

FOAM CONCENTRATES APPLICATION RATE AND THEIR FLOW RATES: AN OVERVIEW ON FLOATING ROOF TANK FIRE EXTINGUISHMENT

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Abstract

The basic characteristics of foam concentrates application rate and their flow rates for fire fighting to extinguish tank fire are briefed. It is pointed out that the present fire fighting systems of large scale crude oil storage depots cannot meet the need to extinguish tank fires. In petroleum refinery, various hydrocarbons, both liquid and gaseous are handled. These hydrocarbons are flammable and explosive in nature and volatile to varying degrees depending upon their operating conditions. As the process operations are carried out at elevated temperatures and pressures, they offer high risk of fire and explosions and therefore it is imperative that proper safety precautions are taken in carrying out operations safely and prevent incidence of fires and explosions. This paper covers the application rate and flow rates of foam onto a fire is normally expressed as the amount of foam solution, in litres per minute, to be applied to every square metre of the total area to be covered with foam.

Keywords: Foam concentrates application rate; flow rate; pool fire; tank fire; fire suppression system;

1. INTRODUCTION

Foam is a homogeneous mass of tiny air or gas filled in bubbles of low specific gravity which, when applied in correct manner and in sufficient quantity, form a compact fluid and stable blanket which is capable of floating on the surface of flammable liquids and preventing atmospheric air from reaching the liquid. It is produced, by mechanically mixing a gas or air to a solution of a foam compound (concentrate) in water. The foam produced from concentrates are of low expansion (up to 20 times), medium expansion (20 to 200 times) and high expansion (above 200 times). The low expansion foam concentrates are of following types:

- Protein foam,
- Aqueous film forming foam (AFFF),
- Fluoro Protein foam,
- Synthetic foam (This can also be medium and high expansion foam), and
- Multipurpose aqueous film forming foam.

2. GENERAL

The application rate of foam onto a fire is normally expressed as the amount of foam solution, in litres per minute, to be applied to every square metre of the total area to be covered with foam. The following five terms are often used to describe various foam application rates and it is important to know the difference between them, they are:

- Critical application rate

- Recommended minimum application rate
- Optimum application rate
- Overkill rate
- Continued application rate

The following section describes the meaning of these various terms. The most important of these for operation use is recommended minimum application rate.

2.1 Critical Application Rate:

The critical application rate is the application rate below which fire cannot be extinguished. When applied at below this critical rate, the finished foam will be broken down, by both the fuel and the heat of the fire, to such an extent that a complete foam blanket will not be able to form over the surface of the fuel.

2.2 Recommended Minimum Application Rate:

The Recommended Minimum Application Rate is the minimum rate at which foam solution is recommended to be applied to a fire. The rate assumes that all of the foam made from the foam solution actually reaches the surface of the burning fuel. The Recommended Minimum Application Rate is based on the critical application rate with the additional safety margin to help to take into account factors such as

- Variations in the quality of foam concentrate
- Variations in the quality of finished foam produced

3. Some of the detrimental effects forceful application

2.2.1 Fire Involving Water-Immiscible class B liquid:

These rates should not be considered as being definitively allowance must be made to compensate for losses due to circumstances such as fall out of finished foam from the foam stream, adverse whether conditions and breakdown of foam due to flames before it reaches the fuel surface and loses of foam due to thermal convection currents caused by fire.

It has a direct bearing on the quantity of concentrate and water required and also should dictate the amount of delivered equipment. For storage tank fire these rates need to be increased by up to 60% to account for foam losses.

2.2.2 Fires Involving Water-miscible Class B Liquid:

Application rates for water-miscible fuels vary considerably depending on the following factors:

- The type of fuel
- The type of foam
- The manufacture of the foam
- The method of foam application

Some of the most widely used water-miscible liquid includes:

- Alcohol
- Ketones
- Vinyl Acetate
- Acrylonitrile

Due to large number of water miscible fuels in use and varying fire fighting performance of different foams on each of them information on the recommended application rate for a particular water miscible risk should be obtained from the manufacture oh the alcohol resistant foam concentrate to be used.

2.3 Optimum Application Rate:

The optimum application rate is sometimes referred to as the most economical rate. It is the rate at which the minimum overall quantity of foam solution is needed to extinguish a fire. The optimum application rate is not rate at which the quickest extinction is achieved. To achieve the quickest extinction time, rates in excess of the optimum application rate are required. The small reduction in extinction times achieved by these increased application rates are at the cost of large increased in the use of resources such as water, foam concentrate.

2.4 Overkill Rate:

There is a limit to how quickly a fire can be extinguished when using fire fighting foam. Once the application rate has reached a certain level, higher application rates gives no

improvement in extinction time they only result in wastage of resource.

2.5 Continued Application Rate:

Various standards quote lower rates for continued application after a fire have been extinguished. These rates should be sufficient to maintain the integrity of foam blanket and are often around 50% of the minimum recommend foam application rate.

3. HAZARD ANALYSIS OF TANK FIRE:

The radiant heat of the oil tank liquid combustion flame is the main reason of the fire spread between the oil tanks. In recent years, with the rapid development of economy, national demand for crude oil is larger and larger. Crude oil tanks have the risk of fire and explosion, and can cause a pool fire easily. The fire spread between the storage tanks is generally caused by the fuel vapors ignited from adjacent storage tanks. The energy of the fuel vapor generated by adjacent storage tank fuel is provided by radiant heat of burning tank flame. Therefore, researching the risk of storage tank fire heat radiation has vital significance to fire prevention of storage tank fuel and emergency rescue .The thermal radiation flux will lead to disastrous fire or explosion of the adjacent oil tanks.

4. CHARACTERS OF FULL SURFACE FIRE OF LARGE FLOATING ROOF TANKS:

Although the properties and developing rules of full surface fire of large floating roof tanks need to be researched further, the following points are evident at present.

1. Since crude oil is of low flash point, high volatility and fluidity, the flame travels quickly on the oil surface and the hot air stream in the flame is turbulent.
2. The flame is of high temperature, strong heat radiation, thick smoke layer. The temperature in the flame center reaches 1050 - 1400.
3. The oil surface is easy to reburn.
4. The heat transmitting velocity in oil layer is quick and the long time burning in oil tanks may cause spillage and boil over.

5. METHODOLOGY:

5.1 Flame Height:

Flame height is an important parameter that evaluates the flame danger level. It influences the heat exchange of flame radiation to the external environment and combustion rate and the development process of combustion of the oil products can be predicted according to the flame height. Generally, the larger oil supply rate is, the higher the height of the flame is. But dimensionless height H/D (the ratio of average flame

height and tank diameter) of the flame becomes small with the increase of oil tank diameter. The experimental correlations of dimensionless flame height and tank diameter can be expressed as following

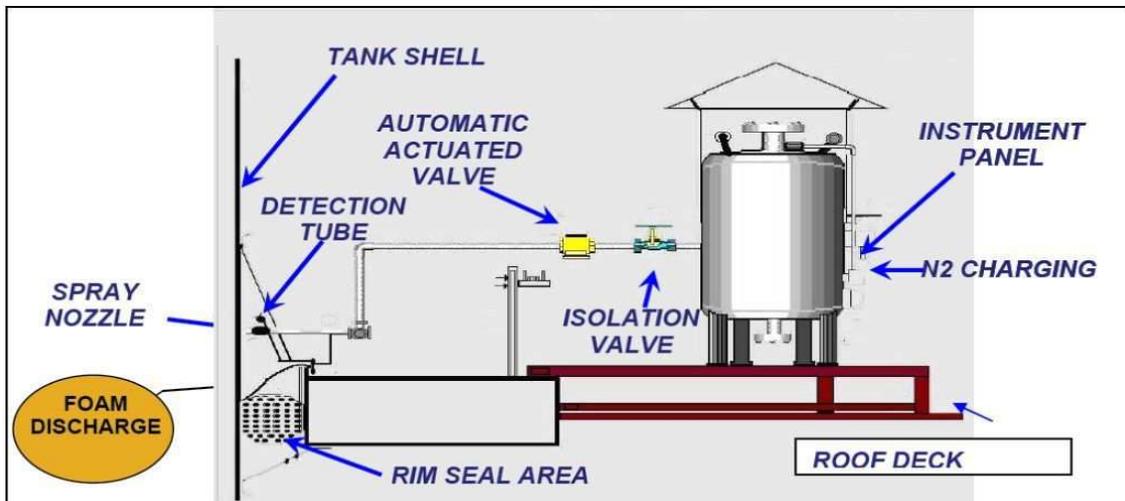
$$H/D = 2.89 \times D^{-0.258} \dots\dots\dots (1)$$

Where H is flame height and D is pool fire diameter. In this paper, pool fire tank diameter D, that is to say the tank diameter, is 68 m. The height of pool fire flame is 66 m according to formula (1).

A floating roof tank consists of a circular open top tank with a hollow pontoon roof that sits on the fuel surface and floats up and down as the level changes. To prevent evaporation around the edges of the roof, a seal, usually made of rubber, is used to fill the gap between the tank shell wall and the roof. These seals come in many different types and designs, but all are subjected to the day-to-day forces of movements that result in wear and tear. It is in this seal area that fires most commonly start.

6. DESIGN OF FOAM SYSTEM FOR EXTERNAL FLOATING ROOF TANK:

RIMSEAL PROTECTION FOR FLOATING ROOF TANKS:



Foam Fire Suppression System

1. The Automatic Rim Seal Fire Protection System shall comprise of highly sensitive and Field configurable Linear Heat Detection System of Hollow Metallic Tube coupled with no. of pre-mixed Foam storage /Discharge modules of adequate capacity and fire alarm panel .The Rim seal fire suppression system shall include the appropriate number of equally spaced identical modular foam units mounted adjacent to but outside the containment area of the foam dam so as to protect the entire rim seal area. The foam units shall be charged with premixed foam solution pressurised with nitrogen as an expellant gas. All modules on a tank shall be actuated simultaneously in the event of automatic detection of fire from any detector in case of more than one linear detector on the tank roof or by actuation of a manual release station outside the bund. The system shall be designed for a minimum foam application rate of 18

lpm /m2 of rim seal area. An application period of minimum 40 seconds shall be considered.

2. The system shall be modular in design with each section of foam distribution manifold protecting the equal length of rimseal area. In order to ensure full foam coverage in the entire rimseal area, the placement of the nozzle shall be such that foam application shall be uniform including the area at the ends of the manifold. The nozzle shall be made of SS-316 material. Foam concentrate to be used in the rimseal fire protection system shall be UL listed 3% concentrate Aqueous film forming foam (AFFF) or 3% type Film Forming Flouro Protein (FFFP) or 3% Alcohol Resistant-Aqueous Film Forming Foam (AR-AFFF).

6.1. System Design:

Design Calculations for Foam Quantity for Rim Seal

Fire Protection System:

Design Criteria:

Tank Size: 68 Mtr. Dia. X 20 Mtr. Height

Rimseal: 250mm Wide (Considered 300mm for Rim seal Protection)

Foam/Water Application rate: 18 lpm/m²

Duration of Discharge : 40 Seconds

Total storage capacity in one dyke area = 120,000 m³
 No. Of tanks = 2
 Diameter of each tank = 68 m
 Height of each tank = 20 m
 Rim seal = 250 mm wide
 (considered 300 mm for rim seal protection)

System Design:

Rim seal Area of Tank : = 3.142 X 68 X .300
 = 64.10 Sq. Mtr.

Rate of Foam Application : = 64.10 x 18
 =1153.8 LPM

Total Foam Solution Required in 40 Seconds = $\frac{1153.8 \times 40}{60}$ =769.2 Ltrs.

Total No. of Modular Units In one Tank =6 Nos.

6.2. Calculation of Fire Water Flow Rate in One

Dyke of Floating Roof Tank:

Total storage capacity in one dyke = 120,000M³
 No. of tanks = 2

Cooling Water Requirement:

Cooling water rate @ 3 lpm/m² of tank shell area for tank on fire
 Cooling water required = 3.14x68x20x 3
 =1281.70 lpm
 =769 m³/ hr

One tank to other tank distance out of (R+30) then application rate of spray system 1 lpm/m²

So,

Cooling water requirement: = 3.14x68x20x1
 =4272.56 lpm
 = 256.35. m³/ hr

Total cooling water requirement: = 769 m³/ hr +256 m³/ hr
 =1025 m³/ hr

6.3. Foam Water Requirement for Rim Seal Area for (One Tank Only):-

Water flow required for applying foam on a largest tank burning surface area.

For floating roof tank of 68m diameter

Diameter of the tank (D) =68m

Distance of foam dam from shell=0.8m

Diameter of roof up to foam dam (d) = 68 - (2x0.8)
 = 66.4m

Rim seal area = $\pi/4 (D^2-d^2)$
 =0.785 x (68² -66.4²) m²
 =168.81 m²

Foam solution rate @ 12 lpm/m²:
 =168.81 x 12
 =2025.7 lpm

For 3% foam concentrate: = (0.97x2025.7) lpm
 =1964.93 lpm
 =117.89 m³/ hr

Total Water Requirement for Floating Roof Tank

Protection (For 1 Tank Only) –

TANK COOLING: 1025 m³/ hr
 FOAM APPLICATION: 118 m³/ hr
 SUPPLEMENTARY STREAM: 372 m³/ hr
 TOTAL: 1025+372+118=1515 m³/ hr

6.4. Foam Compound Requirement for Floating Roof Tank (For One Tank Only):

Total storage capacity = 60000m³
 Diameter of tank = 68m
 Height of tank = 20m
 Foam solution application rate =12 lpm/m²
 Distance of foam dam from shell = 0.8
 Diameter of roof upto foam dam = 68-(2x0.8)
 = 66.4m

Rim seal area = 0.785x (68²-66.4²)
 = 168.81 m²

Foam solution rate =12 lpm

$$= 168.81 \times 12$$

$$= 2025.72 \text{ lpm}$$

$$3\% \text{ foam compound required} = 2025.72 \times 3/100$$

$$= 60.77 \text{ lpm}$$

$$\text{Foam compound required for 65 mins.} = 60.77 \times 65 = 3950 \text{ litre}$$

$$\text{Foam compound required for one monitor} = 8775 \text{ litre}$$

$$\text{Foam compound required for two no. of hose stream} = 4446 \text{ litre}$$

$$\text{Total foam compound for floating roof tank} = 3950 + 8775 + 4446 = 17171 \text{ litres}$$

6.5. Floating Roof Tank after Sinking Foam Solution

Required

Diameter of tank - 68m

Type - Floating roof

Foam application rate = 8.1 lpm

Foam solution requirement - $(3.14 \times 68 \times 68) / 4 \times 8.1$

$$= 29401.70 \text{ lpm}$$

$$= 1764 \text{ m}^3 / \text{hr}$$

Foam compound requirement -

$$= (29401.70 \times 3)$$

/ 100 = 882.05 lpm

Foam compound requirement for 65 mins = 882.05 x 65

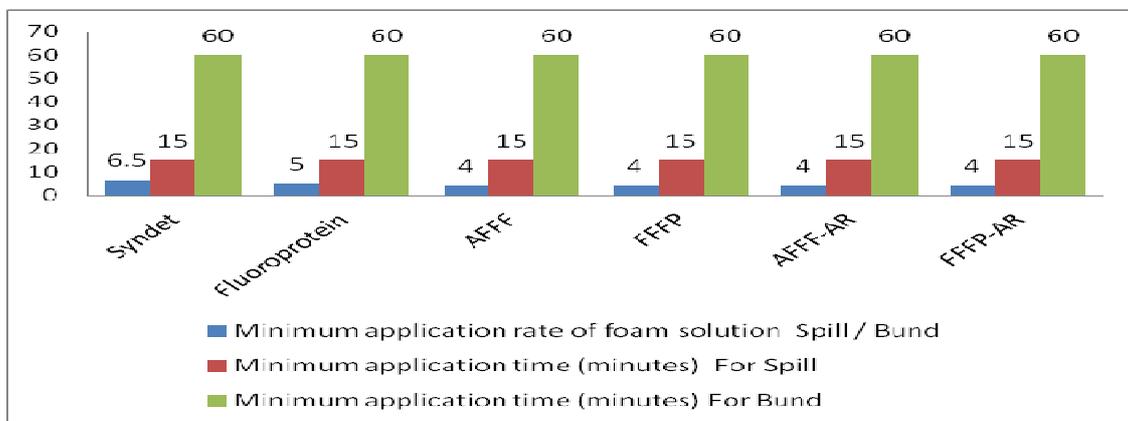
Total Foam compound required = 57333.25 litre

Table 1: Application rate of foam solution for the production of low expansion foam for use on liquid hydrocarbon fuel (class B) fires:

Foam type	Minimum application rate of foam solution (lpm/m ²)				Minimum application time (minutes)		
	Spill / bund	Tanks D < 45 m	Tanks D >= 45m D < 81m	Tanks D >= 81m	spill	Tanks fuel flash point > 40 degree c	Tanks fuel flash point <= 40 degree c/bund
Protein	6.5	NR	NR	NR	15	NR	NR
Fluoro protein	5	8.0	9.0	8.1	15	45	60
AFFFF	4	6.5	7.3	8.1	15	45	60
FFFP	4	6.5	7.3	8.1	15	45	60
AFFF-AR	4	6.5	7.3	8.1	15	45	60

D = Diameter of tank, 1lpm/m² = litters per minute of foam solution per square meter of building area of fire, NR = not recommended for this use

Graph for minimum application rates of foam solution for the production of medium expansion for the foam for use on liquid hydrocarbon fuel (class B) fire:



CONCLUSIONS

Although rim seal fire of large floating roof tank is of high risk and low probability, it will cause great loss for national properties and harmful effect on environment once it occurs.. The Automatic Rim Seal Fire Protection System shall comprise of highly sensitive and Field configurable Linear Heat Detection System of Hollow Metallic Tube coupled with no. of pre-mixed Foam storage /Discharge modules of adequate capacity and fire alarm panel. Each module should be dedicated for protection of an equal portion of the Rim Seal Area. The operational philosophy should ideally work as Feedback signal from detector actuates Solenoid Valve and Foam discharge instantly into the rim seal area. Low expansion foam necessarily to be UL listed which will be delivered to the Rim Seal area of the floating roof tank.

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STANDARD TEXT

- OISD -116 &117
- NFPA – 11