Electrostatic hazards of applying foam to protect exposed flammable product pools

He Meng[a,b], Yipeng Li [a,b], Liangliang Li [a,b], Xuqing Lang [a,b], Quanzhen Liu [a,b]
[a]State key laboratory of safety and control for chemicals, China
[b]SINOPEC research institute of safety engineering, China
[a]e-mail: 453179339@qq.com

***Abstract*—The techniques of foam blanketing onto exposed pools of flammable products as a safeguard against fire can itself be the cause of ignition by the generation of electrostatic discharge from investigation reports of a considerable amount of circumstantial evidence. The aim of this experiment is to study electrostatic potential and discharge that can be generated during the process of applying foam to protect exposed flammable product pools. The research conclusions provide reference for further research on safe foam blanketing procedures.**

Key words: foam blanketing; electrostatic discharge; electrostatic potential ;flammable product

Introduction

In oil tank area of petrochemical enterprises where pools flammable and explosive products are deposited, foam blanketing onto these products is a common way when fire accidents happen. However, high-speed liquid foam jetting and spraying may lead to a huge generation of static electricity, which led to the occurrence of electrostatic discharge on the oil surface. When the energy discharged is greater than the minimum ignition energy of that flammable and explosive product gas, electrostatic accidents happen. That's why electrostatic problems during the process of foam blanketing was discussed as an urgent problem to be solved by LSATFIRE International Conference in 2013.

Two of the most commonly used types of fire foam is aqueous film-forming foam fire extinguishing agent and fluorine protein foam fire extinguishing agent, and generally speaking there are two main ways of foam blanketing: one is the foam bubble's falling along the tank wall onto the oil surface and the other is foam's spraying severely directly onto the oil surface. Aqueous film-forming foam fire extinguishing agent, also known as light water foam fire extinguishing agent, english referred to as AFFF, is mainly composed of fluorocarbon surfactants, foam stabilizer, preservatives, polymer and so on. Fluorocarbon surfactants have the ability to significantly reduce the surface tension, with high heat resistance, chemical resistance of the performance, and the use of hydrocarbon surfactants, showing a good synergistic effect, both to effectively reduce the surface tension of the solution, can also reduce the oil interface tension. Fluorine protein foam fire extinguishing agent, english referred to as FP, is prepared by appropriate fluorocarbon surfactant on the basis of protein foam extinguishing agent. Fluorocarbon surfactants not only can make FP have fire extinguishing property but also make the it used in a "liquid jet" method to fight large-scale oil products tank fire. The fire extinguishing rate of FP used together with dry powder extinguishing agent and is one-third faser than FP used only.

In this paper we made an comparison about the electrostatic properties between the two types of fire extinguishing agent during the process of foam blanketing firstly and then analyzed the electrostatic risk in the process of foam spraying onto flammable products taking AFFF(6%) as an example. The conclusion of the study is to provide reliable reference for the safe of foam blanketing.

Experiments and Results

Charge density experiment

We carried out experiments by using AFFF(3%), AFFF(6%), FP(3%) and FP(6%) respectively. Each type of foam measures six sets of data at the same flow rate, and finally takes an average. The ambient conditions were temperature 28 °C and relative humidity 34.2%.

In this paper,the parameter for evaluating the electrostatic charge characteristics of the foam is the volume charge density. The main components of the test device shown in Figure 1, including foam cans, pumps, valves, nozzles,faraday tube, digital charge scale, conductivity meter and so on. The digital charge scale is ME284 with a range of 2000 nC.The diameter of the Faraday tube is 300 mm the foam and volume can be calculated from the foam height. The masuring range of conductivity EMCC1152 is 2×10^6pS / m.

The test procedure is as follows: (1) Mix the water with the foam stock in the foam tank according to the characteristics of the foam liquid and the flow rate of the foam can

Be controlled by the pump; (2) Iject the foam into the 21L plastic bucket and calculate the rate of foam by using the stopwatch; (3) calculate the foam volume by measuring the the height of the bubble and record the value of the charge and different rate of foam; (4) calculate foam volume charge density according to the amount of charge and foam volume.

The static electricity is mainly generated from three detail process of foam blanketing: pipeline transportation of the foam, spraying of the foam and burst of the foam bubble.

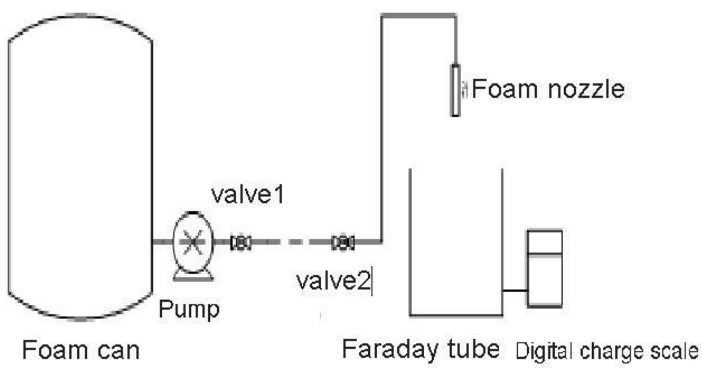

Figure 1 Experimental devic of Charge density experiment

The test datas are shown in the table below.

Table1 Experimental data of AFFF(3%)

Serial number	Rate of foam（m/s）	Charge density（μC/m^3）
1	23	12
2	21	18.85
3	18	23.69
4	10	45.72

5	5	154.72

Table2 Experimental data of AFFF(6%)

Serial number	Rate of foam（m/s）	Charge density（μC/m^3）
1	26	25.13
2	22	27.57
3	14	43.12
4	9	79.16
5	5	174.03

Table3 Experimental data of FP(3%)

Serial number	Rate of foam（m/s）	Charge density（μC/m^3）
1	24	9.96
2	15	55.38
3	12	80.67
4	10	99.30
5	4	267.89

Table4 Experimental data of FP(6%)

Serial number	Rate of foam（m/s）	Charge density（μC/m^3）
1	23	49.58
2	17	74.67
3	15	89.74
4	12	105.03
5	3	612.14

Eectrostatic potential experiment

In this test, the parameter for evaluating the electrostatic characteristics of the foam is the liquid level potential. The main structure of the test device shown in Figure 2, including foam cans, pumps, valves, nozzles, metal cans(d=1000mm), electrostatic voltmeter, conductivity meter. The static voltage meter is JDY type electrostatic voltage tester, its range is 2kV and 20kV adjustable. The masuring range of conductivity EMCC1152 is 2 × 10^6pS / m.

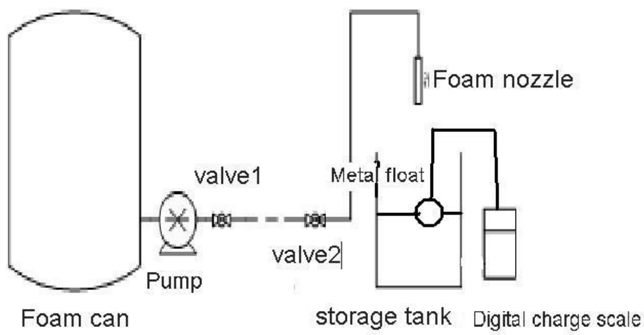

Figure 2 Experimental devic of Eectrostatic potential experiment

The test procedure is as follows: (1) find out the the biggest electrostatic risk of fire extinguishing agent by measuring the eectrostatic potential of different types of them; (2)test the affects of the liquid level on the the static electricity generated during its foaming process by testing at different liquid level of foam; (3) test its ectrostatic potential at different rates.

The environmental conditions were (11.7-22.1) ℃ and (28.6-39.6)% RH. The gasoline conductivity was 40 pS / m.

The test datas are shown in the table below.

Table5 Static electricity generated by different types of foam

Foam rate	1.5m/s	**Liquid level**	500mm
Foam type	**Serial number**	**Initial voltage（V）**	**Final voltage（V）**
AFFF(3%)	1	0	32
	2	0	25
AFFF(6%)	1	0	70
	2	0	51
FP(3%)	1	0	11
	2	0	10
FP(6%)	1	0	22
	2	0	19

Table6 Static electricity generated by different types of foam

Foam rate	3.0m/s	**Liquid level**	500mm
Foam type	**Serial number**	**Initial voltage（V）**	**Final voltage（V）**
AFFF(3%)	1	0	22
	2	0	18
AFFF(6%)	1	0	29
	2	0	21
FP(3%)	1	0	18
	2	0	15
FP(6%)	1	0	9
	2	0	8

The results shows that the liquid surface potential comes to the highest when using AFFF(6%) which is 70V compared to other types of agents and the static electricity generated by AFFF(3%) is more than the other two types of FP.

Table7 Static electricity generated by different liquid level

Foam type	AFFF(6%)		
Liquid level	**Serial number**	**Initial voltage（V）**	**Final voltage（V）**
200	1	0	9
	2	0	12
300	1	0	14
	2	0	22
400	1	0	61
	2	0	35
500	1	0	70
	2	0	51
600	1	0	46
	2	0	33
700	1	0	48
	2	0	25

It can be concluded that ectrostatic potential rises to the top when the liquid level is close to the tank radius.

Table8 Static electricity generated by different rate of foam

Liquid level	500mm	**Foam type**	AFFF(6%)
Foam rate	**Serial number**	**Initial voltage（V）**	**Final voltage（V）**
1	1	0	27
	2	0	22
1.5	1	0	70
	2	0	51
2	1	0	32
	2	0	39
2.5	1	0	25
	2	0	18
3	1	0	29
	2	0	21

4	1	0	33
	2	0	38

It's clear that the detection of the level potential at the rate of 1.5m / s is the highest and the flow rate of the foam mixture is 46L / min.

Discussion

For better analysis of the results of charge density experiment, we integrate the dates of four kinds of foam type into one excel table with different colors shown below.

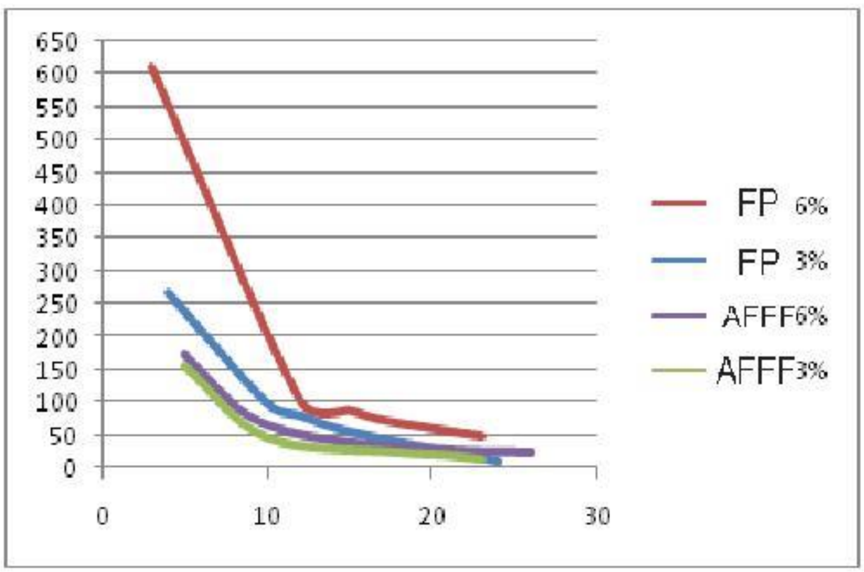

Figure 2 Charge density of different types of foam

From the pictures above we can conclude that:

1) Lots of static electricity generated can be generated during the process of foam spraying and the maximum value detected is 612.14μC/m^3;
2) FP can generate more static electricity than AFFF does when spaying;
3) Foam with concentration ratio 6% generate more static electricity than concentration ratio 3%;

4) More static electricity foam can generate when its spraying rate is reducing maybe due to the worse foaming ability and the smaller foam bubble, resulting in the foam unit capacity within the larger volume.

From the results of ectrostatic potential experiment we can conclude that:

1) Etrostatic potential caused by AFFF(6%) is the highest which comes to 70V;
2) Etrostatic potential rises at first and then reduce while the foam rate increases.The electrification of foam is mainly affected by two aspects: static electricity carrried by bubble itself and static electricity generated new during the movement of oil, and both of them contribute to the ectrostatic potential. The movement of the oil dominant this process when the rate of foam is faster. Then it can be deduced that the liquid level increases as the foam flow rate increases;
3) Etrostatic potential rises at first and then reduce while the liquid level increases and it rises to the top when the liquid level is close to the tank radius.
4) The results of the conductivity test also showed that foam blanketing increased the probability of static electricity from the oil because parts of the foam exist in the form of impurities in the oil. The characteristics of the bubble is very close to the water. The static electricity is the largest when the water content of oil is 1% -5%.

Assuming that the shape of the foam when it instantly contact the oil is similarly lindrical, define the amount of the foam as Q and contact area on the oil as S, then the oil flow rate in its influence range is approximately:

$$v = K\frac{Q}{S} \quad (1)$$

According to the Japanese Institute of "static safety guide -2007" related to the derivation of the movement of oil, the charge density and oil flow rate of the relationship is:

$$\rho = 4.7\times10^{-6}\nu \quad (2)$$

At the same time, the relationship between the center potential of the pipeline and the charge density of the oil is:

$$\varphi_{\max} = \frac{\rho_{m\infty}(\frac{D}{2})^2}{4\varepsilon} \quad (3)$$

v - Oil flow rate

K - is constant for the same oil

Q - the amount of the foam

S – contact area between foam and oil

ρ -charge density

$\varphi_{\max}$ -highest potential in oil center

D-foam diameter

ε -dielectric constant of oil

And the relationship between the foam action area S and the foam diameter D is:

$$S = \frac{\pi D^2}{4} \quad (4)$$

The relationship between $\varphi_{\max}$ and Q is:

$$\varphi_{\max} = \frac{\rho_{m\infty}(\frac{D}{2})^2}{4\varepsilon} = \frac{\rho_{m\infty}S}{4\varepsilon\pi} = \frac{4.7\times10^{-6}\nu S}{4\varepsilon\pi}$$
$$= \frac{4.7\times10^{-6}KQ}{4\varepsilon\pi} = \frac{3.74\times10^{-7}K}{\varepsilon}Q$$

For a same kind of oil, ε , K are constants, so the above can be written as:

$$\varphi_{\max} = K^{'}Q \quad (5)$$

During the process of foam blanketing, the highest potential detected is 70V when the flow rate of the foam mixture is 46L / min. Safety oil potential is 12000V, so the corresponding fire facilities, the flow of 7886L / min. The relevant tests show that when the liquid level reaches 25000V, the electrostatic discharge may occur on the liquid surface. The corresponding fire facilities have a flow of 16429 L / min.

In this paper, the test data show that the fire foam impact oil will cause the process of electrostatic potential changes, the detection of the maximum voltage of 70V. Theoretical analysis shows that the fire facilities flow rate of 7886L / min, it may make the liquid level to 12000V, with a certain degree of electrostatic risk.

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