal from a tank. The advantage of this method is that the sludge is transferred directly from the tank into a transport medium, so that double handling is avoided. The relatively small capacity of the vacuum tank however, (typically $6m^3$), makes it unsuitable for cleaning jobs where large amounts of sediment have to be removed.

12.4 Hazardous Conditions and Safety Procedures

There are several causes of accidents which occur during tank inspection and cleaning:

1- Prominent among them are explosions due to the inadvertent ignition of an explosive air-vapour mixture within the tank. Conditions for creating explosive air-vapour mixtures in the vapour space of tanks storing petroleum products are seldom present under operational conditions. This is due to the fact that the upper and lower explosive limits for mixtures of hydrocarbons lie close to each other, approximately between 1 % and 10% for normal petroleum products. Tables are available giving the explosive limits and other combustion data for a range of compounds. It should be noted that the upper explosive limits of the lighter hydrocarbons are somewhat higher than those of the heavier products.

2- A hazardous condition may also occur outside a tank, due to gases expelled during ventilation. When a tank, vessel, or confined space, which has contained a volatile hydrocarbon, is being ventilated, e.g. prior to cleaning or repair, the large volume of vapourlair mixture which is released may travel beyond the limits of the usual safe distances. Continuous checks should therefore be made on wind direction and speed, and volume of discharge.

12.4.1 Explosive Air-Vapour Mixtures

In general, the vapour spaces of both crude and light product tanks will contain air-vapour mixtures which lie above the upper explosive limit. Only during the filling of an entirely empty tank is it certain that an explosive mixture will be present during a short period.

Explosive mixtures may also sometimes occur in fixed-roof tanks when emptying, due to the ingress of air into the vapour space. This also applies to floating-roof tanks when the roof is allowed to settle on to its legs.

Other products, such as gasoline and kerosene, can give rise to hazardous atmospheres under normal storage conditions, and, in a few cases, even heavy products may be considered hazardous, particularly if they are stored at temperatures above their flash points. In general, oil products are hazardous when the vapour pressure lies between 0.1 and 1.3 psi at storage temperature.

From this it can be seen that there is little danger of gas oil, diesel oils and fuel oils forming explosive mixtures under normal conditions. Nevertheless the procedure of gas testing, isolation of lines, and the issuing of gas-free and entry permits must be carried out.

Although crude oil and light product tanks will not contain explosive air-vapour mixtures under normal working conditions, the situation is quite different when such tanks have to be cleaned. Gas-freeing by ventilation will bring the air-vapour mixture in the tank through the explosive range and eventually below the lower explosive limit.

However, as long as traces of liquids remain in the tank, it is quite possible that, as a result of gradual evaporation, or of vapours being freed by the cleaning measures, the explosive zone is re-entered. This is one of the greatest dangers of tank cleaning, and frequent use of the combustible gas detector (explosimeter), is therefore essential. In order to reduce the risk of vapour concentrations rising to dangerous levels, good ventilation should be maintained at all times while men are working inside the tank.

12.4.2 Ignition Sources

In addition to the presence of an explosive mixture, a second condition is necessary for an explosion or fire; that is, a source of ignition in the vapour space. Sources of ignition are:

1. Static electricity.
2. Pyrophoric (self ignition) iron sulphide.
3. Sparks by metal-on-metal impact.
4. Use of electrical equipment.
5. Unsafe procedures, such as smoking in tanks.

12.4.2.1 Static Electricity

Static electricity is generated when any material moves relative to a different material. Generation of static charges occur in such operations as the filtering or agitating of liquids, or in vapour mists in which droplets of different sizes lead to the generation of space charges. This latter aspect is of particular importance in tank cleaning, when jets are often used to spray water or other fluids in the tank. These jets can create highly charged mists when rebounding off an oily internal tank surface. Once a space charge has been established, it is then possible that a dislodged piece of scale or even a slug of liquid from the jet, can act as an insulated conductor and pick-up charge whilst falling / travelling through the mist. When the charged object approaches an internal tank surface an incendiary spark is possible. In a non-gas-free tank an explosion may result.

All liquids in motion are capable of generating electrostatic charges. Under certain conditions, non-conducting liquids, for example hydrocarbons, may accumulate high static charges. Therefore, all equipment used in gas-freeing, cleaning and repairing work must be efficiently bonded and earthed. This also applies to the lines and hoses used for removing tank residues and mechanical ventilation exhausters, steam nozzles, jetting equipment and CO_2 inserting lines.

Steam is sometimes used for gas-freeing and cleaning of tanks, particularly the smaller sizes. Steaming is considered safe providing the steam is dry at the point of entry into the tank or vessel. Wet steam can give rise to high electrostatic space charges. Also, wet steam lines may contain slugs causing an incendiary spark, as described above. If this happens in the initial steaming period, before the steam has inerted the tank vapour space, an explosion may occur. Because of the location of some tank farms it is often difficult to ensure that it remains dry unless some form of superheating is employed and checks of steam quality are made in the vicinity of the tank being cleaned.

If superheated steam is used, care must be taken to ensure that the steam temperature does not exceed the auto-ignition temperatures in the region of 200° C.

The actual size and shape of the tank plays an important part in the level of charge that can be reached in the vapour space due to the effect of cleaning jets. For floating roof tanks, with the roof standing on its legs, the flat pancake shape of the vapour space does not allow the generation of dangerously high space charges with normal cleaning equipment. The different geometry of fixed-roof tanks, however, may lead to space charges high enough to create incendiary sparks, which is hazardous. The tank and equipment must be efficiently bonded and earthed, even if the space charges are considered to be at a safe level.

The use of cathodic protection for tanks, vessels or pipelines may be a source of danger. To prevent sparks on the bridging of insulating flanges or contact with earthed equipment, the power supply to any tank or pipeline which is cathodically protected should always be disconnected by an authorized person before any work is permitted. In order to allow time for depolarization, this should be done at least 24 hours before any work is commenced. The tank, vessel or pipeline should then be bonded to earth before the work is commenced.

12.4.2.2 Pyrophoric Iron Sulphide

Pyrophoric iron sulphide is formed by a chemical reaction between a sulphur compound, such as H_2S, and iron oxide (for example on the steel of a tank's inner surface), in an atmosphere virtually free of oxygen. This product remains innocuous so long as it does not dry out.

A hazard associated with pyrophoric iron sulphide may arise when the tank has been used for a continuous period in storing sour crude or some gasolines. When scale from such a tank is permitted to dry out, oxygen in the air may cause the scale to ignite spontaneously. This source of ignition can be controlled by dissipating the heat to prevent a temperature rise until the atmosphere in the tank is below the flammable range. This may be accomplished by wetting all interior surfaces with water or steam. The wetting also tends to isolate these pyrophoric deposits from oxygen present during ventilation.

While steam may be used to wet pyrophoric deposits it must be either dry or superheated at the point of entry into the tank. For large tanks, steam supply is often inadequate, and water has to be used to wet pyrophoric deposits. In non-gas-free fixed-roof tanks, water jets are dangerous and should not be used for this purpose. However, wetting can be safely achieved by filling the tank with water and using fog nozzles.

12.4.2.3 Spark Formation By Striking of Metal Objects

Great care is required when handling equipment on tank roofs or when removing manholes from non-gas-free tanks. In order to prevent the occurrence of incendiary sparks should articles be accidentally dropped, damp sacks should be placed on the roof and immediately below shell manholes. These sacks should be kept continuously dampened during the work and removed immediately on completion.

Light metal (e.g. aluminium, magnesium) are particularly dangerous in this respect because they can produce high energy sparks on impact with other metals or concrete. In view of this, it is recommended that aluminium water jet nozzles, hose connections, etc. should not be used in flammable atmospheres. Furthermore, the casing and connecting flanges of airblowers and extractors should preferably not be made of aluminium.

12.4.2.4 Electrical Equipment

When work has to be carried out in a non-gas-free atmosphere inside tanks, only the use of approved battery powered lights and air operated lighting equipment should be allowed. No other electrical appliances such as tools, handlamps, etc. should be used.

Floodlights should be installed outside the tank away from areas where vapours may enter. Only when it is certain that no explosion or fire hazard exists in the tank or vessel may any other electrical appliances (portable and transportable) be used. Such appliances must be adapted for a supply not exceeding 42V AC or 110V DC. The isolating safety transformers or rectifiers, subject to the issue of a relevant permit, should be placed outside the tank or vessel.

The condition of electrical appliances should always be checked before issue and after use.. When in use for some time they should be periodically checked. The equipment should not be used when in any way defective.

12.4.2.5 Smoking In the Tank

This hazard is by no means imaginary, especially when the cleaning job is performed by casual workmen employed by contractors who are not trained in refinery or oilfield work. Continuous strict supervision in this respect is necessary. As a precautionary measure workmen should not be permitted to carry matches or lighters in the tank farm area.

12.4.3 Gases Discharged During Gas-Freeing

Hydrocarbon vapours are generally heavier than air and although they can sometimes be easily and safely dispersed by a light breeze, a flammable concentration may travel a considerable distance in a still atmosphere. Thus when a tank, vessel, or confined space, which has contained a volatile hydrocarbon, is being ventilated prior to cleaning or repair, the large volume of vapourlair mixture which is released may travel beyond the limits of the usual safe distances. Continuous checks should therefore be made on wind direction and speed, and volume of discharge.

Particular attention should be paid to gases discharged from an eductor during gas-freeing. Measures should be taken to eliminate all sources or ignition from the vicinity of the eductor exhaust.

12.4.3.1 Petroleum Gases

In order to avoid any hazard to health through inhalation of toxic vapours, special care should be taken to ensure that hazardous areas are not entered by anyone except in an emergency. This includes personnel carrying out the gas-freeing procedure and other person who may happen to pass through the area. In emergencies, personnel must be provided with breathing apparatus and protective clothing. This is also applicable if inert gas has been used for purging and it is in the process of being replaced by air or hydrocarbon. In this case, there is a danger of asphyxiation in the area outside the tank.

Continuous supervision is therefore essential during the gas-freeing operation to ensure safety of personnel and equipment. The supervisor should stop the operation during very still air conditions or during electrical storms.

When a portable air compressor is used to supply air to the eductor, care should be taken that the compressor be placed at a safe distance outside the bund wall upwind of the source of the vapour. Distinction should be made between the hazards from: petroleum, hydrogen sulphide, organic lead compounds, benzene (benzol), and lack of oxygen.

When the percentage of petroleum vapours in an air-vapour mixture lies below the lower explosive limit, there may nevertheless still be a hazard through inhalation of petroleum vapours.

As a general rule, it is considered that exposure to petroleum vapour concentrations of less than 0.1% volume over a long period is unlikely to be damaging to the health of personnel. There are, however, many cases known

where even lower concentrations have had an adverse effect on persons who are particularly susceptible.

12.4.3.2 Hydrogen Sulphide Gas

Besides the danger caused by the presence of petroleum gases in certain concentrations, hydrogen sulphide gas (H_2S) may also constitute a serious hazard.

Concentrations, even as low as low ppm of H_2S may cause unconsciousness and even death. Before a crew is allowed to enter a tank it is necessary to ascertain the extent of any hazard present. In certain circumstances suitable air supplied breathing apparatus and life-lines must be worn. The men should be under constant supervision by two others stationed outside the tank holding the life-lines, one of whom should also have air supplied breathing equipment at the ready.

It should be stressed that the odor of hydrogen sulphide is not a reliable guide to its presence as with exposure to the gas, the sense of smell is very rapidly lost.

Lack of oxygen may result from chemicals absorbing or replacing oxygen in the tank air, or from inert gas often used to exclude or to reduce the possibility of explosions.

Air in clean tanks which are closed for an extended period may become deficient in oxygen because of rusting (oxidation) of the metal of the tank.
Improper or inadequate ventilation during tank work may also result in a lack of oxygen. No tank should be entered without breathing apparatus unless the oxygen content is 20% or above.

12.5 Safety Procedures

12.5.1 General Safety Instructions

The above mentioned hazards can be minimized by following safety procedures that are summarized below. They should be adhered to for all operations that involve the entering of personnel into tanks.

1. All lines to and from the tank must be disconnected or blanked off.

2. A gas-free and oxygen certificate must be obtained or air-supplied breathing apparatus specified as appropriate.

3. Before entering the tank, a permit, signed by the supervisor, must be issued. The permit should list all safety measures and the necessary protective clothing and equipment, and should also be endorsed only for a specific time period. .

4. During a thunder-storm nobody should be allowed on the roof or inside the tank. If an explosive mixture could still be present, operations should be stopped, and, if there is time before the storm, the tank should be closed.

5. If work has to be done in non-gas-free tanks, there should always be two people present outside the tank for control of the air source (usually an air compressor), the air supply to the respirators, and for any emergency assistance to personnel in the tank.
There should also be two independent air supply respirators, preferably self-contained, ready for immediate use in an emergency. One of the persons outside the tank should have one set at the ready, and be stationed at a tank manhole, keeping personnel in the tank under observation. If the personnel inside cannot remain within view of the outside observer, they must be joined inside by another person.

6. A fresh activated carbon type filter should always be connected in between compressor and respirators to absorb any obnoxious vapours. If there is a chance of temperatures near freezing point, air driers will also be needed. These should be connected between the compressor and the filter.

7. The air compressor should be located upwind of the tank being cleaned. A wind sock should be kept flying to indicate changes in wind direction.

8. Sludge of pyrophoric nature, (as could be the case in gasgline and crude tanks, and in tanks which have contained sour stocks), should be kept wet and, as soon as possible, taken out of the tank pit to a place for final safe disposal.

9. The maximum working temperature inside a tank should not be above 40°C unless special precautions are prescribed in the permit. The temperature can be decreased by ventilation. It should also be noted that the readings of combustible gas detectors tend to be low at high temperatures (40°C) and cautions required in the interpretation of results in hot weather.

10. Until a tank is declared gas-free, only approved battery powered lights and air operated lighting equipment should be permitted.

11. Portable lights used outside the tanks should preferably be placed away from possible vapour travel. If this cannot be done, these lights should be of an explosion-proof type, connected to extension cords equipped with connectors or switches approved
for hazardous locations. Such equipment should be thoroughly inspected prior to its use.

12. Only tools that are specifically covered by the work permit should be used in tanks that are not gas-free.

13. Cleaners etc. should always wear protective clothing whilst working with products of a corrosive nature, both inside and outside the tank. This should consist of plastic gloves, boots, and face-mask with helmet, and preferably, also PVC-coated clothing.
Specific requirements should be stated on the work permit.

14. Fire fighting equipment should always be on site during cleaning in accordance with the permit. Personnel should be trained in handling the type of equipment prescribed.

15. Pumping equipment should be preferably air-.or steam-driven, If this is not possible, care should be taken that:

- The equipment is installed at the windward side;
- The flammable vapours will not be released at ground level;
- The area around the equipment is properly tested for flammability before any equipment is connected;
- Spark arrestors and overspeed prevention devices are fitted if applicable.

16. Smoking inside a tank should never be allowed even when the tank has been declared gas-free and clean.

17. The power supply to any tank that is cathodically protected should be disconnected at least 24 hours before any work is permitted, in order to allow time for depolarization.

18. If work has to be done inside a tank, vessel or other confined space, which is gas-free and well ventilated and where entry is permitted without breathing apparatus, there should always be two persons present.

19. If a tank being cleaned remains unattended, e.g. during lunchtime, at night, or during the weekend, warning signs must be posted.

20. If either steam or water jets are used during the gas-freeing or early cleaning stages when the tank is not gas-free, certain precautions are essential to avoid static electricity hazards.

21. If tanks are cleaned at night, exits should be clearly marked by suitable means in case of power failure.

22. Before the last manhole of a tank is closed, the supervisor should ascertain that no people, tools or materials have been left behind and that all work has been satisfactorily completed.

12.5.2 Protective Clothing

1- Boots of good quality (with safety toe-caps), in good condition, and made of material resistant to water and oil should be worn by tank cleaners. Boots should be discarded if the safety toes become exposed, because of the possibility of causing an incendiary spark. It is also good practice to wear gloves made of materials resistant to water and oil, because excessive exposure may irritate and burn the skin. Acid-proof rubber, neoprene, vinyl, etc., are acceptable as resistant materials. Protective hats must always be worn.

2- If there is a danger that clothing can get badly splashed or soiled, special protective clothing (e.g. PVC overalls) should be worn with suitable face/eye protection. When cleaning leaded gasoline tanks, the Octel recommendations on clothing should always be followed.

3- If at any time normal clothing. (e.g. cotton overalls), becomes contaminated with oil or sludge, such clothing should be removed immediately. The clothing should be kept away from any source of ignition, because vapour given off by such clothing may be flammable. A bath with soap and water should be taken promptly, and clean clothing should be put on. Oil contaminated clothing should not be kept in locker rooms or stored in lockers. It should be dry cleaned and not laundered to ensure removal of all contamination.

4- Tank cleaners should take a bath with soap and water at the end of each day's work, and when the tank cleaning job has been completed. In the event of hands, etc. becoming contaminated, cleaners should wash with soap and water, preferably hot, as soon as possible.

12.5.3 Respiratory Protection

- Protective respiratory equipment for tank cleaners should provide a positive air pressure in a full-face piece mask or hood throughout the breathing cycle.
  Canister type masks are not permitted for working in confined spaces or tank cleaning because they do not provide proper protection against vapour concentrations above 2%, nor do they protect against oxygen deficiency.

- Positive air pressure may be supplied to the full-face piece mask in one of the following ways:

1. From a positive-pressure blower either hand-operated or (preferably) motor driven, the discharge of which is connected to the mask by means of a low-pressure hose-line.

2. From an air compressor with activated-carbon filter and, if necessary, air driers. The discharge of this equipment is connected by an intermediate-pressure air line to a reducing valve worn by the cleaner. A low-pressure air line connects the low-pressure side to the mask.

3. Use of air from plant air lines or from compressors supplying power tools should not normally be permitted because the air from such sources is not free from toxic contaminants, nor is the supply under control of the tank crew. If, however, absolutely no other source of air supply is available and air from plant lines etc. is used, it should be purified, e.g. by carbon filter.

4. From one or more high-pressure breathing air cylinders fitted with reducing valves.

5. From a high-pressure breathing air cylinder carried by the tank cleaner. Because of the limited air supply this self-contained equipment is recommended only for tank entries of short duration, such as for inspection, gas testing or to provide emergency assistance.

If an air supply, other than an air cylinder carried by the cleaner, is used, measures must be taken to ensure that, in case the air is interrupted, the people inside the confined space will have enough time to get out safely.

Such measures could consist of placing a pressure vessel between source and mask, or keeping a second air compressor running. If a 'Bloman' apparatus is used, men can breathe with the blower stopped, but must leave the tank in such a case.

Where air is supplied from a blower or compressor, such equipment should always be located to the upwind side of the tank, and should not be near an engine exhaust or other source of contamination.

After the full-face piece mask has been adjusted to the face and tightened, it should be tested for leaks/gas-tightness. This is accomplished by closing the end of the tube with the palm of the hand, or pinching the tube to cut off the air, and inhaling. If the mask collapses against the face, the fit is satisfactory.
If it does not, leaks should be located and eliminated. Under no circumstances should anyone remove his mask while inside the tank.

Face pieces of the mask sets should be cleaned with soap and water at least at the end of each day, and after completion of the job. They should then be dried and tested by a competent person to ensure that the valves are not sticking.

Other parts of the mask sets including hoses and life-lines should be cleaned after completion of each job and protected against excessive heat.

12.5.4 Eye-Protection Equipment

Eye protection equipment, of a full-coverage type, should be worn during the scraping of scale, cutting of rivets and the spreading of sawdust or other absorbent. Such equipment should be cleaned frequently and should be washed and sterilized upon completion of each job.

12.5.5 Use of Life-Lines

Under very special circumstances, e.g. for inspection purposes, tanks and confined spaces which have not been gas-freed or which are deficient in oxygen, may be entered. The use of an air-supplied breathing apparatus, body harness and life-line attached to the person(s) entering, (if safe to do so) is required.

The free end of the life-line should be secured to a fixed object outside the tank and should be attended by two persons, one of whom will keep the personnel in the tank constantly within his vision. The observer may pass tools, but he must have no other job which will take his attention away from the personnel in the tank, or which will interfere with his attempt to withdraw a victim by use of the life-line, or will require his leaving the vicinity of the tank for any time whatever.

In case of emergency, the outside observer must never enter the tank until he is relieved at his post. It is his job to summon aid immediately (various alarms, such as a whistle, may be used), to attempt to remove the victim by use of the life-line and to perform all necessary rescue functions from the outside. Upon arrival of help, he may enter the tank for rescue work only when he is assured that outside assistance is adequate. Such observers should be well trained in basic First Aid principles, such as rescue breathing techniques. Rescuers entering the tank must be protected with the safety facilities required by the situation I.e. life-line and harness and proper personal
protective equipment.

Life-lines can often be a hindrance and may well prejudice effective emergency action under certain conditions. In small spaces containing fittings (e.g. steam coils, stirrers, swing arms, etc.), or in large floating-roof tanks with many legs, entanglement of a life-line may make it extremely difficult or even impossible to extricate an unconscious person. While as a general principle the use of life-lines should always be considered in confined spaces, a local management decision may be made not to use them, if, by doing so, a less safe situation is created. However, a life-line, fitted for quick attachment to a harness, should always be available at the tank entry point.

Tank cleaning operations, especially in the preliminary stages of preparation and gas-freeing, should always be under direct supervision. A competent person, aware of the hazards of the operation and fully conversant with the cleaning procedure and with the use and fitting of protective equipment should be in attendance throughout the entire operation. This particularly applies when such work is performed by contractors.