Stability of fire barriers in tank farms in case of destruction of vertical tanks

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Abstract. The issue of raising the level of safety of people, lands and property from potential threats in emergency situations in oil and gas storage and processing sites is particular concern to all levels of authority in countries, whether they are legal or executive authority.

Study of the statistical data of incidents and fires at these equipment showed that the most negative effects for the damage to the company's personnel, the population and the environment occurred during the quasi-instantaneous destruction of the vertical steel tank. The distinguishing features of such an accident are the complete loss of the integrity of the vertical oil tank hull and the release of all the liquid stored in the tank in the form of a powerful flow (breakout wave), which has a great destructive power, to the adjacent territory within a short term of time.

The most important measures to reduce oil and petroleum products leakage in tank farms are reinforced earth dams and closed walls made of materials that are vulnerable to heat (important in the case of fire), Which led to many unsolvable cases. Recently, vertical steel tank with double walls of the "glass in a glass "type have been used in some oil tanks, in practice, they have not found wide application, which is due, first of all, it needs to allocate a significant territory for their arrangement, and its high cost.

1 Introduction

Tank farms are the main storage site for crude oil and petroleum products at refineries, Harbors, railway and airports [1]. Because of the oil design peculiarities, and the presence of the liquid petroleum in the form of crude oil, gasoline, diesel and kerosene… etc, the oil facilities industry finds itself prone to a range of major problems such as explosions, fires, emissions of dangerous materials… etc [2] .

Oil tanks are usually used as reservoir for large quantities of flammable chemicals in petrochemical and chemical products. When a tank fire happens, the event usually leads to million-dollar ownership losses and serious negative social impacts [3]. When the fuel-air mixture or stored fuel is inflamed, it may break out a large fire or big accident like explosion (in the time of cleaning, rust inhibitor, painting with a spray, storage tank servicing, welding, loading and unloading works... etc), while inflammable liquids for a relatively small the area of the oil tank farm leads to an intension fire hazard in like these industries[4].

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The tank fire is one of the biggest unsafe emergencies that can lead to not only significant material damage, but also human casualties. The situation is getting more complicated and the economically driven trend towards reservoirs larger volume, which further increases the volume of flammable liquids, per unit area. This, in turn, increases danger of fire spreading to neighboring tanks in the absence of timely localization and elimination of the source of combustion [1].

Walls for fire barriers can be used to split buildings into separate areas, which are constructed in accordance with locally applicable building codes. Retardant flame and Fire walls are part of the building's inherent fire preservation systems [5]. These walls also can be used to unrelated high-value transformers in power plants in the event of a break in mineral oil tanks or ignition [6].

One of the typical and most dangerous in its consequences types of emergencies in tank farms is the spill of oil or oil product with the complete destruction of a vertical steel tank . The area of spillage of stored products during the destruction of tanks reaches hundreds of thousands of square meters, as example In Russia, two or three accidents of this nature are registered annually [7].

The greatest effective and economically feasible preventive structures is a protective wall with a baffle cap, capable not only of containing the penetration wave and the entire volume of the spilled fluid when the reservoir collapses within the delayed borders, but also to minimize the effect of a hydrodynamic accident.

In recent times, to prevent leakage and spillage of oil and petroleum products, two-wall tanks (double) have been used [8]. After reviewing previous studies, it was found that there are no such studies, because what has been observed in these studies is that they only consider document provision issues. Regulatory in the field of equipping and constructing steel tanks for oil, gasoline, diesel ... etc., without concern for the effectiveness of additional barriers to eliminate the risks of oil liquid spills in the event of a tank breakdown, such as an added wall (double) with a shield to absorb strong shocks as a result of the spill [9].

This study focuses on recognizing and analyzing important variables relating to accidents. This analysis may be useful in illustrating what the manufacturing should learn from these accidents and be more alert in the future to stop as far as possible, any future major accidents.

2 Analysis

Many fires and explosions (about 90%) [1], as statistics show, occur in vertical cylindrical steel tanks, which are the most popular. The statistics also show that tanks with a fixed roof and also floating roof are the most vulnerable, which are used to reduce the loss of oil as a result of its evaporation. Due to the lower vaporization of the oil product, it the concentration surpass the lower concentration limit of flame spread, which leads to the formation of explosive mixtures, big fire from an ignition source, which most often occurs when the roof be defective due to its distortions.

The least dangerous are tanks with a floating roof. Based on the analysis of statistical data on fires in tanks with oil products, it should be noted that the main causes of fires are: high temperature and repair work, sparks of electrical installations, manifestations of atmospheric electricity, static discharges electricity. A third of all tank fires have resulted from spontaneous burning of pyrophoric residue, careless handling of fire, incendiarism and other sources. At the same time, about 30% of fires on operating tanks occur when technology is infringe [1].

According to statistics, fires in tanks with oil products most often end in partial or complete devastation (fig.1.), the greatest danger is the complete destruction of the oil tank, which is escort by the release (spill) of oil, which can lead to disastrous effects with great material harm and loss of life.

Fig. 1. The tank "collapsed" as a result of an explosion and fire.

Realization of materials related to the destruction of tanks, showed that the most harmful component leads to the fire, is the hydrodynamic outflow of a flammable liquid (oil product), which is storage in the tank.

The risk of such tanks is caused not only by fire and explosion hazardous characteristics of petroleum products, but also structural the features of the reservoirs, their volume, the increase of which is significant features the fire protection of tank fields.

With enlargement the diameter of the tank with increases combustion intensity increases heat flow from the fire. Rising the height of the tank, in turn, complicates the equipping of extinguishing factors to the tank. In case of devastation, the spilled oil product covers a big area, putting people's lives at risk, and causing significant material damage.

Serious danger in the fighting fires in tank farms is tanks adjacent to a burning fire, heating these tanks can lead to inflammation of vapors of petroleum products on respiration valves on the roof or an explosion of steam and vapors inside the tank.

A fire in a tank with an oil product usually starts with explosion of a vapor-air mixture located in the gas space between roof and liquid surface. As a result of the explosion, a complete or partial destruction of the roof of the tank and a fire breaks out. Much less often the explosion of the vapor-air mixture is accompanied by destruction the walls of the tank with the spill of its contents. If concentration the vapor-air mixture in the tank will be higher than the upper concentration limit of flame propagation, the fire begins with ignition and torch combustion of the jet exiting through the breathing armature, open hatches or through non-tightness in the roof and top of the hull.

The boiling point of petroleum products is associated with the existence of water in the form of very small drizzles in the mass of liquid. Boil characterized by violent foaming of the product (increases by 4-5 times volume of heated liquid). Ejection oil product occurs when the formed homothermal layer of oil or fuel oil, heated to a temperature of more 140-150 C^{o}, reaches the bottom water layer. At the same period, the water overheats, a significant part of it goes into steam, which throws the oil product out of the reservoir. Tens of tons of petroleum product can be thrown onto large distance and cover an area of several thousand square meters with all the reservoirs and structures located on it.

Fires in tanks with light oil products are usually start with an explosion of a vapor-air mixture in a gas space

tank and roof tearing or combustion of a vapor-air mixture in a gas space of the tank without tearing off the roof, but with violation of its integrity in some of the weakest points. In tanks with dark oil products with water pillow (regardless of its thickness), boiling and overflow of burning products through the side (shaft) of tank, and explosive ejections of liquid to a great height, (when boiled oil products, the height of the flame will increase to 70-80 m).

The important structures for limitation the spill of oil or any other oil product in tank farms are earth barries and enclosing walls made of non-combustible items, the computation of which is made only for the hydrostatic compression of the spilled material. The analysis of the effects of the destruction of the vertical steel tank showed that such embankments are not qualified for of holding the penetration wave, which has frequently led to a contingency.

Interesting is the behavior of an additional protective wall of a tank of the "glass in a glass" type in the event of a thermic impact of a fire, its constancy and procedures of extinguishing in the inner wall area.

Structured analysis of documents in the field of fire security and the structure of oil tanks with a defensive wall showed that, in fact [8], there are no general state standards for this kind of problems, So we can say that basis of standard documentation is created by industry-specific normative papers and records of the level of standards of institutions and companies (STO, SO, references, instructions).

Anyway, too much of them disagree to each other, let us talk about example, as it is written in GOST 31385-2008 [10], STO-SA-03-002-2009 [11] and the security directory for vertical cylindrical steel tanks for oil and oil products, the thickness of the inner wall area should be at least 1.8 m, while as it is in the basics for the technical procedures of oil tanks (JSC NK Rosneft), the minimum is 1.5 m (in many other references, they said it should be 1.5 m).

Necessity of present Organized documents for extinguishing protection of tanks do not take into account the special features for tanks with a defensive wall, materialistic and alchemical characteristics, different variables burning of storage kinds of crude oil or gasoline, diesel…etc, and styling characteristics.

These days, the only official paper that takes into consideration the particular place of fire extinguishing and equipment for cooling tanks with a defensive wall, is the norm of the agency "Rostekhekspertiza" STO-SA-03-002-2009.

It is worth noting that tanks with a (glass-in-glass) protective wall are used at production sites, also tanks with a defensive wall are constructed near water places (rivers, lake…) and the locations where human living to guarantee the security of the surroundings and the residents.

It is worth saying that the presence of a wall around the cylindrical tank (a wall of protection) helps us to reduce the effect of oil product leakage in the event of the tank's high pressure, and thus the oil leakage will not be over large areas, but in the circular clearance, and thus the area of evaporation will be reduced to the maximum, thus preserving On the environment and reducing material loss - one of the advantages also is that the oil product can be pumped to another tank (because it will still be in good condition) [9].

One of the advantages of having an additional wall around the oil tank is not to allocate a large area around the tank for emergencies around the tank, and with the advancement of the design of this wall, we may reach to cancel this space, and it is intuitive that we have the spacing between each tank and the adjacent tank a little, this leads us to become a space

Oil depots are much less, which makes it easier to monitor and notice accidents faster and reduce the response time to the risk, as it achieves money savings as a result of the need for less land.

The design of the tanks with a protective wall (Fig. 2). It can be noted that one of the important pluses is that the tank will consist of two parts (internal and external), and more clearly we say that the inner tank is for the stored material and its preservation, while the outer one is important in case of emergency (when a spill or explosion occurs in the inner tank, the spill will be preserved outside.). We also point out that this solution is suitable whether the tank has a floating or fixed roof.

The height of the outer wall should be 80% of the height of the inner tank walls. As for the external tank diameter (its volume), we must take into account that when a stored liquid spill occurs, the liquid will move to the outer basin, and the level of the liquid in the external tank after collapsing must be one meter lower than the highest point in this wall, preferably the width of not less This wall is about 1.5 meters [9].

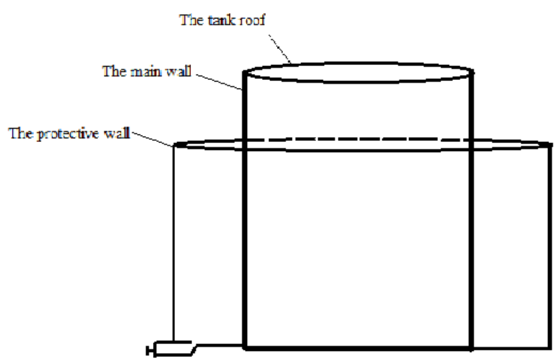

Fig. 2. Design of tank with a protective (double) wall

As a result of previous studies conducted to analyze various accidents in oil reservoirs emergencies, we find that the development and increase of rigidity is very important for tanks with a double wall, and perhaps it is also more beneficial to strengthen the wall of the internal oil reservoir and enhance its durability. The researchers concluded the above after a great effort in the field of mathematics, calculations, and simulating the spill accident and the destruction of the internal tank wall [12].

Based on what was mentioned previously we understand importance of timely noticing rifts in the form of the inner tank, as well as discovering the structure of combustible vapor -air environment in the inner-tank space.

In specific way, it is advised to produce strengthening of the main wall of the tank with high-strength wires and strengthening with circle solidity of the outer wall, however, for the accomplishment in practice of such useful solutions require academic and empirical analysis.

To keep out the chance of formation -flammable mixture with air- in the inner-wall space of tank in case of pressure reduction of the walls of internal tanks and tubes, many experts suggest introducing non-combustible (inert) gases into it[9].

When a adequate amount of inert gas is introduced into the inflammable mixture, ignition it becomes not possible. However, the use of nitrogen as a phlegmatizer seriously complicates and increases the price of the process, requiring extra tools for its storage and transporting, as well as the use of a gas regularize system, according to which a possible fire can spread to neighboring tanks even when used fire arresters.

In case of depressurization of the main tank, it is necessary to resolve the issues:

- assessing the possibility of the formation of a combustible mixture in the inter-wall space and its detection.
- Stability of the protective wall in case of fire.
- Methods of extinguishing a fire in the inter-wall space, if it occurs.
- The need to cool the protective wall and adjacent tanks.

According to the analysis of Russian and foreign regulatory documents, protective structures in the form of earth embankments or reinforced concrete walls used in domestic and world practice are calculated for hydrostatic pressure . Therefore, they cannot keep the hydrodynamic fluid flow, which is formed during the complete destruction of the oil tank,thus, in order to increase the safety of the population and building sites of settlements that may find themselves in the zone of the dangerous impact of the breakthrough wave and the associated hazardous fire factors, it is necessary to apply engineering protective structures adequate to the phenomenon under consideration, and also to be able to predict the area of an accidental oil spill with complete destruction of the vertical tanks [13].

Recently, double-walled tanks have been used to prevent an emergency spill of oil and petroleum products, and to localize the area of the spill, instead of standard fences. Some researchers have suggested to use protective walls with a wave-reflecting visor. Protective walls with a wave reflecting visor should not be used to protect tanks in oil fields, tank farms of small oil depots, with insufficient load-bearing capacity of the soil, since they are monumental structures whose height is commensurate with the height of the protected tanks, and the thickness of the walls at the base reaches 1.5 m or more [14].

The advantages of these types of tanks are:

1. Avoid wasting quantities of oil in the event of a spill
2. Reduction of the space of the entire tank farm.
3. Environmental friendliness - in case of depressurization of the main tank, oil products do not fall into the soil.

Thus, this design of tanks has the following range disadvantages:

1. Possible gas contamination of the inter-wall space.
2. The outer wall does not prevent the collapse -like disintegration of the working wall of the tank and the destroying of its walls. You can use construction made of surrounding elements or winding the tank with a metal cable, which does not require extra calculations and is not an absolute warranty of security.
3. Unregulated leakage of product from the tank outside the protective wall, when the main part of the shut-off valves is defective due to their repeated installation outside the outer (protective) wall.
4. Scanty rigidity of the inner-wall space of the tank in seismic areas causing the main tank to tip over and needs it anchoring during build working. However, anchoring the main tank results in to a violation of the tightness of the protective bottom in the inter-wall space when seismic impact and in some cases with strong seismic impact may be insufficient to ensure the rigidity of the inter-wall space tank.
5. It costs too much (because of two wall).

The research of statistical data on quasi-instantaneous demolition of vertical steel tank (more than 140 situation over a 50-year period) showed that the existing regulatory preventative barriers are not able to keep the wave of penetration within the boundaries of the tank farm, which has repeatedly led to emergencies [15-17].

Given current trends in warehouse design especially for higher rack storage, larger floor areas and portal spans, it would be valuable to gather more recent data on the typology of modern industrial and warehouse buildings including their area, height, wall openings, materials, fuel loads and storage heights [18].

3 Conclusions

The problem of fire safety about using these tanks remains not easy to settle. The task of guarantee fire protection of all types of tanks in cases of man-made emergencies has both technical and scientific relevance, which consists in the lack of a modern and finally formed method of reliable rating of the actual and predicted levels of danger, and, as a outcome, in the absence of standards that guarantee the provision of the standard level of fire security [9].

Auxiliary barriers in the form of dike, built behind the main structures [15], have not received serious employment in real life, and this is due to the need to allocate the necessary region for the arrangement of reservoirs, the insufficiency of which is clearly expressed in modern cases.

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