Influence of Compressed Air Foam Extinguishing System on The Performance of Aqueous Film-Forming Foam Extinguishing Agent

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Abstract. According to the national standard, the relationship between the expansion, the drainage time and the gas-liquid ratio of the water-formed film foam extinguishing agent under different mixture ratio was investigated experimentally by using the gas-liquid two-phase foam gun. The results show that with the increase of gas-liquid ratio, the foaming multiple of water-formed foam first increases rapidly and then tends to a stable value. 25% drainage time first increases and then decreases and finally tends to a stable value. With the increase of mixture ratio, the expansion and 25% drainage time of the water-formed film foam extinguishing agent all increase, which has a significant effect on its performance.

Keywords: Compressed air foam fire extinguishing system, Aqueous film forming foam extinguishing agent, Gas-liquid ratio, mixture ratio.

1. Introduction

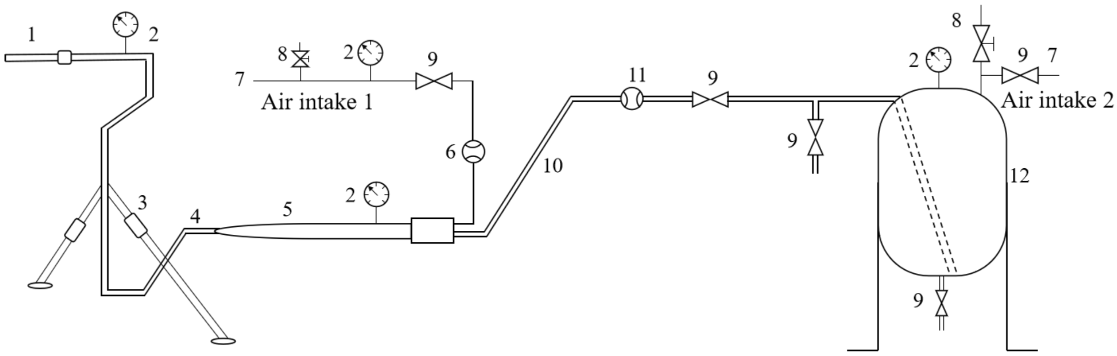
Compressed air foam fire extinguishing system (CAFS) is an efficient fire extinguishing technology, which produces a large amount of foam by mixing compressed air, water and foam fire extinguishing agent to extinguish fires. Due to its high efficiency and reliability, CAFS are widely used in petrochemical industry, tunnels and airports. Water-formed film foam extinguishing agent (AFFF) is a commonly used foam extinguishing agent, which has the characteristics of forming a water film on the surface of the hydrocarbon liquid, so as to effectively isolate oxygen and achieve the purpose of efficiently extinguishing Class B fires, especially in the transformer oil fire and chemical fire protection industry. At present, the expansion and drainage time of most of the water-formed foam fire extinguishing agents cannot be adjusted, which is only suitable for a single system parameter, so that it can not achieve the best fire extinguishing effect. However, most CAFS systems are equipped with Class A foam fire extinguishing agent, which also limits its application in other fields to a certain extent. Therefore, the author studied a series of foam characteristics of water-formed film foam extinguishing agent under the CAFS system, so that it can be adjusted within a certain range to achieve the purpose of extinguishing class B fires more efficiently.

2. Experimental Apparatus and Testing Method

2.1. Experimental Apparatus

In order to investigate the performance of water-formed foam extinguishing agent in CAFS system, a simple CAFS foam generator was built. It is mainly composed of air compressors, liquid storage tanks, gas/liquid flowmeters, gas-liquid mixers, foam spray guns, and various valves and metering meters.

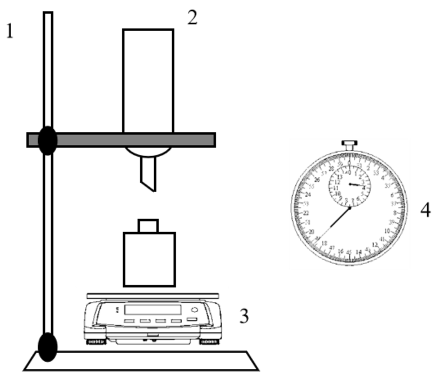
As shown in Figure 1, dry, clean air is generated by the air compressor for the liquid storage tank and the gas-liquid mixer. The real-time gas-liquid flow rate is recorded by gas flowmeter and liquid flowmeter, and the real-time gas-liquid mixture ratio is calculated. 3% water-formed foam fire extinguishing agent was used to configure different mixture ratio solutions according to 3% ratio and 4% ratio, and the performance of water-formed foam fire extinguishing agent in CAFS system was tested under different mixture ratio.



1. Foam spray gun; 2, 6, 10, 16 Pressure gauge (0~1.6MPa); 3. Adjustable support; 4. Foam conveying pipe; 5. Gas-liquid mixer; 7. Gas flow meter; 8, 21 Intake pipe; 9, 17 Needle valve; 11, 14, 15, 18, 20 Spherical valves; 12 Foam mixture conveying pipe; 13. Liquid flow meter; 19. Pressure storage tank.

Figure 1. Schematic diagram of foam generating device

Figure 2. Foam generating device



1. Iron frame platform; 2. Low expansion foam liquid separating tester; 3. Electronic balance; 4. Stopwatch

Figure 3. Foam extinguishing agent detection device

2.2. Testing Method

Setting of test conditions: Ensure that the ambient temperature is 15℃ ~ 25℃, and the foam temperature is 15℃ ~ 20℃.

Sample preparation: The sample of 3% water-formed film foam extinguishing agent was prepared into foam solution with fresh water, and the temperature of the foam solution was controlled within the range of 15℃ ~ 20℃.

Air pressure regulation: Start the compressed air foam system and adjust the gas pressure reducing valve and regulating valve to ensure that the foam solution outlet flow rate reaches (11.4±0.4) L/min.

Measurement of expansion: After collecting foam, scrape and wipe off the excess foam, and weigh. The expansion was calculated according to the formula in GB 15308-2006 "Foam extinguishing Agent".

25% drainage time measurement: While collecting foam, start the stopwatch to record 25% drainage time. Scrape and wipe off the excess foam, weigh and calculate the mass of 25% of the liquidated liquid. When the quality of the precipitated liquid reaches a specific value, the stopwatch is stopped and 25% of the drainage time is recorded.

Result recording: record all relevant parameters during the test, including test environment temperature, foam temperature, test environment parameters, etc.

3. Experimental Results and Analysis

The laboratory temperature is 20℃, and the pure water is configured with 3% and 4% foam solution respectively. After being fully stirred, the foam liquid storage tank is injected. Then, the pressure of the liquid storage tank is maintained at 0.65MPa, and the flow rate of the foam gun is stable at 11.4L/min. The gas-liquid mixture ratio is adjusted by adjusting the opening of the intake pipe valve. Three sets of continuous and stable data are obtained for each test group, and the experimental data are shown in Table 1:

Table 1. Foam properties at 3% mixture ratio

Test number	Mixture ratio	Expansion	25% Drainage time (min)	Gas-liquid mixture ratio	Gas flow (L/min)	Gas flowmeter outlet pressure
1	3%	4	0'50	2.6:1	25	0.04
2		5.3	1'18	4.4:1	40	0.06
3		5.8	3'40	6.1:1	50	0.08
4		6.1	4'19	7.3:1	60	0.09
5		6.4	6'21	9.5:1	75	0.11
6		6.3	6'30	10.8:1	85	0.11
7		6.6	6'20	12.0:1	90	0.13
8		6.6	6'10	14.5:1	105	0.15

3.1. Foam Performance At 3% Mixture Ratio

Based on the data in Table 1, analyze and plot it:

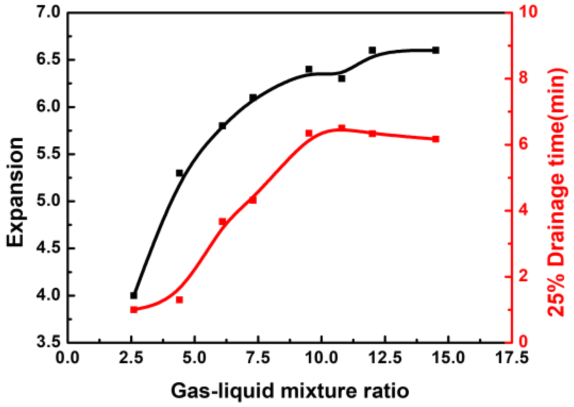


Figure 4. Expansion and 25% drainage time at 4% mixture ratio

From the data in Figure 4, it can be seen that as the gas-liquid ratio increases, the expansion also increases and eventually stabilizes. The increase of gas-liquid ratio means that the amount of air added in a given volume of foam liquid increases. This causes more air to be surrounded by foam liquid, forming more bubbles. The dispersion of air in foam liquid increases the volume of foam, thus increasing the expansion. This is because air is one of the main components of foam, and increasing air volume can increase the volume of foam.

25% drainage time refers to the time when the liquid in the foam begins to precipitate, which is related to the stability of the foam. When the gas-liquid ratio increases, the volume of the foam increases, and increasing the gas-liquid ratio can increase the stability of the foam. This is because more air helps to form a more uniform foam structure, thus extending the time the foam remains in a stable state. In addition, the addition of air also increases the viscosity and elasticity of the foam, which helps to slow down the rate of liquid precipitation, thus extending the liquid precipitation time.

But at lower gas-liquid ratios, a balance point needs to be found between foaming performance and stability. If the gas-liquid ratio is too low, sufficient bubbles may not be generated, resulting in a low expansion. If the gas-liquid ratio is too high, the foam may be too thin, the foam may be unstable and burst rapidly, thus the expansion will have a downward trend.

3.2. Foam Performance At 4% Mixture Ratio

The testing environment and instruments with a mixture ratio of 3% and 4% are exactly the same, and the data is shown in the following table:

Table 2. Foam performance at 4% mixture ratio

Test number	Mixture ratio	Expansion	25% Drainage time (min)	Gas-liquid mixture ratio	Gas flow (L/min)	Gas flowmeter outlet pressure
1	4%	4.8	1'45	2.6:1	25	0.04
2		6.4	3'44	4.4:1	40	0.06
3		6.9	6'57	6.1:1	50	0.08
4		7.7	7'02	7.3:1	60	0.09
5		8.9	8'00	9.5:1	75	0.11
6		10.0	8'59	10.8:1	85	0.11
7		11.4	9'33	12.0:1	90	0.13
8		13.4	9'30	14.5:1	105	0.15
9		12.6	9'30	16.0:1	115	0.17

Perform graphical analysis on the data in the table:

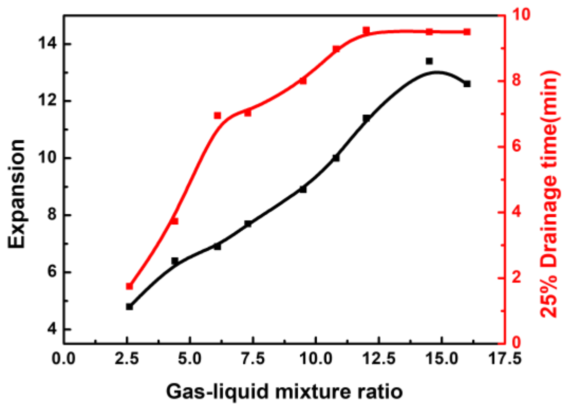


Figure 5. Expansion and 25% drainage time at 4% mixture ratio

As shown in Figure 5, when the foam mixing ratio is increased from 3% to 4%, both the foaming multiple and 25% drainage time are improved, but with the increase of the gas-liquid ratio, the foaming multiple and 25% drainage time also increase first and then tend to stabilize. This confirms that gas has a certain limit to the performance improvement of water-formed film foam fire extinguishing agent, and after a certain threshold, it will not significantly improve the performance of fire extinguishing agent. On the contrary, too high gas-liquid ratio may lead to the thinning of the foam liquid film, resulting in the acceleration of the foam rupture speed, and finally lead to the phenomenon that the 25% drainage time may be reduced.

3.3. Performance Difference of AFFF Under Different Mixing Ratios

As shown in Figure 6 and Figure 7, different mixing ratios have significant effects on the expansion and 25% drainage time performance of aqueous film-forming foam extinguishing agent. The mixing ratio refers to the proportion of foam liquid mixed with air. When the mixing ratio increases, such as from 3% to 4%, the following results will usually be caused:

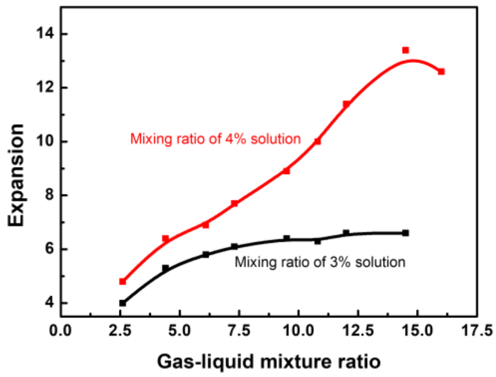


Figure 6. Expansion performance under different mixing ratios

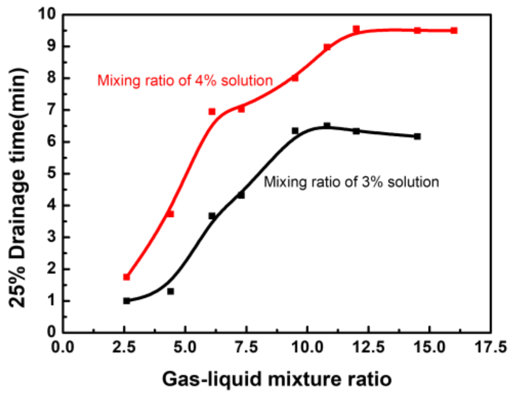


Figure 7. Performance of 25% drainage time under different mixing ratios

Increasing the mixture ratio usually means that there is more foam liquid involved in the foaming process per unit volume, which can increase the potential for foam formation. A higher mixture ratio can provide more surfactants, which help stabilize the foam structure and thus form more foam when air is introduced.

The higher mixture ratio may increase the viscosity of the foam and slow the flow of liquid out of the foam, so the 25% drainage time is also significantly improved. At the same time, the higher concentration of foam liquid improves the mechanical strength and stability of the foam, making the foam less likely to burst when disturbed by the outside world, thus prolonging the liquid out time.

Increasing the mixture ratio will also improve the structure of the foam, making the foam more delicate and uniform, which helps to improve the thermal resistance and coverage effect of the foam.

The surfactant in the foam solution can reduce the surface tension of the water, making it easier for the air to be wrapped in water to form a foam. Increasing the mixture ratio may have increased the surfactant concentration, thereby reducing the surface tension and increasing the foaming effect.

However, an increase in the mixture ratio does not always lead to a linear increase in the foaming multiple and the eluting time. There is an optimal mixture ratio range, beyond this range, too high mixture ratio may lead to too dense foam, poor liquidity, but reduce the fire efficiency. Therefore, determining the optimal mixture ratio is the key to achieve efficient fire suppression.

4. Conclusions

(1) The expansion and 25% drainage time will increase with the increase of gas-liquid mixture ratio, but will eventually stabilize. This means that there is an optimal gas-liquid ratio beyond which increasing the gas-liquid ratio does not significantly improve the foaming effect.

(2) Increasing the liquid-liquid mixture ratio will significantly increase the expansion and 25% drainage time, and also gradually increase and most stable with the increase of gas-liquid ratio.

(3) Increasing the mixture ratio can increase the upper limit of AFFF performance, which will be achieved at a higher gas-liquid ratio.

Acknowledgments

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