Lightning-related petroleum storage tanks fires are not uncommon. Of the 480 petroleum storage tank fires between 1951 and 2003, about one-third were attributed to lightning

Total lightning protection

Lightning protection systems for floating roof petroleum storage tanks (FRTs) should do more than just intercept incoming lightning strikes, which are still likely to cause ignition of the tanks' contents. A total FRT lightning protection system (LPS) should be designed to eliminate all lightning related direct and indirect risks.

A RGA on a floating roof tank

How lightning causes tank fires

The typical strike location on an FRT is the top of the rim or the gauge pole. The FRT is endangered if a stroke terminates on the roof, the shell, anything attached to the roof or shell, or a structure or ground near the FRT. Termination on any of these locations will cause a portion of the total lightning current to flow across the roof-shell interface. If lightning terminates near an FRT, either to the earth or a nearby structure, smaller currents will flow across the roof-shell interface. If the impedance between the roof and shell is high, arcing will occur across the seal.

Lightning strikes are high stroke currents arriving in a very brief time. A typical lightning stroke contains numerous components. The first return stroke (A) is extremely brief, yet contains the peak current. The long, slow component (C) contains less current, but is defined as the continuing current component. This component lasts 500-2,000 times longer than the fast component and thus contains the most energy.

Between components A and C is a transitional, intermediate phase (component B), where the current transitions from fast to slow. Following component C, additional subsequent return strokes (component D) typically occur, followed by additional components B and C, which typically continue to flow until the entire lightning flash is exhausted.

API response

Because of the high incidence of lightning related tank fires, the API formed a technical committee to write a standard to force changes in petroleum storage practices. Key findings included:

1. Shunts arc under all conditions, whether they are clean, dirty, rusty or well-maintained
2. The fast component of the lightning stroke did not cause ignition of flammable vapours, whereas the long duration component did
3. Bypass conductors will carry the intermediate and long duration components of the lightning stroke. If these components were allowed to flow through the shunts, sustained, hazardous arcing would occur, which would ignite any flammable vapours present.

API recommendations

API RP 545, 'Recommended Practice for Lightning Protection of Above Ground Storage Tanks for Flammable or Combustible Liquid' was published in October 2009 and makes three key recommendations to improve the lightning safety of FRTs:

1. Install submerged shunts between the roof and shell every 3m around the roof perimeter. The shunts should be submerged by 0.3m or more, and existing above-seal shunts should be removed
2. Electrically insulate all seal assembly components (including springs, scissor assemblies, seal membranes), and all gauge and guide poles, from the tank roof. The insulation should be one kilovolt or more

3. Install bypass conductors between the roof and shell no more than every 30m around tank circumference. These conductors should be as short as possible and evenly spaced around the roof perimeter and have a maximum end-to-end resistance of 0.03ohms with a minimum length necessary to permit full movement of the floating roof.

Evaluation of API RP 545 recommendations

1. Submerged shunts are used for the conduction of the fast and intermediate duration components of the lightning stroke current (LSC). The API acknowledges that arcing occurs between the shunt and shell during all lightning events. If the shunt is submerged, then theoretically the arcing will occur where no air/oxygen is present and ignition will be avoided. Submerged shunts on new tanks will require substantial design changes. On existing tanks, the changeover from above-seal to submerged shunts will be very costly and will require major overhauls and inspection and maintenance will be difficult
2. Insulation of seal components and poles will encourage lightning currents to travel through preferential paths (shunts and bypass conductors) rather than arcing between the roof and shell. It is debatable if the recommended insulation level of 1kV will be sufficient to cause the desired outcome. Substantial design changes and costly field modifications will be required to implement this recommendation
3. Bypass conductors are used for the conduction of the intermediate and long duration components of the LSC. One observation from testing was the long component of the lightning stroke caused ignition. With above-seal shunts, the sustained arc at the shunts lasted long enough to ignite flammable vapours. Bypass conductors will provide a positive bond and a lower impedance connection between the roof and shell, as compared to the shunts. The long component of the lightning current will be diverted through the bypass conductors. The installation of bypass conductors is relatively easy and inexpensive, on both existing and new tanks and they are easy to inspect and maintain.

Types of bypass conductors

In response to these requirements, tank owners have a choice between two different types of bypass conductors: a conventional fixed length, stranded conductor; or a retractable conductor wound on a spring-tensioned reel.

The ideal bond between the FRT roof and shell would have a low impedance across a wide range of frequencies, be easy to install on new tanks and to retrofit onto existing tanks, easy to inspect and test, and easy to replace when required. US-based Lightning Eliminators & Consultants (LEC) has patented a Retractable Grounding Assembly (RGA) that provides the lowest possible impedance bond between the floating roof and tank shell.

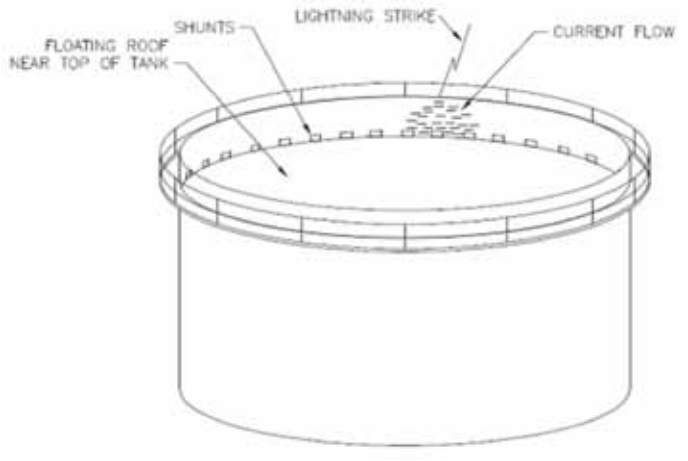
The RGA's conductor is spring-tensioned, meaning that it automatically retracts on the reel when it is not under tension. Therefore, the RGA conductor is always 'of the minimum length necessary' per API RP 545.

LEC's RGA conductor is braided copper strands 40 times more conductive than stainless steel. Stainless steel bypass conductors will not meet the 0.03 ohm requirement of API RP 545.

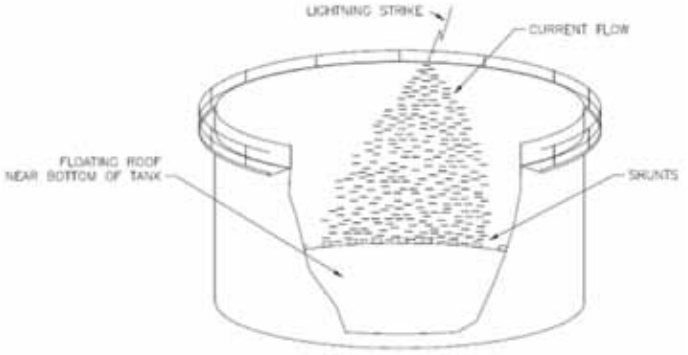
Conventional versus retractable

An FRT is most at risk, and all of the hazards from lightning tend to be worse, when the roof is high. During these conditions, the lightning current flows will be concentrated in the shunts directly below the lightning strike location. In comparison, when the tank roof is low and a lightning strike terminates on the tank, the lightning current disperses and is more evenly distributed among the available roof-shell bonds.

During high-roof conditions, when the tank is most at risk, the conventional bypass conductor will be randomly splayed and coiled on the tank roof. In comparison, when the roof is high the RGA conductor will be as short as possible and provide about one-sixth of the impedance of conventional bonding cables.



Concentration of lightning current flow when roof is high



Dispersion of lightning current flow when roof is low

Direct lightning strike protection

A direct lightning strike will cause an abrupt voltage rise of thousands or millions of volts at the termination point. If a lightning strike terminates directly on an FRT, it is likely the voltage between the seal assembly components and the roof, and/or the gauge and guide poles and the roof, would exceed the API recommended insulation level of 1kV. This could easily lead to an arc in a dangerous vapour space.

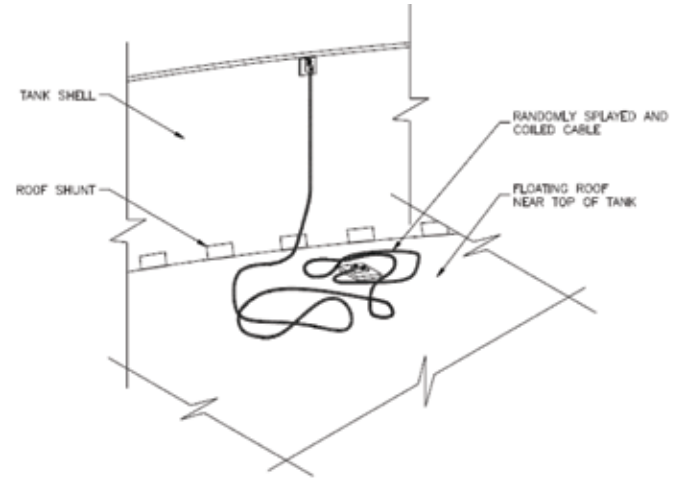
The safest possible environment for an FRT, even with RGAs, would be one where lightning does not terminate directly on the tank. This can be accomplished by the installation of a Dissipation Array System (DAS) on the FRT. A DAS is a lightning strike avoidance system to prevent the termination of lightning strikes on itself or on the protected structure. The DAS produces a combination of effects on the protected structure, which include:

1. The reduction of the electric field
2. The reduction of charge accumulation
3. The retardation of upward streamers being launched from the protected structure.

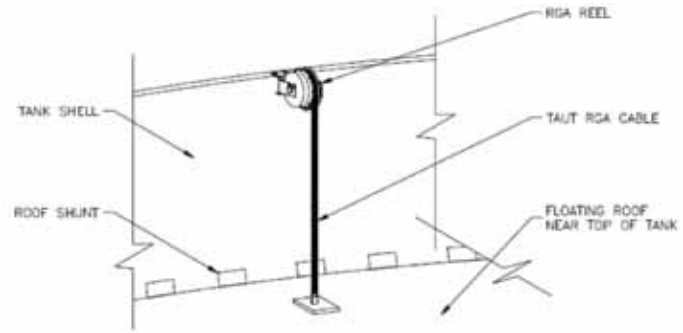
Hundreds of FRTs have been protected using DAS with no known failures. Numerous field tests of the DAS have been conducted in real world applications. In one DAS field test, the customer recorded lightning activity three years before and three years after DAS installation. After the DAS installation, the customer realised an 80% reduction of lightning strikes within a 500m radius of the DAS plus recorded zero direct strikes to the protected structure. Similar results have been found by several independent, third party tests.

Lightning risk management

It is important to understand that the two solutions, RGA and DAS, function



Conventional cable as bypass conductor



RGA as bypass conductor

independently. The implementation of one solution and not the other will have different effects on the safety of an FRT. A risk management evaluation of each solution is important to understand each solution's unique benefits and quantify the return on investment.

An FRT located in a high lightning area, will have a greater chance of a lightning incident. However, just because a tank may be in a low lightning area does not mean that the lightning risk is zero, which is why API 545 includes all tanks without regard to their location.

Even in a low probability area of lightning directly striking an FRT, there is still inherent risk. The DAS is recommended to completely eliminate the possibility of all direct lightning strikes. By implementing DAS and RGA, an operator is truly eliminating all risk associated with direct and indirect lightning strike activity.

Summary

Lightning is the most common source of ignition in 52 of 55 rim seal fires, so the risks must be properly managed. The level of protection is dependent upon the tank owner's risk tolerance. An owner not willing to accept any risk of lightning-related damages should implement both DAS and RGA systems.

However, an FRT owner may accept some level of lightning risk. The likelihood of a lightning strike terminating in the vicinity of an FRT is greater than the likelihood of a lightning strike terminating directly on an FRT. In this situation, a RGA solution could be implemented first. This will provide a high level of risk reduction. If needed, DAS can be added at a later date. If the FRT owner desires to eliminate the total lightning-related risk, then both DAS and RGA systems should be installed.

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