South African Petroleum Industry Association

SAPIA Minimum Guideline for Fire Protection and Fire Response of Geodesic Dome Roof Tanks

DOCUMENT CONTROL

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Contents

1. SAPIA Guideline

INTENT OF GUIDELINE

This best practice guideline is intended to guide SAPIA members on the different fixed fire protection systems that may be installed on geodesic roof tanks and fire response philosophies. This guideline does not take away the responsibility of the Members to ensure that all relevant HSSE risks assessments are conducted, comply with all legislative requirements, and implement appropriate measures to mitigate the risks.

SCOPE OF USE

This guideline is intended for SAPIA members in South Africa (SA). Non-SAPIA members will require the permission of SAPIA on the use of this guideline and will do so solely at their own discretion without any liability to SAPIA or its members. This guideline is not a list of procedures.

EXCLUSIONS OF GUIDELINE

This guideline is not a legally binding document. It serves to share best practice to ensure that incidents and accidents be prevented. This guideline is also not exhaustive. Risk assessments at facilities may determine unique risks peculiar to specific sites which need to be considered.

2. Introduction

The installation of geodesic dome roofs (geodesic dome is a self-supporting cover) on new Internal floating Roof (IFR) tanks and the retrofit of geodesic dome roofs to External Floating Roof (EFR) tanks have become more prevalent during the last 40 years.

Floating roof tanks are designed to eliminate the vapor space above the liquid to reduce evaporative losses, fire danger and corrosion caused by the presence of air.

The main reason for the installation of geodesic dome roofs in refineries and tank farms are to protect the storage product and the structural tank components from atmospheric and environmental influences, while the same time, minimize hazardous vapor emissions and preventing water from entering the storage tanks.

The geodesic dome roof may also reduce the risk of fire caused by lightning strikes as the dome (Faraday Cage phenomenon) has proven effective against lightning strikes. There should be no reason to additionally protect a covered internal floating roof from exposure to lightning, but bonding is required per API 650-H for other purposes.

These geodesic dome roofs on storage tanks (EFR or IFR) have introduced its own unique concerns in regard to the conventional fixed fire protection system installations, fire detection systems and firefighting of EFR tanks and also introduced new challenges in this regard for IFR tanks.

This guideline is intended to provide best practices incorporated Internationally on the types of fixed fire protection that can be installed on geodesic dome roof tanks including probable pros and cons with this installation. It is further intended to guide on firefighting philosophies that may assist in maintaining and extinguishing fires encountered in geodesic dome tanks.

3. Scope

Fixed fire protection for installation on geodesic dome roof tanks (IFR or EFR), detection (mainly the linear heat detection installation, positioning and maintenance challenges) and firefighting philosophies are in scope. All detection equipment should adhere to zone zero as the area classification under the roof is zone zero.

The construction, inspection and maintenance of geodesic dome roof tanks are out of scope

4. Definitions

Aluminium Dome: The aluminium dome is a fully triangulated structure designed as a self-supporting dome roof whereby only its outer edge is connected to the tank shell around the outer rim. These domes are fabricated from high strength aluminium alloys that resist corrosion as well as chemical, ultraviolet and ozone degradation.

Boil Over: "a sudden and violent ejection of crude oil from the tank due to the reaction of the hot-layer and the accumulation of water at the bottom of the tank. The light fractions of crude oil burn off, producing a heat wave in the residue. The residues with their associated heat wave sink towards the bottom of the tank. This heat wave will eventually reach the water that normally accumulates at the bottom of the tank, and when the two meet the water is superheated and subsequently boils, expanding explosively causing a violent ejection of the tank contents and fire. The expanding contents being expelled can travel the distance equivalent of ten tank diameters. Careful consideration should be given during pre-incident response planning of the location of the command post, staging areas, rehab, equipment placement, etc."

Floating Roof tank: The floating roof tank has a movable roof that floats on top of the liquid being stored. The space between the floating roof and the tank shell allows the roof to move freely as liquid is added to or withdrawn from the tank. Floating roofs are used to minimize evaporation losses and reduce the risk of fire, a flexible sealing device is attached to the floating roof. This sealing device can move freely up and down the tank shell and closes off the space between the rim of the roof and the tank shell.

Froth over: "Froth over is a steady, slow moving froth over the rim of a tank without a sudden and violent reaction. Froth over may occur when the tank is not on fire and where water already inside the tank comes in contact with hot viscous oil which is being loaded. An example is when hot asphalt is loaded into a tank car and comes into contact with water in the tank, causing the product to froth over the top. During a fire with crude oil it may also happen when the heat wave created by the burning crude oil reaches the water layers (stratums) in the crude oil. This heat wave will convert the water to steam, causing a froth over".

Geodesic dome roof: A geodesic dome roof, also known as a geodome, is a thin-shell structure based on a geodesic polyhedron. The elements of the dome are usually triangular shaped and are arranged in a pattern that, when completed, is structurally rigid and able to withstand relatively heavy loads compared to their low weight and size

Slop over: "This event can happen when a water stream is applied to the hot surface of burning oil, provided that the oil is viscous and the temperature exceeds the boiling point of water. It causes a short duration of slopping of froth over the rim of the tank with a minimum of intensity".

5. Risks of Storage tank fires

Over the years the number of fires in storage tank facilities has decreased, because the industry has improved on the design, construction, and fire protection requirements for these facilities.

The various codes and standards developed and maintained by the American Petroleum Institute (API) and the National Fire Protection Association (NFPA) have been improved and have assisted in reducing these incidents to the lowest levels in decades.

The actual tank sizes have increased significantly during the last few years which increases the hazard. A fire in these larger tanks can be extremely disruptive to business continuity, costly in terms of property damage, create environmental issues, affect national commerce and create reputational damage. A storage tank fire involving the full surface of the product contained within the tank will require a large commitment of resources, both equipment and human, and will require an extensive logistics structure.

The installation of the most effective fixed fire protection systems and most effective emergency response for geodesic roof tank fires may reduce the impact of such fire

6. Risks imposed by Geodesic dome roofs

6.1 Internal floating roof as well as geodesic dome is of very light aluminium construction and a **sudden collapse of the geodesic dome during seal fires** will most probably sink the floating roof.

i. The sudden application of the geodesic dome's weight on the floating roof could displace some of the burning liquid and possibly spray/expel some liquid from the seals and over the top of a nearly full tank.

ii. The collapsed dome may create numerous void spaces/pockets after the initial collapse, which could elongate a full surface foam application exhausting the foam concentrate supply.

iii. Dome stability during a seal fire, particularly when the tank is near full and there is high heat transfer and/or flame contact on the frame - Level of structural redundancy within the design of a geodesic frame (i.e. how many individual components can fail before the roof collapses)

iv. Larger diameters tanks may have been or need to be fitted with projecting type foam nozzles which traditionally extend inwards to or over the rim of the tank which will be damaged if/when the dome collapses

v. No fixed cooling system on geodesic domes (roof) as they are too fragile to support the installation. Retrofitting is not designed for additional weight bearing.

vi. Cooling by ground monitors can damage and collapse the roof

vii. How long will the geodesic dome survive heat radiation when exposed to an adjoining burning tank?

6.2 **Tanks with geodesic domes are not designed to be vapor tight.**

"Free Venting on an aluminium dome roof is normally achieved by having a gap approx. 200 mm between the dome roof and the curb angle on the tank shell. Therefore, it is not necessary to provide further venting on the tank as this gap will take care of air discharge during filling and air intake during discharge - irrespective of an IFR being fitted or not fitted".

6.3 The lattice work and panel construction of the dome may be more **susceptible to** arcing (between dome components) during a static/lightning induced electrical discharge if not constructed effectively or not maintained (Not function as a Faraday cage)

6.4 Domes are being installed on existing open top floating roof tanks and may not have foam dams, some units still have their original floating roofs and require rim seal pourers

6.5 In normal conditions in well maintained tanks there should not be vapours between floating roof and dome.

6.6 Barrel type pontoons cannot be inspected when the tank is in use. The open EFR have pontoons on the sides which can be inspected on a monthly basis.

6.7 Fire in the rim seal below the roof may not be visible with a delay in response if no fire detection is installed

7. Types of Tank Fires

7.1 Vent Fires

“Vent fires are typically associated with fixed roof tanks such as cone roof, covered floating roof tanks, dome roof, vertical low pressure fixed roof, and horizontal tanks. These are less severe fires and can usually be extinguished using a dry chemical extinguisher or reducing the pressure in the tank. Vent fires can be caused by lightning or sometimes hot work in the vicinity”.

7.2 Rim Seal Fires

“Rim seal fires comprise the large majority of fires in open top floating roof tanks. As with vent fires, lightning is usually the primary source of ignition. If the seals are not maintained, deterioration may cause fugitive vapor emissions to escape. When these vapours are in the flammable range they can ignite when exposed to an ignition source. There is usually a high rate of extinguishment success if there is no associated damage such as a pontoon explosion or if the suppression efforts do not sink the roof by using excessive water during firefighting”.

7.3 Overfill Ground Fires

“Overfill ground, dike, or bund fires result from piping or tank leakage. This may be caused by operator error, equipment or instrumentation failure. These incidents are considered the least severe. When a leak occurs without ignition, all ignition sources should be eliminated, and vapours suppressed. Remember that our fire appliances (apparatus) can be the source of ignition. If ignition does occur, the fire is treated as a large pool fire. If valves or piping are leaking, treat these areas as three-dimensional fires”.

7.4 Unobstructed Full Surface Fires

“With sufficient resources and trained personnel, unobstructed full surface fires are relatively easy to extinguish on relatively small tanks (less than 45.72 meters [150’]). Larger tanks greater than this size will be much more challenging because of the size of the tanks, application and flow rates required, resources required, and the logistics involved with the firefighting efforts. Unobstructed full surface fires can occur in fixed roof tanks without internal roofs when the weak seam at the roof-shell joint separates from an explosion or other over-pressure event, leaving an exposed full liquid surface in the tank. EFR tanks can have unobstructed full surface fires when heavy loads (e.g., rains) exceed the weight capacity of the roof, causing it to sink below the surface of the product. This may also occur if the roof drains have been left closed during periods of heavy rains”.

7.5 Obstructed Full Surface Fires

“Full surface fires with a fully or partially sunken roof can occur where tanks have fixed roofs, internally floating roofs, or external floating roofs. These fires are challenging because access to the burning surface is blocked by the roof or floating roof (pan). An increase in vapour pressure between the liquid and the roof can cause the pan to tilt, partially exposing product above the pan. Pontoon failure may also cause a pan to sink. Heavy rains may also tilt or sink a pan”.

8. Geodesic Dome Tank Fires with Challenges

8.1 Rim Seal Fires

Rim seal fires in internal floating roof tanks without fixed foam system may be very challenging as the only openings to apply foam into the tank would be the small vent openings at the top of the tank. These openings typically have protective screens in them, hampering foam application further. With open top and internal floating roof tanks, fixed or semi-fixed foam systems are the preferred method of extinguishment for rim seal fires.

8.2 Obstructed Full Surface Fires

"Full surface fires with a fully or partially sunken roof can occur where tanks have fixed roofs, internally floating roofs, or external floating roofs. These fires are challenging because access to the burning surface is blocked by the roof or floating roof (pan). An increase in vapor pressure between the liquid and the roof can cause the pan to tilt, partially exposing product above the pan. Pontoon failure may also cause a pan to sink. Collapse of the geodesic dome due to a Rim seal fire or other failure may also tilt or sink a pan".

9. Fixed fire Protection for Atmospheric storage tanks

Fire Protection Systems

Fixed and semi-fixed fire protection systems are used in industry to protect various equipment and processes. (**Appendix 1)**. Water and foam-based systems may be activated manually or activated by the use of devices such as smoke, heat, or flame detectors. A semi-fixed system is required to be supported by a fire vehicle.

9.1 Rim Seal Protection

Is installed on either an open top or covered floating roof tank. The rim seal will typically have a 30 cm to 60 cm foam dam designed to hold the foam in the rim seal area so that it can flow and extinguish fire along the seal. These systems can either be fixed or semi-fixed. The manual procedures could include starting the fire and foam pumps as well as opening and/or closing valves. A semi-fixed system will require a fire vehicle to connect to a lateral terminal connection and supply the foam chambers with foam solution at a specific pressure.

Foam chambers are typically installed for rim seal protection, but in some instances, they may be installed for extinguishment of full surface fires in both floating roof and covered storage tanks.

9.2 Subsurface Injection

Subsurface injection may be found on some covered roof storage tanks. Aqueous Film Forming Foams (AFFF) have low fuel tolerance and will not effectively rise to the surface. Subsurface injection also cannot be used with polar solvent products. The foam solution must be injected above the water level in the tank. Foam injected below this level will dissolve into the water and not rise to the surface.

9.3 Cooling Systems

Cooling rings (**Appendix 2)** on the exterior of the tank are placed so that they discharge water onto the tank's exterior, protecting it from radiant heat from fire in close proximity. In many instances, these systems will have to be manually activated.

9.4 Linear Heat detection

Linear heat detection poses challenges in terms of the positioning and maintenance once installed. A good practice may be utilizing the vents and installing the detectors at a higher position. This will however require sensitivity temperature adjustments and a detailed engineering solution to support this installation by technical experts.

10. New Technologies

New technologies have been developed to make fixed and semi-fixed systems more efficient. As tank diameters increase, the degree of difficulty for extinguishment also increases. Some of the new technologies for storage tank fire protection are:

10.1 Dual Agent Chambers

Traditional foam chambers would aerate the foam and distribute it evenly on rim seal or full surface fires. (**Appendix 3)** A dual agent chamber is a two-phase application through the same chamber. The first phase cascades a rich blanket of foam to extinguish and seal the surface of the contained product, while the second phase injects dry chemical powder to evacuate the internal vapor space of any lingering flammable vapours, rendering the space inert. These systems would be used on covered tanks.

10.2 Multiple Discharge System (Down and Left/Right Lateral)

A Multiple discharge system (**Appendix 4 and 5)** provides a more aggressive and more efficient foam application as compared to traditional foam chambers. These systems may provide as much as 73 meters of coverage from one wand, a 200% increase in performance over a foam chamber. The foam wand will distribute foam from three orifices, two lateral and one discharging down the wall of the tank immediately below the wand. An optional feature is the addition of a separate riser to allow a specialized monitor to be quickly deployed and mounted to the tanks rim for additional extinguishment and/or vapor suppression.

10.3 Multiple Discharge System (Central and Left /right Lateral)

These types of systems (**Appendix 6)** were developed to overcome issues faced by foam chambers when they are installed on a fixed or cone roof tank for the purpose of full surface protection. When foam chambers are installed, they rely on gravitational forces and the static head pressure of the foam to provide the propulsion for the foam to cover the surface area of the product. This system projects the foam toward the center of the tank as well as to the left and right along the tank wall.

10.4 Multiple Discharge System (Central, Down and Left /right Lateral)

These systems (**Appendix 7)** are designed for use on large diameter jumbo (>120-meter diameter tanks) storage tanks. Type II “Over the top” applications on these tanks require huge amounts of resources and firefighting equipment. This system is designed to provide enhanced fixed system response for external floating roof storage tanks. The system reduces foam fallout from the stream to provide more efficient foam/water application densities. It addresses four distinct areas of the tank simultaneously; the area to the left of the wand, the area to the right of the wand, the Centre of the tank, and the area directly below the wand. Multiple units may be required for complete coverage depending on the tank diameter.

11. Firefighting Strategies and Tactics

11.1 Pre-Incident Response Planning

Pre-incident response planning information that should be gathered may include the following:

I. Type of Tank, Tank dimensions, contents and volume
II. Pipe isolation valves, locations, and operating mechanism
III. Fixed fire protection systems
IV. Access to facility and tank
V. Contact numbers
VI. Locations and operation of emergency shutdown devices (ESD's)
VII. Availability of firefighting resources
VIII. Fire Water supplies
IX. Pumping requirements
X. Foam concentrate requirements
XI. Mutual/automatic aid available

11.2 Size Up

An emergency call should supply the following information to plan firefighting strategies:

I. Personnel needing rescue
II. Life safety hazards to site personnel
III. Extension
IV. Confinement
V. Extinguishment
VI. Environmental impact
VII. Community impact

The type of fire present:

I. Vent fire
II. Seal fire

III. Flange fire
IV. Full surface fire
V. Overfill fire
VI. Tank and dike (bund) fire
VII. Multiple tank fires
VIII. Exposures

11.3 Firefighting tactics

11.3.1 Ground Spill or Dike Fires

I. These are pool or spill fires.
II. The Product type will dictate the correct type of foam concentrate and application method.
III. Firefighters should not enter the dike area unless safe to do so.
IV. Exposures such as tanks, associated piping, and pumps should be protected with water via ground or fixed monitors.
V. Ground fires should be extinguished first, then using dry-chemical equipment, the valves and flanges can be extinguished. The most effective equipment for these combined fires would be hydro-chem™ technology whereby foam/water solution as well as dry-chemical can be delivered simultaneously through the same nozzle.

11.3.2 Rim Seal Fires

I. Rim seal fires can usually be extinguished by using the fixed or semi-fixed foam systems installed.
II. On external floating roof tanks, if the fixed or semi-fixed fire protection systems are not present, manual firefighting will need to be performed. A firefighting crew will ascend to the gauging platform with hand-held foam equipment. The primary method should be the use of foam wands to capture the fire which allows the placement of specialized monitors to be placed on the lip of the tank. **(Appendix 8 Specialized portable monitor)** These monitors can then be used to extinguish the rim seal fire so that hose lines and personnel are not operating

from the wind girder away from the ladder. If this equipment is not available, then foam hose lines could be used from the wind girder. This is a hazardous operation and Personnel should be secured to prevent falling.

III. In some instances, elevated streams from fire vehicles may be used which may sink or tilt the roof under the excess water/foam solution if not done properly and create an obstructed /unobstructed full surface fire.

IV. On tanks fitted with internal floating roofs, these fires may be considered rare, but they do occur. They will be extremely difficult to extinguish unless fixed or semi-fixed fire protection systems are installed. Foam chambers and foam dams are the most effective, and the design of the system should be calculated on a full surface fire, especially if the pan below is aluminium.

V. The most difficult method of extinguishment in a covered floating roof tank will be to shoot foam water solution through the eyebrow vents. Using hydro-chem™ into these vents has proven effective in the past

VI. Dedicated spotters be placed to monitor the dome during all seal fire operations (Use of Drones is a good practice).

VII. Evacuation be undertaken immediately if any roof movement or frame component failures are noted/suspected.

VIII. Evacuation routes and signals be in place prior to undertaking seal fire operations.

IX. The resources for full surface extinguishment be summoned immediately to be on standby in case of dome collapse

11.3.3 Full Surface Fires

I. Staffing requirements for a major tank fire will vary depending on the type of tank, location, water supplies, nature of the incident and the availability of trained personnel.

II. These fires will predominantly use the Type III “Over the Top” method of extinguishing agent delivery.

III. The product involved will determine the required foam application rate and percentage of concentrate to water flowed. The size of the tank will also determine the application rate. For larger tank diameters a larger application rate is required.

Other factors that are important:

I. Position and condition of roof drains
II. Product volume in the Tank
III. Status of tanks and valves
IV. Depth of water bottoms
V. Structural condition of tank
VI. Physical properties of product in the tank
VII. Is there room in the tank to accept the total foam solution without causing an overfill
VIII. What other tanks, piping, or structures may be exposed
IX. Wind direction
X. Weather conditions

11.4 Firefighting strategy

I. Do not attempt to extinguish a full surface fire without all necessary resources on the scene.
II. Cooling of adjacent tanks would be a tactic to be used prior to all foam delivery and personnel resources are on the scene.
III. The cooling of the tank that is on fire is not recommended unless complete 360-degree cooling can be accomplished, which is rare.
IV. When cooling a tank, use only the amount of water necessary.
V. When the cooling water stops turning to steam, you may shut down the streams and start them up again when necessary.
This will conserve water supplies for extinguishment and reduce the water flowing into the dike areas.

VI. Foam can travel effectively across at least 30m of burning liquid According to the National Fire Protection Association (NFPA) but it may be good when calculating foam runs to reduce this number to 24m to ensure that the landing zones travel and overlap each other.

VII. Attacks on these fires will predominantly use the Type III "Over the Top" method of extinguishing agent delivery which may be hampered by the Dome roof still intact/Partially intact and Floating roof sunk/partially sunk – Obstructed full surface fire.

12. Fixed Fire Protection and Geodesic Domes

12.1 Foam systems

Geodome tanks can be protected using specialized products:

I. Roof panel penetration systems for geodesic dome seal protection. A pipe is installed up and over the walkway which allow a nozzle to penetrate a single dome panel. A boot/cuff can be installed on the pipe where it goes through the panel. These can be spaced around the circumference of the tank and minimize dome penetration/supply piping

II. The multiple discharge system that may be applied under the roof. It fits under the dome and is fed by a standpipe system that can be manifolded away from the tank for safe operation.

III. Multiple discharge system simply penetrating the shell at the very top of the tank **does not provide seal protection**. The tank either didn’t have a foam dam or had supplemental seal protection.

IV. An IFR that has no foam dam must be designed for full surface protection. The assumption is made that this type of roof will sink during an incident and top pourers designed to go through the roof panel to avoid damage if the roof collapses.

V. Floating roofs that are structurally adequate to hold a foam dam are also substantial enough to contain a fire in the seal area in which case rim seal pourers are most effective. Small foam makers are installed above the hi-hi level of the tank and utilize shallow deflectors. The shallow deflectors, in the event of an overfill, will allow the pontoon to rise over the deflector and not get hung up.

VI. Fixed foam systems for the protection of the rim seal for the tanks (rim seal pourers) should be the type that penetrate the roof panel to avoid damage if the roof does collapse. (**Appendix 9)**

VII. Annual maintenance on the fixed pourers will require the installation of spades between pourer and tank and removal of the bursting disks for the test.

12.2 Water system:

I. Fixed water spray cooling systems for the roof (roof cooling) could prevent the roof to collapse in case of radiant heat from adjacent burning tank. Roof to be designed for the additional load.

II. Fixed fire water monitors or water curtain systems can be considered when the roof is not designed for the additional load. It can be installed on the tank shell rim covering the lower exposed panels.

12.3 Other Protection:

I. An external thermal imaging camera or a beam thermal imaging that monitors all tanks for heat. Assist with early detection of a rim seal fire IFR.

13. Appendixes

Appendix 1: Foam injection system for storage tank fire protection.

Source:https://i2.wp.com/iffmag.mdmpublishing.com/wpcontent/uploads/sites/3/2015/03/IFF_45_Mar15_Storage_2_CS.png

Appendix 2: Cooling rings on storage tank.

Source: https://i0.wp.com/iffmag.mdmpublishing.com/wp-content/uploads/sites/3/2015/03/IFF_45_Mar15_Storage_4_CS.png

Appendix 3: Foam chamber and Dual Agent Foam chamber

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Source:https://1nvksv2pf5341ixqxh4bvi52-wpengine.netdna-ssl.com/wpcontent/uploads/sites/3/2015/05/IFF_46_Jun15_Storage_CS_1.png

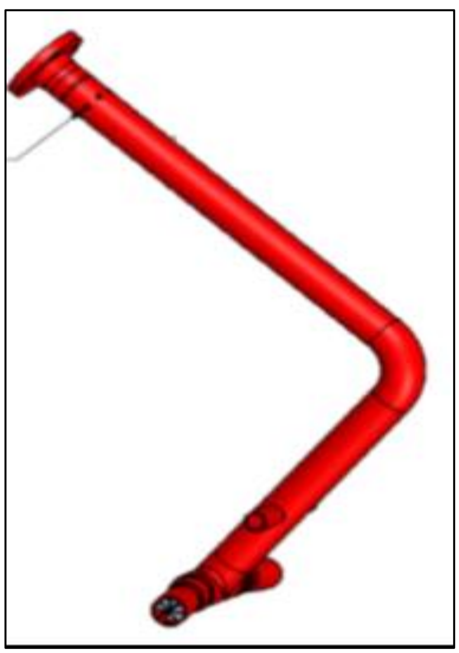
Appendix 4: Multiple Discharge System

Note the two lateral and one downward discharge ports.

Source:https://i0.wp.com/iffmag.mdmpublishing.com/wp-content/uploads/sites/3/2015/03/IFF_45_Mar15_Storage_5_CS.png

Appendix 5: Multiple Discharge System

Note the two lateral and one downward discharge ports

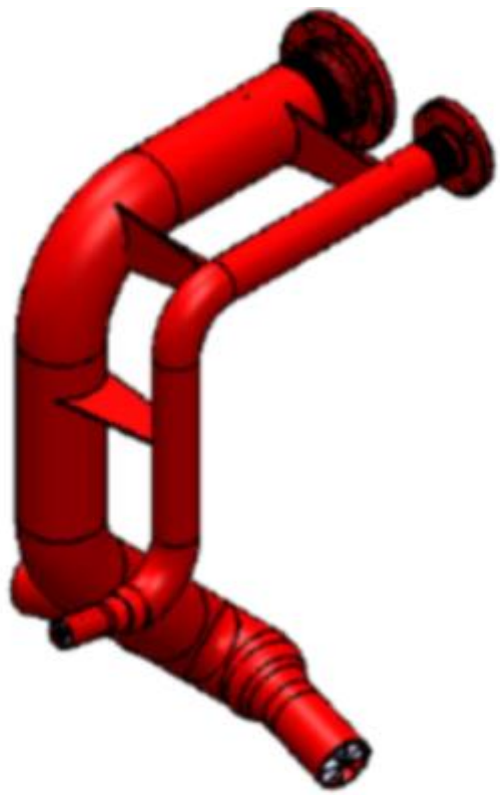


Appendix 6: Multiple Discharge System.

Note the two lateral and one central discharge ports

Appendix 7: Multiple Discharge System

Note the two lateral, one downward discharge ports



Appendix 8: Specialized portable monitor placed on lip of storage tank

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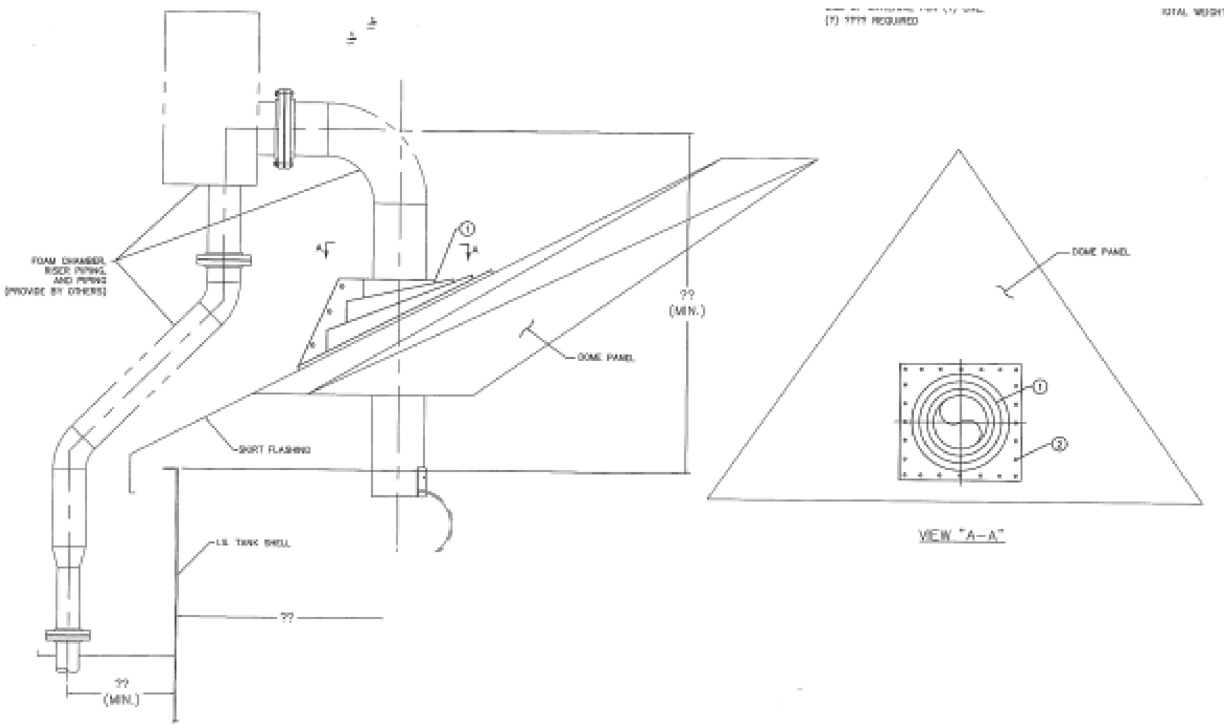
Source: https://1nvksv2pf5341ixqxh4bvi52-wpengine.netdna-ssl.com/wp-content/uploads/sites/3/2015/05/IFF_46_Jun15_Storage_CS_2.png

Appendix 9: Pourer through roof panel



Appendix 10: Fire detection system in rim seal area.
Interruption in electrical current by fire will activate foam system.

Source: https://i1.wp.com/iffmag.mdmpublishing.com/wp-content/uploads/sites/3/2015/03/IFF_45_Mar15_Storage_1_CS.png

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Standards:
American Petroleum Institute (API)-RP-2016(2001): Guidelines and procedures for entering and cleaning of petroleum storage tanks
American Petroleum Institute (AP)I 650 (2007): Welded steel tanks for oil storage
National Fire Protection Association (NFPA) 11
South Africa National Standards (SANS) 10089-1

END