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Fire Protection for Oil Storage Tank

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***Abstract*—Large liquid storage tanks are used in industries to store petroleum and its allied products for a variety of purposes, and these tanks contain large amounts of oil that can catch fire. Because of the enormous fuel supply for the fire, oil fires are more difficult to extinguish than regular fires. These fires can result in the loss of millions of barrels of crude oil, as well as ecological problems caused by the large amounts of smoke. To extinguish oil fires, several techniques such as foam systems and high powered water sprays are used. The primary goal of this project is to propose an active firefighting system for the Super Kerosene Oil storage tank in plants, Industry. There are altogether four tanks situated in the plant. The diameter and height of first two tanks are 10.65m and 9m. The diameter and height of other two tanks are 8m and 7.5m. The total storage capacity of four tanks is 2140 K.Lts. Detailed study was carried out on various factors which include type of tank, type of oil stored, location of tanks etc. According to OISD Standard, Semi fixed foaming system with minimum one discharge outlets using AFFF type of foam has been suggested. The amount of foam and water required Safe distance between tanks has been calculated and suggested. Many other important suggestions also have been included in the project.**

***Index Terms*—AFFF; Semi fixed foam system.**

I. INTRODUCTION

Atmospheric storage tanks are an essential aspect of refineries and terminal installations. The basic technology of tank design and fire protection is well established and has not changed substantially in recent years; however there have been some incremental improvements. In the last century, a series of major accidents, such as Flixborough, and Bhopal, have focused attention on the potential hazards posed by the chemical industry and the impact of such hazards on nearby communities [1]. Attention has primarily centered on process areas and pressure storage and, in particular, on situations where large vapour clouds of flammable or toxic materials may form [2]. Atmospheric storage tanks have received much less attention and this could be due to several reasons, including:

- The fact that the offsite hazards are relatively small.
- The fact that the technology is relatively static and thus new hazards are unlikely.

In such major storage tank fires, the incident may escalate to adjacent tanks, due to the effect of radiant heat from the fire on the adjacent tank and the subsequent effect on the contents of the tank [2]. This heat can cause the temperature of the liquid and vapour in the adjacent tank to rise and, as a consequence, the vapour space pressure will increase and exceed the pressure/vacuum relief valve (PVRV) set point, in order to allow the vapours to escape. If the adjacent tank contains flammable material, there is the potential for the ignition of the vapours and thus escalation [3, 4]. In order to minimize the risk of escalation, there is a need to reassess the existing basis for atmospheric storage tank spacing, fire protection and fire fighting resources. The existing engineering codes are extensive and have largely been proven to be very effective in the detailed design of atmospheric storage tanks; however, they are deficient, in respect of the above issues. 1 This is due to the fact that the engineering codes relating to tank spacing and tank fire protection are based on experience, rather than proper engineering judgment [10].

II. PROBLEMS IDENTIFICATION

- To carry out a detailed study regarding fire safety for the oil storage tank situated in Plant industry.
- To suggest a suitable foaming system for fire suppression in oil storage tank.
- To suggest modifications and improvements regarding fire safety for oil storage tank.

III. METHODOLOGY AND CALCULATION

A. FLOW CHART

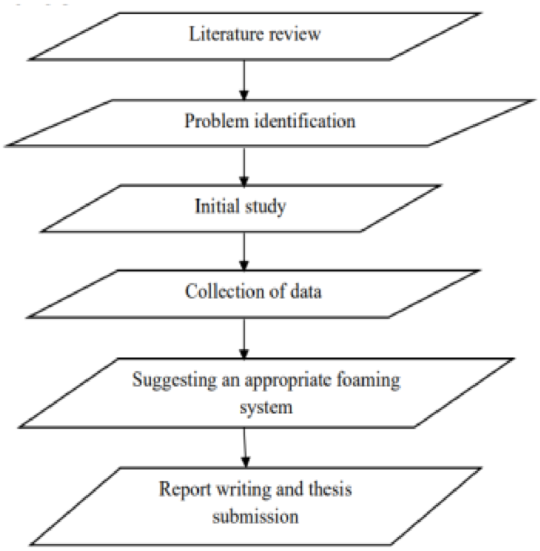

Figure [1] Flow Chart

B. PLANT VISIT AND DATA COLLECTION

The project is carried out in Plant Industry (one of the heavy engineering industries), Seamless Steel Tube Plant (Industry) was set up in 1979. They manufactures Seamless Steel Tubes of world Standards, catering to the needs of a wide spectrum of customers from power stations , petrochemicals ,oil & gas exploration, automobiles, refineries, sugar industries, textiles, etc. It has the most advanced facilities for the manufacture of seamless steel tubes and pipes – both hot finished and cold-drawn in carbon and low alloy steel grades. Industry offers seamless steel tubes and pipes in a wide range of sizes with outer diameters ranging from 19mm to 133 mm and wall thicknesses from 2mm to 12.5mm. The SKO is mainly used for heating of the tubes for the production process. Thus the SKO storage tanks play an important role in the production of seamless tubes.

- Tank infrastructure in Plant industry (Typical):

Table [1]: SKO storage tank details

Tank.no	Tank	Product	Dia.(m)	Height (m)	Capacity (K.Lts)
1	CVRT	SKO	10.65	9	750
2	CVRT	SKO	10.65	9	750
3	CVRT	SKO	8	7.5	320
4	CVRT	SKO	8	7.5	320

Table [2]: Water storage tank details

Tank no	Type	Service	Dia (m)	Height (m)	Tankage (KL)
1	CVRT	WATER	10	8	630

The water tank is situated at 8(m) height, by using the head of the tank they are maintaining a pressure of 2-3 kg/cm2 in the hydrant line in the plant.

Physical properties And Characteristics:

- Sp. Gravity : 0.81-0.91
- Vapor density : 3-5
- Flash point : 32ºc - 56ºc
- Explosive limit : 0.7 to 9% by volume in air
- Ignition Temperature : 256.6 ºc
- Vapor Pressure : < 1mm Hg
- Insoluble in water
- Brown to light brown

C. INFERENCE

Depend upon the physical properties of SKO oil it belongs to the petroleum products of class B. According to OISD STD-116 fixed roof tank storing class-A and class-B petroleum products, semi-fixed foam system is suitable.

Semi-Fixed foam system:

A fixed piping system from outside of dyke area is connected to foam maker cum vapour seal box in case of cone roof tank. It gets foam through mobile foam tender.

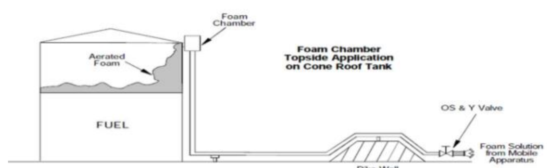

Figure [2] Example of Semi-fixed foam system with foam chamber

D. CALCULATION OF FOAM COMPOUND REQUIREMENT:

According to OISD-116 the amount of foam compound required has been calculated for the fixed cone roof tank storing SKO.

Data:

Total storage capacity = 3140 m^3

No. of tanks = 2 with 750 m^3 and 2 with 320 m^3 capacity each Diameter of each tank = 2 with 10.65(m) and 2 with 8(m) each

Height of each tank = 2 with 9(m) and 2 with 7.5(m) each

The quantity of foam compound shall be calculated as follows:

Consider foam solution application @ 5 lpm/m^2 for the liquid surface of the single largest cone roof tank in the dyke area.

Foam solution rate = 446 lpm
Foam compound required = = 13.3662 lpm
Foam compound quantity for 65 minutes = 868.54776 litre
Consider one portable foam monitor of 500 lpm foam solution capacity : 3% Foam compound required = 15 lpm
Foam compound required for 65 minutes = 975 litre
Consider 1 hose streams of foam with a capacity of 200 lpm of foam solution capacity
3% Foam compound required = 6 lpm
Foam compound required for 65 minutes = 390litre
Total foam compound required for cone roof tank area Protection:
Foam compound required for Cone Roof Tank = 869 litre
Foam Compound required for 1 Foam Monitor = 975 litre
Foam Compound required for 1 hose streams= 390 litre
Total = 2234 litre
Say : 2300 litre

E. CALCULATION OF FIRE WATER FLOW RATE:

According to OISD-116 the amount of fire water required for foam making and for cooling the surface of tanks has been calculated.
Data:
Total storage capacity = 3140 m3
No. of tanks = 2 with 750 m3 and 2 with 320 m3 capacity each
Diameter of each tank = 2 with 10.65(m) and 2 with 8(m) each
Height of each tank = 2 with 9(m) and 2 with 7.5(m) each
Cooling water requirement:
Cooling water rate=3 lpm/m2 of tank shell area for tank-on-fire
Cooling water required = 903 lpm
Cooling water required for other tanks at the rate of 3lpm/m2 of shell area for tanks falling within (R+30) metre from centre of tank on fire,
= 162.54 m3/hr
Total cooling water rate = 216.72 m3/hr
Foam water requirement (for 1 tank only) @ 5 lpm/m2,
Foam solution rate = 445.18 lpm
Fire water for supplementary hose stream = 43.71 m3/hr
Total water required :
Tank cooling = 216.7m3/hr
Foam application = 26.71 m3/hr
Supplementary stream = 43.71 m3/hr
Total water required = 290 m3/hr
The number of discharge outlets required, application rate, time of discharge, number of hose streams required, time of discharge of hose streams required is taken according to OISD-116 and they are given below:
1) Foam agent used = AFFF
2) Application rate and discharge time of foam: According to OISD-116 for cone roof tanks containing liquid hydrocarbon foam solution delivery rate shall be at least 5lpm/m2 of liquid surface area of tank. Duration of foam discharge for tanks containing class A and class B petroleum is 65min.
3) Supplementary protection:

Table [3]: Operating times for supplemental hose streams

Diameter of tank (m)	Minimum operating time (min)
Up to 10.5	10
10.5 to 28.5	20
above28.5	30

Table [4]: Selection of supplementary hose streams

Diameter of tank (m)	Number of hose stream
Up to 19.5	1
19.5 to 36	2
above 36	3

From the above tables we can determine number of hose streams required and minimum operating time.

4) Number of discharge outlets required can be determined from the table given below:
Table [5]: Selection of number of discharge outlets

Tank diameter(m)	Minimum no. of discharge Outlets
Up to 20	1
20 to 25	2
25 to 30	4
35 to 40	5
40 to 45	6
45 to 50	8
Above 50	10

F. CALCULATION OF SAFE DISTANCE BETWEEN TANKS USING POINT SOURCE MODEL:

In this model, it is customary to model the flame by a point source located at the center of the real flame in order to predict the thermal radiation field of flames. The point source model is the simplest configurationally model of a radiant source. The critical value of incident heat flux, defined as the minimum value of the heat flux which can ignite the fuel in the target tank is given as:

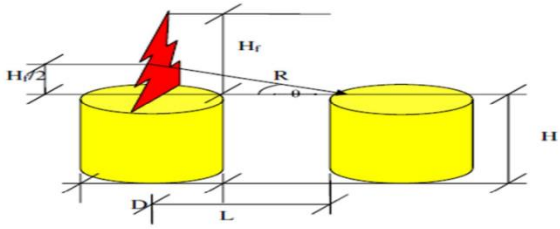

Figure [3] Schematic diagram of tank on fire for point source model

Here, Qr is obtained Qr = λQ

Here, λ can be determined as λ = (0.21- 0.0034 x D)

D is diameter of tank in (m) Q is the total heat released by fire and can be estimated as follows:

Q = (ή x m" x π x D2 x ΔHc)/4

Where, ή is the combustion efficiency.

m"(kg/m2 s) is the volumetric loss of liquid per unit pool surface area.

ΔHc is heat of combustion of fuel (KJ/Kg).

$$R = \sqrt{\left(\frac{H_f}{2}\right)^2 + L^2}$$

Where Hf is the flame height(m) above the tank. It is obtained as

Hf = 0.235Q(2/5) – 1.02D

Cosθ = L/R

L is the inter-tank separation distance measured from the centre of source tank to the edge of target tank. Substituting values of all the parameters in equation and calculating qr" for various distances, for each of the configurations, one can obtain the safe distance corresponding to the critical heat flux, qrc" which is generally taken as equal to 4.732 kW/m2.

For SKO ή = 1 , m" = 0.039 (kg/m2s), ΔHc = 43,200(KJ/Kg)

Assuming that the large diameter (D=10.65m) tank on fire and the inter-tank separation distance measured from the centre of source tank to the edge of target tank. Substituting values of all the parameters in equation and calculating qr" for various distances, for each of the configurations, we can obtain the safe distance corresponding to the critical heat.

flux, qrc" which is generally taken as equal to 4.732 kW/m2.Critical heat flux is the radiation at which no other material will catch fire.

Table [6]:Intensity of radiation at particular distance.

Distance between rims (m)	Radiation (Kw/m2)
3	11.66
4	10.036
5	9.34
6	7.94
8	6.68
9	5.45
10	4.57

Distance (vs) Radiation Graph by using Point source model:

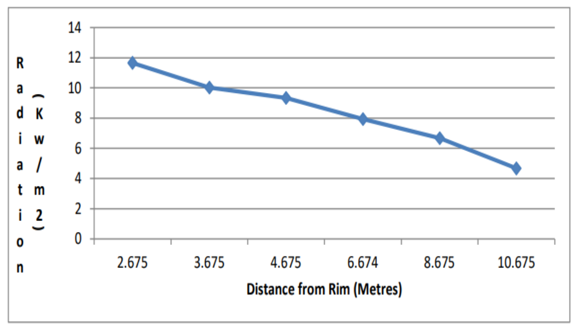

Figure [4] Distance Vs Radiation graph

By using this model the safe distance between the tanks is determined as L_{safe}= 9.6(m)

IV. RESULTS AND DISCUSSIONS

Result Outcomes:

- The amount of foam compound required is 2300litre
- Amount of water required for making foam, cooling of tanks and supplementary stream is 290m3 /hr.
- By using point source model safe distance between tanks is 9.6m.

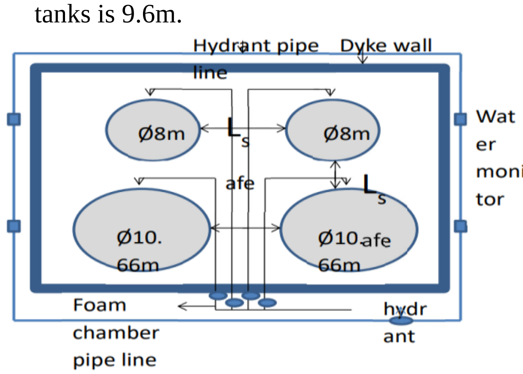

Figure [5] Model layout with foaming system arrangement.

IV. CONCLUSION

The Super Kerosene Oil storage tank at plant (Industry) lacks a standard fire fighting system. This project aims to suggest an adequate fire fighting system for the storage area. By going through many sources like OISD standards, NFPA standards, etc., the amount of foam, water required has been calculated. By using the point source model the safe distance between tanks has been calculated in no wind condition. By going through OISD standard the following recommendations have been suggested. The recommendations made will act as guidelines for the design of an adequate fire fighting system for SKO storage tanks at Plant industry.

- According to OISD-STD-116 Fixed roof tanks storing Class-A and Class-B petroleum products semi-fixed foam system is applicable.
- Each dyke shall have roads all around for access for normal operation and maintenance as well as for emergency handling.
- The minimum distance between a tank shell and the inside toe of the dyke wall shall not be less than half the height of tank.
- In any case the boundary wall shall be of minimum 3m height.
- According to OISD-STD distance between tanks (up to 10m diameter) should be 0.5D= 5.325m. By using point source model the safe distance calculated is 9.6m.
- Considering the maximum of the two distances it is suggested to use the safe distance measured by point source model (9.65m).
- Loading/unloading point should be at least 4.5m away from the tanks.
- The minimum distance between Storage tanks and stores or amenities is minimum 4.5m or Diameter of tank.

V. SCOPE FOR FUTURE WORK

In this, the safe distance between tanks has been calculated under no wind condition only, by using some other methods like Mundans model and Sanegupta model safe distance between tanks in case of wind and no wind condition also will be calculated and by comparing them much better result can be suggested. By using the Thermal Response Model thermal response of contents of adjacent i.e variations in the liquid and vapour temperature, any increase in the vapour space pressure, thermal loading over the surface of the tank can be predicted. Combining the all those models presents a number of innovative features such as predicting the distribution of thermal load on tanks adjacent to the tank on fire and thermal load on the ground. A wide range of design and fire protection alternatives, such as the water cooling system and the minimum separation distance between storage tanks, can be assessed using these models. The subsequent results will help to identify any recommended improvements in the design of facilities and management systems (inspection and maintenance), in addition to the firefighting response to such fires.

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