2013 WJTA-IMCA Conference and Expo
September 9-11, 2013 ● Houston, Texas

Paper

STUDY ON PHOTOELECTRIC CONFRONTATION OF WATER MIST SCREEN SYSTEM

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ABSTRACT

The water-based fog screen system for photoelectric interference, with low cost, energy-saving and environmental features, is a new type of interference material. This paper describes and investigates the physical characteristics of the water-based fog screen, the principle behind the interference of visible light, infrared and other electromagnetic waves using mist, the composition of the water-based fog screen system and its significance in cooling, dust removal and photoelectric interference applications.

The mist's shielding effect from visible light is significant. The test results show that with three nozzles generating mist, after about 10 seconds, a fully shielded effect from visible light is achieved. The dual-nozzle takes about 15s to achieve the full mask against visible light. The experimental results show that the high-pressure rotary water spray used in this experiment can instantaneously produce a large number of fine mists, rapidly cooling, dust removal and mask the target.

1. INTRODUCTION

In the field of mining, coal mines, oil fields, power plants, textile mills and municipal areas, most of the air pollution and high temperature environment, how to improve the cleanliness of the working environment, cooling and reduce air pollution and dust is an important issue for today's energy conservation and environmental protection. In addition, advanced surveillance and guidance technology applications in the photoelectric interference have rapidly developed over the years in order to achieve all-weather, high-precision and multi-functional means. In modern high-tech warfare, one's protection against multi-spectral light and electromagnetic wave surveillance systems is very important. The fog has excellent absorption and scattering properties when it comes to visible light [1], infrared, laser, thermal infrared [2] and also, on the shorter wavelength of the radar, has a certain damping effect [3]. The water mist has no toxic effects on humans and do not pollute the environment, but have strong attenuation, absorption and interference properties in regards to visible light and infrared rays. These features make water mist a noteworthy interference, cooling and dust removal material. Therefore, the investigation on the protective functions of water mist in cooling, dust removal and photoelectric interference applications is very important.

Until currently, the study of the micro-physical properties of a variety of natural fog system's shielding effect is limited to theoretical derivations [4]. There have not been a large number of significant experiments that have been carried out. Therefore, the investigation of the generation of artificial fog and its micro-physical properties under different external conditions and photoelectric shielding effect has important practical significance.

In this paper, the formation of high-pressure rotary mist and the mist’s interference properties against multi-spectral light are examined through theoretical analysis and research. Experiments such as using infrared imaging tests and videos before and after mist exposure were also conducted, showing results that the water-based fog screen system has a degenerative effect on targets sporting visible light, infrared and multi-band characteristic signals. Conclusions and recommendations are given at the end of the paper.

2. THE PRINCIPLE BEHIND THE WATER-BASED FOG AS A PHOTOELECTRIC INTERFERENCE MATERIAL

The physical properties of the water mist screen include the droplet spectrum, average particle size, number density, moisture content, etc. The mist particle size is generally in the range of 1μm -60μm and the particles are usually spherical. When the electromagnetic waves pass through a water mist screen, due to the mist particle shape, size, and uneven surface roughness, the water mist can have scattering, transmission, refraction, reflection, and absorption effects on infrared, visible light, laser and such signals. When the water mist concentration reaches a certain value, the target and the background seem to blend together, therefore, decreasing the obvious signals from shielding target, and the probability of being detected and distinguished. It can also decrease the required distance and precision of infrared, visible light or radar systems, as well as the combat ability.

Through a strong cooling effect, the infrared radiation intensity can be reduced. The higher the target temperature, the stronger the infrared radiation signals and the easier it is to be detected by

the signals. When small droplets of mist are exposed to a high temperature, it will quickly evaporate, rapidly cooling the target, thereby reducing the intensity of the target seen by the infrared radiation signal. In the field of mining, coal mines, oil fields, power plants, textile mills and municipal areas, most of the air pollution and high temperature environment, through water mist a strong cooling and dust removal effect, improve the cleanliness of the working environment, reduce air pollution, cooling and dust.

2.1 WATER-BASED FOG SCREEN OF VISIBLE LIGHT STEALTH MECHANISM

The mist particles having absorption and scattering effects, reduces the contrast between the object and background in regards to the luminance and chrominance. This phenomenon is usually represented by visibility (V). The visibility of the water mist screen is related to the mist particle size distribution, the density, moisture content, and other factors. According to the simplified formula [1], mist visibility can be represented as such (1):

$$V = 2.6\frac{\bar{r}}{W} \tag{1}$$

Where V – visibility, r - the average radius of the mist particles, W - fog water content.

As seen from formula (1), the concentration of water-based fog screen and the water content is inversely proportional to the visibility and the visibility is proportional to the average particle diameter of mist particles. In other words, smaller average radius of the mist particles, and greater concentration and water content results in lower visibility and increases the shielding ability from targets.

2.2 THE WATER-BASED FOG SCREEN'S MECHANISM OF PROTECTION AGAINST INFRARED LIGHT

The water-based fog screen's protective effect against infrared light is divided into two areas, the first being the optimal use of the absorption property of the water-based fog system. Water molecules are polar. They can absorb the incident infrared energy, reducing the outwardly radiated energy of the infrared light. The energy level of the water molecules is determined and the absorption of water-based fog curtain is significantly selective, with the absorption bands mainly concentrated at 0.76μm to 6.6μm. Through the absorption effects of the water-based fog screen, the near-infrared and far infrared that protects a target will be affected tremendously and be attenuated. In addition, the phase change of the water-based fog screen will absorb the heat radiated from the target, thereby reducing the surface temperature of the target, and reduces the intensity of the infrared radiation of the target. With lower temperature difference with the background, the target and background can achieve better integration.

The second factor is that the water-based fog screen can decrease the target infrared's characteristic signal. This then decreased the probability of the target being detected or recognized.

The mist particle size is generally in the range of 5μm to50μm, with a particle size of $\alpha=2\pi\gamma/\lambda$ >0.1 to 0.3. The Mie scattering theory can be used to analyze the mist's infrared scattering effect. The Mie scattering calculation can be attributed to determine the scattering efficiency

factor Qs(*a*, m), the absorption efficiency factor Qa (*a*, m) and attenuation efficiency factor Qe (*a*, m), and a corresponding cross-section and the relationship of the efficiency factors:[5]

$$\sigma_i（r，\lambda，m）=\pi\gamma^2 Q_i（a，m）\qquad（i=s，a，e）$$

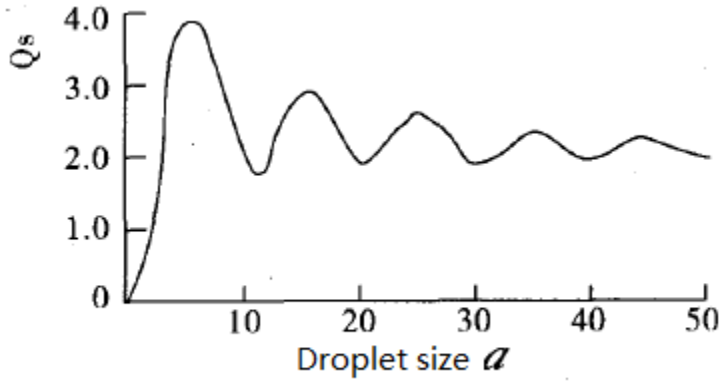

Figure 1: Qs curve showing water droplet scattering

Figure 1 shows a small droplets Qs (*a*, *m*) curve. The figure shows that at a = 6.2, QS→ max, when r ~ λ, results in maximum scattering. After a > 25, Qs→ 2, the scattering effect does not relate to the wavelength. In addition, the mist will absorb part of the heat distributed by the target, thereby reducing the surface temperature, and reducing the intensity of the infrared radiation of the target. Reducing the temperature difference between the target and the background can achieve better integration.

3. EXPERIMENTAL STUDY OF THE OPTICAL INTERFERENCE OF THE WATER-BASED FOG SCREEN

3.1 High pressure, rotating, water jet spray device

This paper is on using a high pressure water-based fog as a photoelectric interference material. As the high pressure water enters the rotating spray nozzle, the high pressure of the water turns into high speed rotating water jet. The high speed rotating water condenses in the air, forming a water-based fog screen.

Rotating high pressure water jet hydraulic atomization apparatus, the spray nozzles ejected high-speed rotation, in a relatively short period of time to produce large amounts of water mist obscured the need to protect you want to target. The fog van vehicle is shown in Figure 2. The system mainly consists of water source, filter, Adjustment valve, high pressure pump, power means, vehicle and spray nozzles.

Figure.2 Fog van vehicle generating mist

3.2 Simulation equipment

In order to check the mist of visible light, infrared multi-spectral attenuation performance and the moderating effect of the infrared camera. Test artificial mist into the fog conditions in different weather conditions. The minivan were carried out before and after applying a mist infrared imaging experiment equipment primarily consist of mist device, the 4 sets rotating spray nozzle, digital cameras, camcorders, minivan (masking target), infrared imager , Kestrel4000 wind / weather analyzer (see Figure 3). Water mist generating device is away from the masking target 3 meters, imagers and imaging apparatus 8 meters away from the shielded target (see Figure 4).

Figure.3 Test artificial mist into the fog conditions in different weather conditions

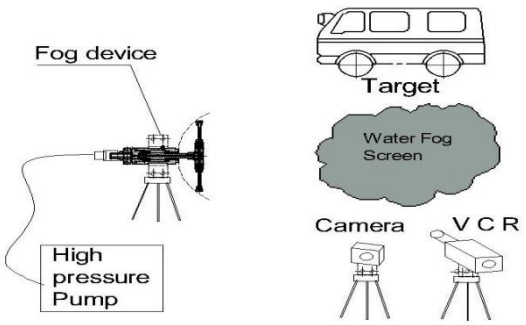

Figure.4 Water-based fog screen photoelectric interference experimental system layout

3.3 Water-based fog curtain the infrared shielding effect of experimental research

Infrared Imaging Spectrometer masking experiment, launched minivan after 10 minutes to reach thermal equilibrium state, the two tested sit in the car and lit a cigarette, followed by the infrared thermal imager and camera device on the van before and after the mist is applied at different times The situation imaging.

Figure 5 is not applied mist thermal imaging photos, shows a minivan in the engine is turned on after 10 minutes to reach a thermal equilibrium state, and a person in the minivan smoking status infrared imaging photo. Thermal imaging photos can be seen from Fig. 6 is not applied the mist minivan infrared target feature is particularly evident character outline and the cigarette characteristics are particularly evident. Can find and identify the target feature, especially the

more obvious engine, minivan shape, the character shape and cigarettes attempting characteristic infrared signals, etc., become the main source of infrared radiation from the camera and photo.

Mist is applied in Figure 6,7,8 thermal imaging photos can be seen, the characteristic infrared signal and the radiation intensity of the minivan, the character and cigarettes, when applying a high speed rotating mist gradually reduced, the water spray is applied only 3 seconds(see Figure 6), minivan main The characteristic signal attenuation and fuzzy. With the increase in the time of mist, mist concentration increasing further attenuation of infrared radiation intensity of the van, figures and cigarettes. After applying mist 6 seconds (see Figure7), basically can not tell from the photo the target characteristics. A further increase in spray time; increase the concentration of mist, the minivan, figures and cigarettes to quickly lower the infrared radiation intensity. When the mist is applied for 12 seconds (see Figure 8), the infrared signals and features of the minivan, figures and cigarettes disappear from the photo could not tell the difference between the target features completely.

Figure 5 is not applied mist thermal imaging photos

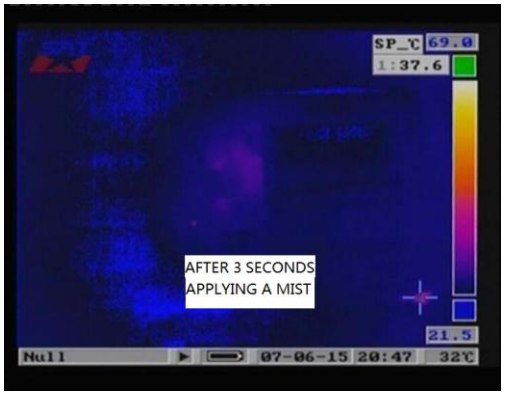

Figure 6 after 3 seconds applying a mist thermal imaging photos

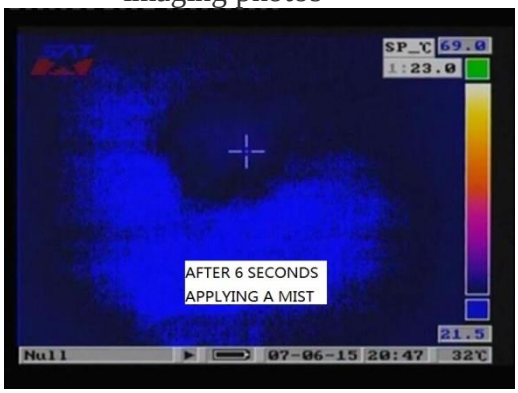

Figure 7 is applied to a water mist for 6 seconds after thermal imaging photo

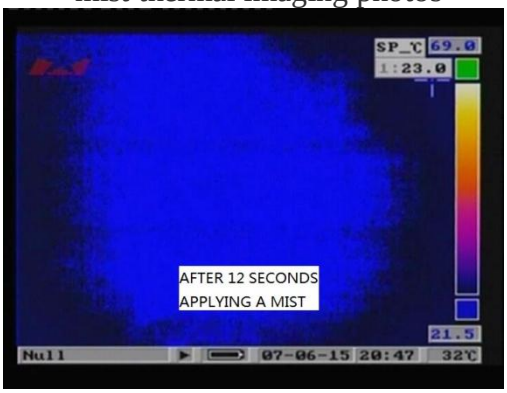

Figure8 mist is applied after 12 seconds, the thermal imaging photo

3.4 A variety of meteorological conditions on the shielding effect of the artificial mist

In front of the mist, use the Kestrel4000 wind / weather analyzer, the measured the temperature, humidity, wind speed and other parameters before and after the mist generated. With these parameters, observing the mist sprays pattern, the shielding effect and coverage.

Test 1: 3 nozzles, nozzles spacing of 1.16 meters, and nozzles height of 1.5 meters. The nozzles are bent at an angle of about 35°, and its high-pressure water ejected away from the shroud. Test pressure of 30MPa, test time from 15:00 to 15:04, the time of the trial of 4 minutes.

Test Results: Test data shown in Fig.10, you can see from the figure, the mist is applied, the ambient temperature by 35°C approaching 26°C, humidity 25% to 82%, we can see, the mist on the environment temperature, humidity effect obvious. The two sets of nozzle about a certain angle of the nozzle, forming a bowl-like form forward spray mist generated, the ejection distance of about 7 meters Figure 9.

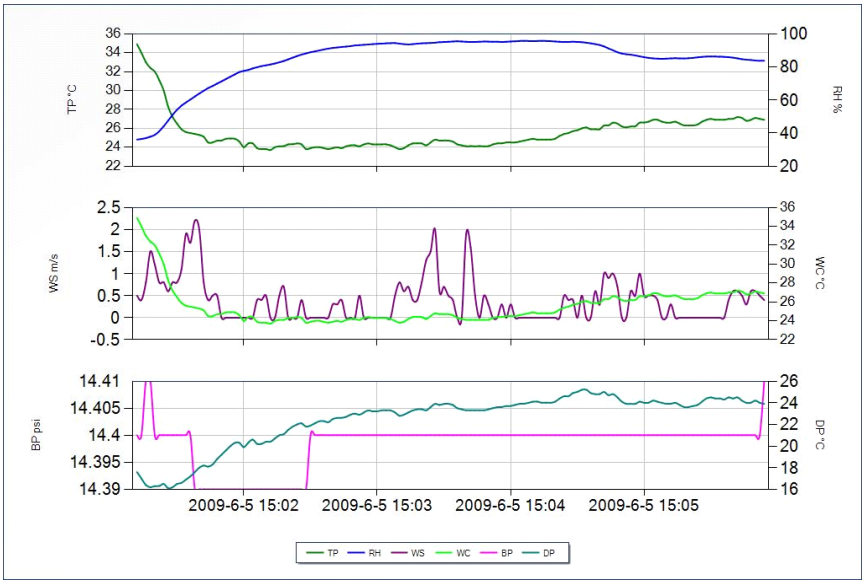

Figure 9 is applied to the mist curve of temperature, humidity, etc.

Test 2: 2 sets of spray nozzle spacing of 1.3 m, nozzles height of 1.5 meters. The nozzles are bent at an angle of about 35° angle, and its high-pressure water ejected away from the shroud. Test pressure 25Mpa, test time from 15:33 to 16:51, the time of the trial of 1 hour 18 minutes.

Test Results: In the climatic conditions of the two-level wind, spray nozzles discharge stable mist, forming a bowl-like form forward spray generated mist diameter of about 1.8 meters, mist with a spray distance of approximately 6-10 meters, test data are shown in Table 1. Can see from Table 1 and Fig.10, the wind speed under the climatic conditions of less than 4 m / sec (2-level wind), capable of forming a stable mist band having a certain concentration, the object can be effectively shielded. As can be seen from Table 1 and Fig.11, when the wind is greater than 2-level, the water spray density is greatly reduced and diffusion, can not be effectively shielded target.

Figure 10 in the two-level wind weather conditions mist shielding effect

Figure 11 in the greater than two-level wind weather conditions mist shielding effect

Table 1 The speed of wind mist shielding effect

Time	Test process
15:33	Measured: Temperature: 26°C, humidity: 37.8%, AL: 1008M, atmospheric pressure: 14.25 PSI cold: 25.2°C
15:43	Test wind speed: 3.4 to 3.5m/s wind, the nozzle 1.5 m high. Mist high 2.5m, width 3m, 6 to 8m long, ideal shielding effect, trucks and all the buildings shelter, as shown in Figure 10
15:48	Wind speed 3.5m/s. Mist 3m, width 3m length of 6 to 10m. Extreme wind speed: 6.2m/s, 7.4m/s to 7.6m/s, 7.2m/s, water flow: 18L/min
16:33	Started experimenting. Head holder on the ground, and from 1.5 m to. Mist 3m, width 5m, 12 ~ 15m long
16:36	Wind speed: 5.1 m / s, temperature: 16.6 ℃, Humidity: 86% (matte side)
16:51	Downtime. Humidity: 66.7%, wind speed 4.8m / s Temperature: 20.3 °C
	Mist 3.5m, width 4m, length 4m, due to wind, water mist is dispersed by the wind, the shielding effect is not ideal, trucks and buildings can still be seen, as shown in Figure 11

4 CONCLUSION

1. The water-based fog screen belongs to an aerosol mist system, the dispersion medium is air and the dispersed phase is water. High-pressure rotary water mist particle's size is generally between 1-60μm and the particle is generally spherical. The water mist can shield the target from visible light, infrared radiation and such, having strong absorption and scattering effects.
2. The mist's shielding effect from visible light is significant. The test results show that with three nozzles generating mist, after about 10 seconds, a fully shielded effect from visible light is achieved. The dual-nozzle takes about 15s to achieve the full mask against visible light.
3. The mist's attenuation of infrared light is good. The test results show that the performance of the mist on the attenuation of the infrared spectrum is good. The three nozzles and dual-nozzle used to generate a foggy mist obscured the target within 10 seconds. But its effect is

affected by the concentration of water mist, wind and other factors.

4. The experimental results show that the high-pressure rotary water spray used in this experiment can instantaneously produce a large number of fine mists, and rapidly mask the target. Rapid and timely implementation of the mist optical interference against objectives and can attenuate mid-infrared, far-infrared and higher frequency band communications in the atmosphere, guidance systems with a spectrum of electromagnetic waves [6].

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