文章编号：1006-9941(2007)03-0294-01

Study on the Anti-infrared Performance of Liquid Smoke Composition

ZHOU Zun-ning[1,2], YAN Fei[2], CUI Yu-ling[3], LIU Wei-qiang[1], MEI Qing-he[2]

(1. *The Fifth Division, Institute of Chemical Defense, Beijing* 102205, *China*;
2. *The* 710 *Division, China Ship Industry Co., Yichang* 443003, *China*;
3. 73921 *Army Unit, Nanjing* 210016, *China*)

In the technical field of reconnaissance, target location, target tracking and arms technology, IR sensors are increasingly used for making the entire battlefield transparent up to far into the opponents' area. An effective method of neutralizing or obstructing the effect of the IR sensors consists in cutting off the line of sight by smoke systems. The liquid smoke compositions are interested for their low cost, high yield speed and high yield efficiency. However, earlier liquid smoke compositions can absorb or scatter electromagnetic radiation only in the visible range, but not in the IR range. Therefore, the study on anti-infrared liquid smoke composition has important military significance.

Modern IR sensors are effective in the range from 3 μm to 5 μm and from 8 μm to 14 μm. According to extinction theory, the extinction property of smokescreen in 3 – 5 μm mainly depends on the shape and size of the smoke particles which is effected by discharge method. Besides the shape and size, the obscuration power in 8 – 14 μm depends on the refractive index of smoke particles. The choice of smoke composition for 8 – 14 μm bands should base on the relationship between the vibration of radicel in molecule and radiation.

The bonds with heavier atoms such like C—O, P—O—C, Si—O—C are needed to obscure 8 – 14 μm radiation. So the liquid anti-infrared smoke composition is made up of ethylphosphate, silica gel, propanetriol emulsifier and dispersant. Successional absorption would be obtained by admixture compounds which were linked through emulision polymerization reaction.

The smoke chamber used in this study is 6.1 m × 2.0 m × 1.8 m with 20 m^3 effective volume. A special window material (KBr crystal) is installed on the chamber as IR passage which has a flat IR pass characteristics for 1 – 14 μm. The generated smokes are stirred continuously by two fans to keep uniform aerosol concentration.

To obtain the IR transmittance spectrum, transmittance of IR smoke from a 1073 K black body through the aerosol smoke chamber, will be measured by an IR spectroradiometer (Model 12 – 550 Mark Ⅲ, USA) in 1.34 – 13.94 μm bands with a HgCdTe detector operated at liquid nitrogen temperature. Smoke screening time of IR radiation will be measured by a thermal imaging system (Model 99 – 112KWII, CHINA) working in 8 – 12 μm bands with a SPRITE detector, and another black body target. IR radiation temperature difference between the black target and background was 303 K. Mass concentration samples are drawn upon quartz fiber filters. Sampling duration is typically one minute at a nominal rate of 36 $L \cdot min^{-1}$.

The liquid composition sample with 80 mL volumes is sprayed into smoke chamber. Timing starts after liquid sprayer stops working. The IR transmittance spectrum and mass concentration of smoke are measured every 0.5 minute, and the thermal image of target is observed through an IR thermal imaging system in real time.

At 0.5 minute, measured mass concentration of smoke is 2.03 $g \cdot m^{-3}$, the average spectrum transmittance is 11.7% in 3 – 5 μm bands and 3.9% in 8 – 14 μm bands respectively. At this time, the IR thermal imaging system is totally obscured. At 1.5 minute, measured mass concentration is 0.93 $g \cdot m^{-3}$, the average transmittance is 26.1% in 3 – 5 μm bands and 52.8% in 8 – 14 μm bands respectively (Fig. 1). At this time, the IR thermal imaging system is partially obscured.

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Received Date: 2006-10-19 **Revised Date**: 2007-01-30
Project Supported: Post Doctor Fund of People's Republic of China
Biography: ZHOU Zun-ning(1969 –), male, post doctor, millitary chemical and pyrotechnic technology.
e-mail: zl_zzn@163.com or zzn1969@yahoo.com.cn

Table 1 Particle size and density of two HMX particles

		different batches FD-HMX						commercial HMX
		1	2	3	6	7	8	
particle size/μm	size distribution	4 – 40	4 – 40	4 – 40	4 – 40	4 – 40	4 – 40	1 – 100
	d_{50}	14	13	18	15	16	17	19
	d_{90}	23	21	36	33	33	29	62
particle density /g · cm^{-3}	density distribution	1.9012 ~	1.9013 ~	1.9011 ~	1.9008 ~	1.9012 ~	1.9018 ~	1.8979 ~
	mean	1.9020	1.9018	1.9017	1.9015	1.9019	1.9022	1.8994
	density(±0.0005)	1.9018	1.9015	1.9014	1.9012	1.9018	1.9020	1.8994

Note: d_{50} is the particle size of 50% of total volume, d_{90} is the particle size of 90% of total volume.

Table 2 Sensitivities of two HMX particles

	commercial HMX	FD-HMX	remarks
explosive probability 0.95 (Pi,Pu)	88(0.69,0.98)	32(0.15,0.54) batch 1 24(0.09,0.45) batch 2	sample 50 mg hammer 10 kg drop 25 cm
drop height H_{50}/cm	16.8 ±0.1	72.2 ±0.1 batch 1 * 46 ±0.1 batch 2	sample 35 mg hammer 2 kg * hammer 5 kg
gap thickness/mm	17.0 ±0.5	15.0 ±0.5	aluminium gap Φ20 mm charge HMX/binder 88/12

Note: 0.95 (Pi,Pu) is confidence interval at 0.95 confidence level.

Key words: analytical chemistry; insensitive HMX; crystal quality; sensitivity

CLC number: O65; TJ55

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In conclusion, a liquid smoke composition which can effectively attenuate IR radiation in 3 – 5 μm and 8 – 14 μm bands is developed. Chamber test results show that the developed composition can effectively attenuate IR radiation. The transmittance of formed smoke is 11.7% in 3 – 5 μm bands and 3.9% in 8 – 14 μm bandsrespectively. It can also totally obscure IR thermal imaging system as long as 30 s.

Key words: pyrotechnic; liquid; infrared countermeasure; smoke composition; smokescreen

CLC number: TQ567.5

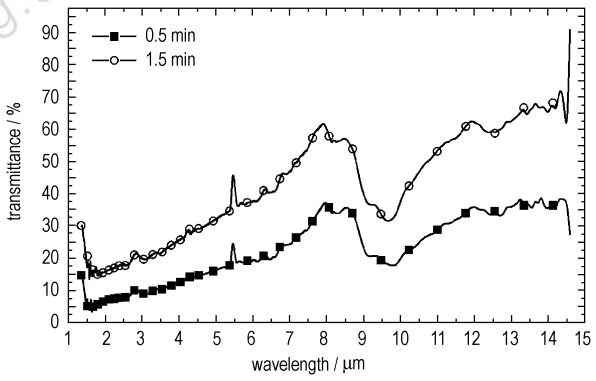

Fig. 1 Curves of IR spectrum transmittance at 0.5 min and 1.5 min