

THE ENGINEERING EQUIPMENT AND MATERIALS USERS' ASSOCIATION

Safe and effective operation of storage tanks for oil movements

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ENGINEERING EQUIPMENT AND MATERIALS USERS' ASSOCIATION

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Preface

On the basis of extensive operational experience, storage tank operations or 'oil movements', as they are known in the oil and gas industry, have been identified as constituting a process unit. As such, they are often perceived by the petroleum industry as areas with limited process safety risks or at least as areas less hazardous than the other process units in a refinery or other plant within the industry. This perception is often reflected in: training course material on process safety; internal practices and procedures; site documentation and process safety management systems.

However, there continues to be a number of safety-related incidents in tank farm areas across the petroleum industry. Failure of pipelines in oil movement operations, fires of storage tanks due to hidden sources of ignition (such as static electricity), failure of final or intermediate product tanks and overfill of tanks can occur, with potential severe safety, environmental and operational consequences.

Furthermore, investment and project proposals in industry are critically reviewed and scrutinised over budget costs and, in new or revamping projects, oil movement areas are optimised as much as possible. In practice, this means that spare storage capacity is hardly considered, multi-purpose tanks are used and multi-product lines are implemented despite operational complexity. Small process incidents in oil movements that may temporarily bring tanks, pipelines, or loading arms out of operation, even for a short period of time, can result in a substantial financial burden plant-wide.

In view of the above facts and other observations, the objective of this Publication is to increase the level of awareness of process safety in oil movements by providing specific guidance for safer operations and practices throughout.

This Publication serves as a technical supplement to the extensive existing standards and procedures, and focuses on areas in which higher risks in oil movements exist. It also demonstrates the way that specific process safety recommendations can be implemented in day-to-day operational practice. Given its supplementary role, EEMUA 217 refers to existing standards and guides, aiming to avoid reproduction of information on the relevant subjects that is already available.

Reference is made to the 'Safety and environmental standards for fuel storage sites', Process Safety Leadership Group (PSLG) final report⁽¹⁾. This document can be obtained via the British Health and Safety Executive website www.hse.gov.uk. It describes in detail issues such as: leadership and safety culture; process safety management; hazard identification; management of plant and process changes; roles, responsibilities and competencies.

EEMUA 217 does not provide detailed engineering information and therefore is not especially directed at those who are engaged in detailed engineering design of oil movements. However, given the fact that sound knowledge of operational practices, procedures and hazards can assist in the delivery of a thorough and integrated design, from this perspective the Publication can also contribute to process design in oil movements.

Scope

Although this Publication has been developed specifically for oil movements, namely hydrocarbons, it includes much information relevant to the large-scale storage of other products.

The oil movements covered include: liquids stored under atmospheric pressure, as well as LPG stored under pressure or under refrigerated and cryogenic conditions. Again the advice given for these latter hydrocarbons may also be applicable for other refrigerated gas liquids but it is not the intention in this document to advise specifically on those products.

Oil movements occur in refineries, terminals and storage depots and this document can be considered applicable in all these situations.

1. Introduction

Sustainable improvement in HSSE (Health, Safety, Security and Environment) and reliability has been, and will remain, a top agenda item for companies. Special attention is being given to: reviews of present and future strategies; leverage of internal and external learning to improve HSSE performance; setting policy and standards; and responding to the high expectations of all stakeholders on safety performance.

The focus is on process safety without neglecting the implications of personal safety. Recent industrial history has shown that even one process safety incident can be catastrophic (such as the US Texas City refinery explosion, March 2005, and the UK Buncefield oil depot fire, December 2005).

The availability of standards, codes and manuals (internally as well as externally) provides the basis for setting safe operational practices and procedures in process plants as well as in operational safety courses and documentation.

Despite the enormous quantity of information available, it appears that procedures and/or training courses need further clarity to ensure that process safety elements are embedded, or avoid gaps that affect the manner in which operational duties are carried out in process units. As experience in the industry shows, oil movements are an area in which those gaps can be identified.

Incidents such as Buncefield dictate attention on oil movements process safety as an inseparable part of a process plant. At an industrial level, and notwithstanding the incidents described above, oil movements process safety aspects need to be clearly addressed. Furthermore, personnel at refinery sites can have the perception that oil movements is a lower risk area, which given the incidents that have occurred is questionable.

In view of the above, this Publication is intended to provide a supplement to the aforementioned internal or external standards and technical guides, aiming to contribute towards more effective process safety in oil movements. For the subjects that are covered, specific references are given in order to avoid reproduction of information that is available elsewhere. Finally, the objective is to show how to incorporate process safety elements into the operational daily practice of oil movements.

A summary of the areas covered by this Publication is given below:

- Different process safety considerations apply to tanks on the basis of the tank type (fixed roof, floating roof and combinations of floating and fixed roofs). Furthermore, phenomena related to overpressure and the establishment of vacuum conditions, or dealing with water on the tank roof and/or in the tank have different causes and preventive actions in fixed roof and floating roof tanks.
- Ignition sources in oil movements remain a significant process safety issue. Static electricity and lightning are major sources of ignition. However, there are other sources of ignition, which are not always assessed, such as diesel driven equipment and carbon canisters. With respect to static electricity, the principal challenge is the fact that the conditions that can lead to ignition due to static electricity are not always

known, or cannot easily be predicted, turning the efforts towards prevention which is not always effective.

- The preparatory procedures in the oil movements related to gas freeing of tanks and pipelines, tank entry procedures and depressurisation and opening of gas pipelines, require special attention, together with compliance with the existing standards.
- The introduction of systematic operational tank inspection can provide very useful feedback in the prevention of incidents. The guidelines for operational inspection, and the areas in which this inspection can have realistic influence, are covered in existing standards.
- Tank overfill protection is an important safeguard in oil movements. It is a common cause of accidents in oil movements, some of which can be catastrophic (such as the Buncefield accident). The existence of independent safeguarding systems is essential.
- Other process safety issues in oil movements are created for meteorological reasons, such as lightning, which mainly affects the floating roof tanks and for this reason the issue is elaborated on.
- The storage temperature of products in tanks is another potential process safety risk. Therefore, specific guidelines are given and measures towards prevention of storing products at excess temperatures are covered.
- Storage and handling of Liquefied Petroleum Gas (LPG) is a major aspect in oil movements. It requires comprehensive and error-free procedures. The guide mentions: the characteristics of LPG that make it special in storage and handling; the guidelines for a process safeguarding memoranda as the basis of control and safeguarding documentation; and refers to the existing standards that extensively cover all issues related to LPG.
- The main aspects of ship to shore activities (which involve oil movements) are briefly covered, and points of process safety concern are identified while referring to the extensive detailed international standards on the subject.
- Finally, this Publication covers issues related to shift handovers - an administrative aspect of process safety that deserves attention. Guidelines for effective shift handover in oil movements are covered, and potential weak areas are addressed.

2. Tank Safety Design Considerations

2.1 Design Factors versus Tank Type for Atmospheric Tanks

The safe design of tanks is extensively covered in recognised design standards, such as EN 14015⁽²⁾, ISO 28300⁽³⁾, API 650⁽⁴⁾ and API 620⁽⁵⁾. A summary of tank selection criteria and guidelines for the different types of tanks versus product classification is provided in Figure 5 of EEMUA Publication 213⁽⁶⁾ and is reproduced in Appendix 1 of this Publication. A summary of those principles is given below:

- The selection process starts with the type of product to be stored and its physical properties, mainly volatility (which is a function of the true vapour pressure (TVP) of the liquid at storage temperature).
- The flash point classification of products to be stored is an important physical property when deciding the size and type of tanks required.
- Volatile products (with high vapour pressure) such as crude oil, gasoline, and naphtha should be stored in external floating roof tanks, covered floating roof tanks, or internal floating roof tanks.
- The type of storage tank used for a specific product is mainly determined by the safety, engineering, and environmental requirements and the need to operate with minimum losses when the tank is in service.
- Cost effectiveness elements during manufacturing are also considered. As an example, for diameters above 39 m, it is recommended to have only covered floating roof tanks (CFRT).

Further to the above, oil movements operational personnel usually encounter dissimilar issues on the different types of tanks (fixed roof or floating roof tanks) that are directly related to the operability and process safety of tanks. The focus of the Section below is on aspects of low-pressure and atmospheric storage tanks.

2.1.1 Fixed Roof Tanks

The main safety concern in fixed roof tanks is that the vapour phase above the liquid product is in contact with the atmosphere through the open vent or the pressure vacuum valve (PVV). If the product is volatile, the vapours may mix with the air to form a flammable mixture.

Flammable atmosphere shall be avoided in fixed roof tanks through control systems and/or installing internal floating covers (IFC), nitrogen or gas blanketing arrangements. Blanketing gas is an effective barrier to the development of a potential hazardous situation in the tank vapour space. Rundown temperatures from process should be kept below the flash point of the product.

Other ways in which flammable atmospheres can be generated in fixed roof tanks include the following:

- **Fuel oil in storage.** Degradation of fuel oils in storage, especially those containing cracked or vis-broken residues, represents another possibility of having flammable mixtures. The reason is that cracking reactions can continue in downstream piping, resulting in gas coming out at the vapour space of the fixed roof tanks. This can happen regardless of the quenching and stripping facilities of the process units. Furthermore,

degradation (an exothermal reaction) can also occur in heavy products tanks contaminated with light ends.

- **Blending contamination.** It is very easy to produce a flammable atmosphere above a low volatile product (such as fuel oil or gas oil) with contamination. For example, a quantity of 3% blend of gasoline to gas oil can bring the flash point down from 70 °C to 10 °C, resulting in a flammable atmosphere. A possible cause of this contamination is where manifolds or pipelines are used for both high and low volatile fuels (multi-purpose lines).
- **Segregation of light and heavy slops systems.** Poor segregation of light and heavy slops systems is always a potential cause of a flammable atmosphere. Light slops and heavy slops are segregated on the basis of their density and vapour pressure.
- **Exceeding normal operating conditions in heated slops tanks.** The maximum heating temperature and minimum tank level are exceeded (with the subsequent effect of exposing heating coils) for heavy slops tanks. Note that light slops tanks should not be heated.
- **Mixing incompatible waste materials.** Mixing incompatible waste materials can be a source of creating a flammable atmosphere. For example, pumping an oxidizing mineral acid into a tank containing hydrocarbon material can be the cause of generating a flammable atmosphere and then tank explosion.

2.1.2 Floating Roof Tanks

Floating roof tanks can be either external floating roof (pontoon or double deck) or internal floating roof tanks. The main advantages of the floating roof tanks with respect to process safety are as follows:

- Vapourisation is prevented by a cover over the liquid, and therefore, there is no vapour space. Consequently, the source of a flammable atmosphere is eliminated.
- If proper sealing is applied, it demonstrates reduced evaporation losses.
- Internal floating roof tanks can increase protection from fire exposure.
- In general, the vapour emissions from internal floating roof tanks are lower than those of external floating roof tanks. From an emission and safety point of view only full contact internal floating roofs are allowed. The non full contact internal floating cover types have an emission reduction efficiency which is a fraction of the emission reduction performance of a full contact type internal floating cover. The full contact type can be made of aluminium, steel or glass fibre reinforced epoxy (GRE or GRP). (Reference Section 3.6.1 of EEMUA 213). The unsinkable types are the most reliable from a safety point of view as the fire fighting scenario is easier to handle.

Two aspects of particular interest with respect to floating roof tanks are the landing and re-floating of the roof, which are dealt with in more detail below.

2.1.2.1 Landing of (External or Internal) Floating Roofs

Landing of a floating roof presents numerous risks to equipment and personnel. Roofs should normally only be landed for scheduled maintenance/inspection, capital work, or possibly product change requirements. In the unlikely event that a roof must be landed for considerations other than the ones mentioned above, a proper task risk analysis should be carried out in order to justify the risk to the site. Expected hazards involved in the landing of an internal or external floating roof are the following:

- Roof legs should be inspected and declared fit for service well before the commencement of the landing process.
- As the liquid level is drained away, it is possible to create a flammable mixture underneath the floating roof above the liquid level. If there is electrical storm activity (as discussed in subsequent Chapters), the potential for ignition of these vapours exists.
- High ambient temperatures can increase vapourisation of the product leading to a possible flammable mixture inside the tank above the LEL (lower explosive limit).

2.1.2.2 Re-floating of Floating Roofs After They Have Been Standing on their Legs

Similar to landing, the roof re-floating process also requires special attention. As product is introduced into the tank, hydrocarbon vapours evolve off the liquid surface. The space between the liquid level and underside of the floating roof will go through the flammable zone. As the liquid continues to flow, vapours below the floating roof are pushed into the vapour space above the floating roof. The area above the roof then passes from a lean atmosphere into the flammable zone.

On external floating roofs, the time required to dissipate the high LEL's above the floating roof is typically shorter than for internal floating roofs. In either case, extreme caution must be used to prevent excessive built up of static electricity and to refrain from refloating the tank during any electrical storm activity. In addition, external sources of ignition must be eliminated. Once the tank roof is floated, a 24-hour wait time is required to ensure LEL's above the floating roof have dissipated.

In periods of very calm weather, the wait time may be longer. Extreme low temperatures can cause the legs to freeze up in bottom sludge/water. The possibility of having a roof frozen to the bottom while product is re-introduced cannot be excluded.

2.1.2.3 Installation of an Internal Floating Cover

When installing an internal floating cover in fixed roof tanks with PVV's, the vapour phase may no longer be above the upper explosion level (UEL), and therefore, PVV's should be changed to open vents, Reference Section 3.6.1 of EEMUA 213.

For further information on roof vents and IFC's, please refer to EEMUA Publication 213.

2.2 Other Design Considerations – Tank Farm Layout

2.2.1 Introduction

The arrangement and layout of storage tank sites and installations takes into consideration normal as well as emergency operation, fire fighting or oil spill activities in a tank farm. Furthermore, tanks should be placed so that vapour emissions can be diffused to atmosphere to a concentration below the lower flammable limit before reaching a non-hazardous area. People in oil movement departments should be aware of the guidelines for tank layout for the following reasons:

- Contribute to the initial plan and/or modifications to a tank farm if they are involved.
- Make sure that the tank layout considerations are also met during reallocating tank duties.

The reference document for tank farm layout is the relevant IP standard⁽⁷⁾ and EEMUA Publication 183⁽⁸⁾. In US sites, spacing/layout is dictated by NFPA 30 (National Fire Protection Agency)⁽⁹⁾.

2.2.2 Other Guidelines and Regulatory Directives

ATEX is the name commonly given to the framework for controlling explosive atmospheres and the standards of equipment and protective systems used in them. It is based on the requirements of two European Directives.

- 1) Directive 99/92/EC (also known as 'ATEX 137' or the 'ATEX Workplace Directive') on minimum requirements for improving the health and safety protection of workers potentially at risk from explosive atmospheres. The text of the Directive and the supporting EU produced guidelines are available on the EU-website.
- 2) Directive 94/9/EC (also known as 'ATEX 95' or 'the ATEX Equipment Directive') on the approximation of the laws of Members States concerning equipment and protective systems intended for use in potentially explosive atmospheres. The text of the Directive and EU-produced supporting guidelines are available on the EU website.

In Great Britain, the requirements of Directive 99/92/EC were put into effect through Regulations 7 and 11 of the Dangerous Substances and Explosive Atmospheres Regulations 2002 (DSEAR). The DSEAR places duties on employers to eliminate or control the risks from explosive atmospheres in the workplace. A summary of those requirements can be found below.

In DSEAR, an explosive atmosphere is defined as a mixture of dangerous substances with air, under atmospheric conditions, in the form of gases, vapours, mist or dust in which, after ignition has occurred, combustion spreads to the entire unburned mixture.

Atmospheric conditions are commonly referred to as ambient temperatures and pressures. That is to say temperatures of -20 °C to 40 °C and pressures of 0.8 to 1.1 bar.

The requirements in DSEAR apply to most workplaces where a potentially explosive atmosphere may occur. Some industry sectors and work activities are exempted because there is other legislation that fulfils the requirements. These exemptions are listed in Regulation 3 of DSEAR. Employers must classify areas where hazardous explosive atmospheres may occur into zones. The classification given to a particular zone, and its size and location, depends on the likelihood of an explosive atmosphere occurring and its persistence if it does. Schedule 2 of DSEAR contains descriptions of the various classifications of zones for gases, vapours and dusts.

Areas classified into zones must be protected from sources of ignition. Equipment and protective systems intended to be used in zoned areas should be selected to meet the requirements of the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996. Equipment already in use before July 2003 can continue to be used indefinitely provided a risk assessment shows it is safe to do so.

Where necessary, the entry points to areas classified into zones must be marked with a specified 'EX' sign.



Figure 1 The 'EX' sign as stipulated by regulations

This sign must fulfil following requirements:

- Triangle shape.
- Black letters on yellow back field with black outline (the yellow area must at least contain 50% of the sign surface).

Before a workplace containing zoned areas comes into operation for the first time, the employer must ensure that the overall explosion safety measures are confirmed (verified) as being safe. This must be done by a person or organisation competent to consider the particular risks in the workplace, and the adequacy of the explosion control and other measures put in place.

The specific DSEAR requirements dealing with explosive atmospheres come into effect at different times depending on when the workplace is first used.

In Great Britain, the requirements of the Directive were put into effect through the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations 1996 (SI 1996/192)⁽¹⁰⁾.

The Regulations apply to all equipment intended for use in explosive atmospheres, whether electrical or mechanical, and also to protective systems.

Table 1 Workplace requirements

Workplace	When requirements must be met
Workplace in use before July 2003	Equipment already in use before July 2003 can continue to be used indefinitely provided an operators risk assessment shows it is safe to continue to be used in a hazardous environment
Workplace comes into use for the first time after June 2003	Workplace must meet requirements from the time it comes into use

The UK Department of Business Innovation and Skills (BIS) has policy responsibility for the Regulations (although HSE enforces them). More information on the 1996 Regulations and the ATEX EU Directive 94/9/EC can be found on: <http://www.hse.gov.uk/fireandexplosion/atex.htm>.

2.3 Vapour Collection/Recovery Systems

A vapour collection system routes the vapours from the emission sources (e.g. road tanker, rail tanker car, marine vessel or storage tank) to the vapour recovery unit or incinerator or to a safe location for venting to atmosphere. The design and installation must minimise the risk of overfill, overpressure, vacuum and pipeline detonations. Detailed information about the vapour collection/recovery systems are presented in EEMUA Publication 213.

3. Overpressure/Vacuum of Tanks

The maximum design pressure for each tank is an important parameter that should be available in oil movement discussions. Where there is a change in use of the tank, the design pressure should be checked to ensure it is sufficient for the vapour pressure of the new product.

All too often during operation of fixed roof tanks, under certain circumstances/processes, the tank can be over pressurised or have inadequate vacuum capacity. Knowledge of those processes can prevent a potential incident related to overpressure/vacuum in the oil movements. In the paragraphs below, some typical cases are presented.

3.1 Pressure Vacuum Valves and Open Vents

Fixed cone/dome roof tanks are equipped with pressure vacuum valves (PVV) or open vents to maintain conditions inside the tank and consequently, to avoid conditions inside the tank leading to overpressure or vacuum. Sizing of PVV is based on the condition that vapour outflow speed is faster than flame propagation speed. The vacuum part of the valve should be sized to allow air/inert gas ingress at a rate that is greater than the outflow of tank liquid and condensation of vapour.

Pressure/vacuum valves are installed on tanks equipped with a gas blanket or if the tank could contain high volatile or low flash points liquids (mainly Class I compounds). Open vents with flame arrestors are installed on tanks containing low volatile and high flash point liquids.

ISO 28300 'Petroleum, petrochemical and natural gas industries -- Venting of atmospheric and low-pressure storage tanks' is the reference for the proper design and maintenance of pressure/vacuum valves. The correct sizing of PVV's is critical in ensuring that the pressure in atmospheric fixed roof tanks will maintain constant with the prevention of vacuum or overpressure conditions at all times. At the same time, those relief valves should be inspected periodically for fouling and, if necessary, cleaned thoroughly. The interval of inspection and cleaning should be condition based, depending on the fouling loads.

Special attention is required for ensuring that free vents and flame arrestors (in the exceptional case that they are present) are regularly inspected to verify that they are free from rust, wax, dust or other debris. Other vent conditions that may result in bursting or collapse of atmospheric tanks are listed below. The following have been incidents in the industry related with the failure of vents:

- Vent blanked off.
- Plastic bag over vent.
- Modified vent without design considerations taken into consideration.
- Flame arrestor choked.
- Vent connected to water seal.
- Too small vent.

Finally, it should be notified that opening dip hatches when a tank is fitted with a PVV releases a significant quantity of vapour. Therefore, in the event that opening of dip hatches is required, all safety precautions should be taken into consideration by oil movement personnel.

3.2 Tank Overpressure

Tank overpressure can be caused by:

- **Liquid movement into the tank.** The inflow of liquid into a tank at excess rates and vapourisation including flashing of the feed liquid beyond design limits.
- **Temperature increase of liquid contents.** Expansion and vapourisation, which is the result of an increase in atmospheric temperature or failure of the unit product cooler.
- **Fire exposure.** Vapourisation and expansion of the liquid that occurs when the content of the tank absorbs heat from external fire.

Besides the above-mentioned causes, there are also other circumstances that result from equipment failures and operating errors:

- **Pressure transfer blow off.** Pressure transfer blow-off can be generated from a flow surge of a receiving tank at the end of a transfer of liquid from other vessels due to vapour breakthrough.
- **Failure of external heat transfer devices.** Tanks, which require internal elevated temperatures, are heated with media such as water, steam or hot oil. Failure on the temperature control system of the heating medium (control valve, temperature sensing element, etc.), tank vapourisation occurs and tank overpressure is possible. Leak of heating media (due to corrosion for instance) could also result in overpressure.
- **Chemical reactions.** The contents of some tanks may be subject to chemical reaction, which may generate heat and/or vapours. Examples of chemical reactions may be the addition of water to acid or spent acid tanks by mistake, runaway reaction of phenol tanks, etc.
- **Pumping of hot oil into water.** Sudden change of water into steam with increase of tank pressure.
- **Blowing in air, steam or gas.** Blowing into the tank of air or steam or gas during maintenance in an uncontrolled manner.
- **Control valve failure.** Failure of a control valve on the liquid line to a tank must be considered because it may result in high rundown temperature due to insufficient cooling.
- **Water in a heated tank.** Introducing water into a heated tank (above 100 °C), see Section 4.1.
- **Blockage of PVV or open vent.** Blockage due to fouling deposits, bird nests, or cover of PVV's or open vents can also result in overpressure

3.3 Tank Vacuum

Tank vacuum can be caused by:

- **Liquid movement out of the tank.** The outflow of liquid from a tank at excessive rates (beyond design limits) can generate tank vacuum conditions (e.g. gravity draining).
- **Temperature decrease of liquid contents.** Condensation of vapours that is caused by a decrease in atmospheric temperature or other weather conditions (such as wind changes, precipitation, etc.).
- **Tank steaming out procedure.** During tank steaming out, it may be possible that the condensing rate may exceed the venting rate.
- **Blocked vents or PV valves.** Vents and PV valves can be partially or fully blocked due to various reasons. This could lead to overpressure or vacuum (beyond design limits) in the tank. Any flame arrestors fitted to tank vent can have a restricted flow capacity due to corrosion and consequently create a vacuum or overpressure conditions beyond design limits.



Figure 2 Roof collapse due to vacuum in the tank

4. Dealing with Water

4.1 Water in Tanks

The presence of water at the bottom of tanks is a common issue that oil movements personnel need to deal with. The most common source of water in tanks is the product that it stores. The usual sources of water in tanks are the following:

- Water in Products.
- Roof dip hatch.
- Holes in the roof.
- Leaking steam/water coils in heated tanks.

Water can cause explosions in process units for intermediate products during the transition from the liquid phase to the vapour phase, or affect the product quality for final products. For that reason, the draining of water is an important operation and operational instructions of tank draining should be present in all operational oil movements manuals.

Furthermore it is required to drain the water in order to prevent a boil over scenario of a storage tank in case of a tank fire. Settled water will rapidly vaporise to steam when heat of the fire reaches the water level.

Good practices related to water draining are the following:

- When draining off, water is manually carried out. This should never be left unattended.
- For automatic water draw-off valves, their reliability should be guaranteed before the whole system is left unattended.
- Draining systems that may be frozen in cold weather are adequately heat traced and maintained in good condition.
- Naphtha or gasoline tanks are examples of products that an operator can often be mistaken if the tank is water-drained or not. Experience shows that testing with a wooden stick can often provide good indication if the drain is completed. The reason is that wood tends to absorb naphtha or gasoline whereas water stands on the wood surface.
- Use of detection paste is another method for checking water drawn-off from tanks. In the presence of water, the paste changes colour.

4.1.1 Heated Tanks

Special safety concerns are related to the presence of water in heated tanks since it is a potential serious hazard for water explosion (or froth over). The reason is that at atmospheric pressure and 100 °C, a volume of water expands 1600 times when it changes phase (from liquid to steam). As a result of that, sudden foaming will result to a froth over, leading to tank overpressure and failure of the tank, at the roof/shell weld, which should be the weakest point of the tank construction.



Figure 3 Tank collapse due to rapid temperature changes

For products, such as **Bitumen**, with storage temperatures of 120 °C-150 °C (or even above), these are extremely sensitive issues and as a result any water contamination should be avoided.

Slops tanks need special attention, since they receive oil-water mixtures from a variety of sources, and they often contain water/oil emulsions that can separate at 100°C and release boiling lighter hydrocarbons.

4.1.2 Precautions to Prevent 'Froth Overs'

Oil movements personnel should work proactively to prevent 'froth overs' due to water, and for this reason, the following steps need to be considered:

- Whenever there is the possibility of water being present in a tank, then the tank temperature should not exceed 90 °C, which is the boiling point of water minus a safety margin of 10° C.
- Run down lines and tank-heater temperature controls should be provided for heated tanks and tank storage temperatures must be carefully controlled.
- Steam coil pressures in and out of a tank should be carefully monitored to make sure that no leakages in the tank occur.

- Steam supply lines to tank heaters should be accommodated with positive shut off valves which need to be interlinked with a temperature control. The valves will shut off as soon as the temperature reaches a set value.
- Heated slop oil tanks need special attention in maintaining the tank temperature well below 100 °C (i.e. below 80 °C).
- The line-up towards slops tanks should be carefully assessed and HAZOP studies need to be carried out in order to make sure that incorrect line-up of valves will not lead hot hydrocarbon streams into slops tanks with potential presence of water.
- Drain water from tanks regularly, and if the draining is carried out manually, never leave unattended.
- Boilovers during fire scenarios are investigated by the Lastfire project. Information about the Lastfire project can be obtained here www.lastfire.co.uk.

4.1.3 Overheating

Overheating of product shall be prevented. Fire or explosions could occur when storage parameters and conditions are not correctly controlled and monitored within the operating window. For example, taking into account the maximum heating temperature and the minimum storage level.

4.2 Rain Water on Floating Roofs

Rain falling onto a floating roof is drained away via a flexible hose or a metal pipe with articulated joints (swivels) to an outside gate valve close to the tank bottom.

It has been repeatedly debated in the industry whether the gate valve of the roof drain shall remain open or close. The reason is that industry has experienced both types of incidents, namely:-

- Sinking of single deck type of floating roofs due to the fact that the valves of the roof drain were closed and operators forgot to open them during heavy rain.
- Loss of containment after failure of the flexible hose or the metal articulated pipe via the roof drain line. A common cause (which has been repeatedly experienced in the industry) is a crack near the chain support of the roof drain with swivel joints especially for tanks of 50 m diameter or higher.

The site policy needs to consider the risk assessment, roof type and HSE document SPC/Enforcement/163 Version:2009-01-19⁽¹¹⁾;

4.2.1 Single Deck Floating Roofs

These floating roofs are constructed with a central membrane surrounded by a pontoon ring. The pontoon ring is divided by bulkhead plates at the circumference and the flotation is designed such that the roof will still float when two adjacent pontoon compartments as well as the centre deck are punctured. The second specified load case is the accumulation of (rain) water to 250 mm over the total roof surface than collects/accumulates on the centre membrane and the roof drain to be not operating. No emergency drains are allowed on this type of floating roof.