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Detonability of Ammonium Nitrate and Mixtures on Its Base

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Abstract: Quantities of improvised explosive devices on a base of industrial explosives that were applied at criminal incidents or were withdrawn from illegal circulation were reduced on average on 9% during last decade. This tendency is explained in particular by toughening of control under circulation of commercial explosive devices. The most commonly used improvised explosives according to returns of The Forensic Science Center of Ministry of Internal Affairs are mixtures on a base of ammonium nitrate with organic fuels and aluminum powder. Quantitative and qualitative compositions of such improvised mixtures can be various. The most essential question for a criminal case investigator is argument that excepted substance is explosive one. In this connection detonability of the mixtures on base fine (particle size was near 20 microns) and granulated ammonium nitrate with some organic fuels and aluminum powder was experimentally investigated. Failure detonation diameters of systems were measured experimentally.

Keywords: improvised explosive, ammonium nitrate, detonability, failure detonation diameter

Introduction

Quantities of improvised explosive devices on a base of industrial explosives that were applied at criminal incidents or were withdrawn from illegal circulation were reduced on average on 9% during last decade. This tendency is explained in particular by toughening of control under circulation of commercial explosive devices. The most commonly used improvised explosives according to returns of The Forensic Science Center of Ministry of Internal Affairs are mixtures on a base of ammonium nitrate with organic fuels and aluminum powder. Quantitative and qualitative compositions of such improvised mixtures can be various. The most essential question for a criminal case investigator is argument that excepted substance is explosive one. In this connection detonability of the mixtures on base fine (particle size was near 20 microns) and granulated ammonium nitrate (AN) with some organic fuels and aluminum powder was experimentally investigated. Failure detonation diameters of systems were measured experimentally. The properties of mixtures on f base of ammonium nitrate are described in books [1-2] and in articles [3-6].

Results and Discussion

Detonability of Fine Ammonium Nitrate and of the Mixtures on Its Base

Ammonium nitrate (chemically pure grade) was dried at temperature T ~ 100 °C in vacuum during 8-10 hours. After disintegration AN was dressed through mesh aperture with size 0.16 mm. Average size of AN particles was estimated by means of measuring of gas permeability of layer of AN (Russian device PSKH-2). Average sizes of particles of various samples of AN were 18, 22, 25 and 28 microns. Average size of particles of components mixtures under investigation are collected in Table 1.

Table 1. Characteristics of components of mixtures under investigation

Name	Formula	Oxygen balance, %	Average particle size, micron
Ammonium nitrate (AN)	NH_4NO_3	+20	18-28
Wood flour	-	-	<100
Aluminum powder PAP-2	AL	-88.9	~1
Milled foamed polyurethane (Rus. Name- mipora)	$C_{43}H_{115}N_{35}O_{31}$	-114.5	< 10
Trinitrotoluene (TNT)	$C_7H_5N_3O_7$	-74	11
Paraffin	$C_{24}H_{50}$	-346	-

Powder-like fuels with AN were mixed by means of shaking of mixtures with several rubber corks during 25 min in round-bottom flask.

If paraffin was used as fuel it was preliminarily dissolved in benzene, suspension of it with AN was thoroughly mixed on water bath to total evaporation of benzene at T = 100 °C.

Detonation of net fine AN was investigated in conditions of Hess test in paper cylinder charges (d = 40 mm). Detonation does not propagate at initiation by means of electrical cap N8 (Table 2). Water-resistant (WR) ammonium nitrate (AN with addition of small quantities of iron salts of fatty acids) detonated in these conditions. That is why the booster from WR ammonium nitrate was used for initiation of charges of chemically pure AN. The brisance of AN that was measured by means of Hess probe is presented in Table 2.

Detonability of AN with particle size ~0.4 mm according to literature data [1] at density ρ = 0.87-0.85 g/cm^3 was much less − d_f = 80-120 mm.

Table 2. Detonability of chemically pure (CP) and water-resistant (WR) ammonium nitrate

Ammonium nitrate	d, mm	L, mm	ρ, g/cm^3	Initiator	H_b, mm	Result	Brisance according to Hess probe, mm
CP	40	90	0.69	Electrical cap N8		-	
	40	120	0.69				
	50	145	0.65	AN WR Booster	40	+	8.0
	50	130	0.66		50	+	7.4
	50	105	0.52		25	+	2.6
	50	152	0.72		38	+	9.95
	50	77	0.70		38	+	8.62
	45	125	0.67		50	-	
	45	110	0.64		35	-	
	40	80	0.73		40	+	4.2
	40	100	0.60		40	-	
	40	105	0.75		40	-	
	40	100	0.65		45	-	
	35	132	0.74		53	-	
	40*		0.72	booster AN+mipora 97/3		d_f = 38 mm	
						+	
	40	150	0.74		37	+	
	40	150	0.70		60	damping	
WR**	42	92	1.00	Electrical cap N8		-	
	40	45	0.89			+	6.75
	40	90	0.93			+	7.41
	40	132	0.95			+	9.06
	32	94	0.97			-	

*conical charge;
** Russian trademark – ZHV, AN with addition of small quantities of iron salts of fatty acids;
d, L, ρ, are, corr., diameter, length and density of a AN charge, H_b is a length of a booster.

Detonability of mixtures on a base of fine AN with fuels under investigation was estimated in conical charges [7], the angle of cone-shaped charges was $\alpha = 1.8°$. These results are collected in Table 3 and in Figures 1 and 2.

Detonability of mixtures on a base of fine AN with wood flour is not high relatively – failure diameter of detonation is $d_f = 14\text{-}12$ mm at apparent density. Detonability of mixture of AN with 10% of aluminum powder PAP-2 is a lot more in comparison to mixtures with organic fuels (wood flour or TNT) $d_f = 2$ mm at $\rho \sim 0.9$ g/cm^3 (Table 3).

Table 3. Failure diameter of detonation (d_f) of mixtures on a base of fine AN in conical charges

Fuel	Content of fuel, %	Diameter of initiating, mm	Density, g/cm^3	d_f, mm
Wood flour	6	17	0.70	13
		19	0.71	14
		17	0.73	13
		15	0.96	12
Aluminum powder PAP-2	5	15	0.76	6
		15		5.5
	10	20	0.73	<5
		9	0.88	2
		9	0.92	1.5
TNT	21	14	0.76	4.5
		14	0.75	4.5
		10	1.07	6.5
		10	1.07	6.5
		10	1.09	6.0
		10	1.11	6.5

d_f of mixtures with paraffin (density is $\rho \approx 0.6$ g/cm^3) and with milled foamed polyurethane (Rus. name − mipora) were measured more detail, dependences d_f vs. content of fuel in mixtures is presented in Figures 1 and 2.

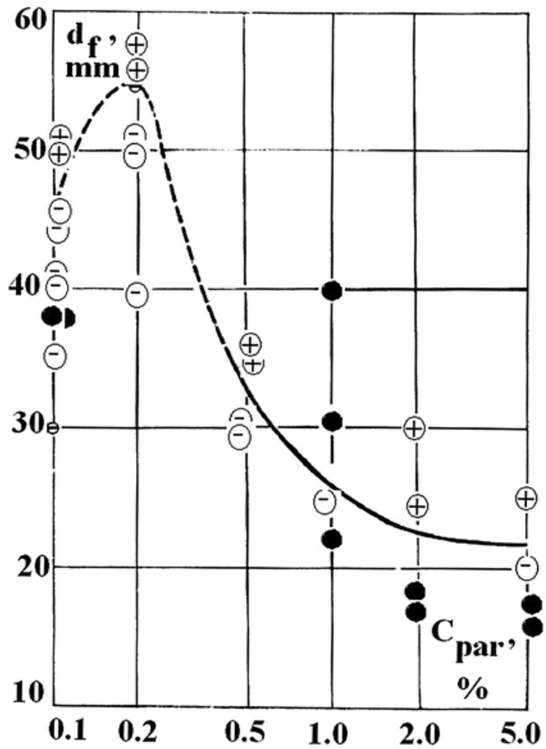

Figure 1. d_f of AN mixtures with paraffin. Black points are results of runs in conical charges. Pluses and minuses are detonation and damping of detonation in cylinder charges, corr.

d_f of AN some increases at addition of 0.2% paraffin, and it begins to diminish at rise of paraffin content. At C_{par} = 5% d_f is half of AN d_f. It is significant, that the heat of explosion of such mixture twice as high than the heat of explosion of AN without additives.

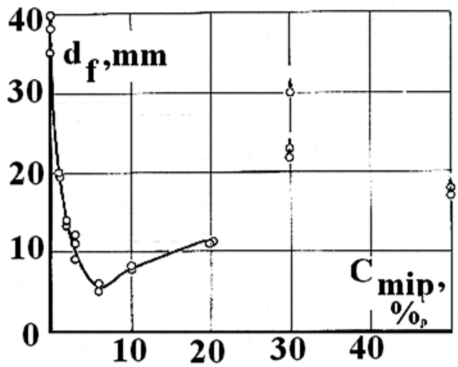

Figure 2. d_f of AN mixtures with milled foamed polyurethane (mipora) in conical charges.

Detonability of AN at addition of flour foamed polyurethane increases − d_f of AN at C_{mip} = 1% is half than without it. One can see minimum of d_f = 5-6 mm in Figure 2 at C_{mip} = 5%. At further rise of C_{mip} d_f of mixture begins to increase. It was impossible to initiate detonation of mixture at C_{mip} = 30% and C_{mip} = 50% by means of electrical cap N8 in paper confinement. However detonation of mixture with C_{mip}=30% propagated stably at the same initiation in steel tube (ρ = 0.25 g/cm^3, inner diameter was d_{in} = 20 mm, wall thickness was δ = 2.6 mm, length of tube was l = 58 mm). The tube was fragmented on pieces. Detonation of mixture with C_{mip} = 50% (ρ = 0.12 g/cm^3) did not propagate in the same conditions.

It is significant to note that mipora is fluffy material and apparent density of charges with it substantially diminishes at increase of its content in mixture. The critical density of mixture AN/mipora 94/6 that had maximal detonability was measured in glass tubes (d = 12 mm, δ = 0.5 mm, l = 95 mm), filling of charges were carried out by means of wood plunger manually. Initiator was electrical cap N8. Results are collected in Table 4.

Table 4. Estimation of critical density of detonation of mixture AN/ mipora 94/6 (d = 12 mm)

Density, g/cm^3	Length of detonation, mm	Result
1.06	18	Damping
1.05	12	Damping
0.93	30	Damping
0.93	95	Detonation

There were two parallel runs at ρ = 0.93 g/cm^3 (Table 4). There was detonation in one of them, and damping of detonation in another one. One can apologize that critical density of the charge at d = 12 mm ρ_{cr} = 0.93 g/cm^3.

Investigation of Mixtures on a Base of Granular AN

Detonability of porous grill AN and mixtures on its base were discussed in research works [8-9]. Nonporous granular AN (GOST 2-85 «B») was used in next experiments. Influence of nonporous granular AN addition on detonability of mixture AN/mipora 94/6 was investigated. d_f of mixture with 20% of nonporous granular AN increased to d_f = 9 mm, and with 50% it increased to d_f = 15 mm. The results of runs are collected in Table 5.

Table 5. Influence of nonporous granular AN addition on detonability of mixture AN/mipora 94/6

Content of nonporous granular AN, %	The greatest diameter of conic charge, mm	Density of charge, g/cm^3	d_f, mm
20	18 18	0.595 0.605	8.5 9.5
50	19	0.84	15.5

Investigation of detonability of mixtures on a base of nonporous granular AN with aluminum powder PAP-2 was carried out in cylinder charges [7] in paper confinement. Density of charges was ρ = 0.8-0.9 g/cm^3, content of aluminum (C_{Al}) was changed from 0.5 to 3.3%, the length of charge in any run was no less than in ten times greater than its diameter. Results of d_f measurement are presented in Figure 3, runs with detonation are symbolized as black points, runs with attenuation of detonation are symbolized as open points. The line in Figure 3 segregates fields of black and open points, and it is changing of d_f vs C_{Al}.

As one can see d_f^{min} = 21 mm is at C_{Al} = 1.5 %. There were shown in previous works [10-12] that d_f of systems "oxidizer–fuel" had the minimal value when oxygen balance (OB) of mixture equaled OB = 0%. Calculated composition of AN/Al mixture at OB = 0% is 84/16. In our runs (Figure 3) content of aluminum did not exceed C_{Al} = 3.5%. The dispersion of components differs one from another: the sizes of AN granules are 2-4 mm, thickness of Al powder plate is part of micron. It could be surmised that at d_f^{min} only outer part of AN granule that had contact with parts of aluminum reacted with it (stoichiometric mixture). Inner part of granule did not participate in reaction i.e. it was a ballast, as it took place in runs with mixtures of nonporous granular AN and fine mixture AN/mipora 94/6 (Table 5). At growth of C_{Al} contact of aluminum particles with

AN causes trouble, aluminum becomes a ballast too, and d_f begins to increase.

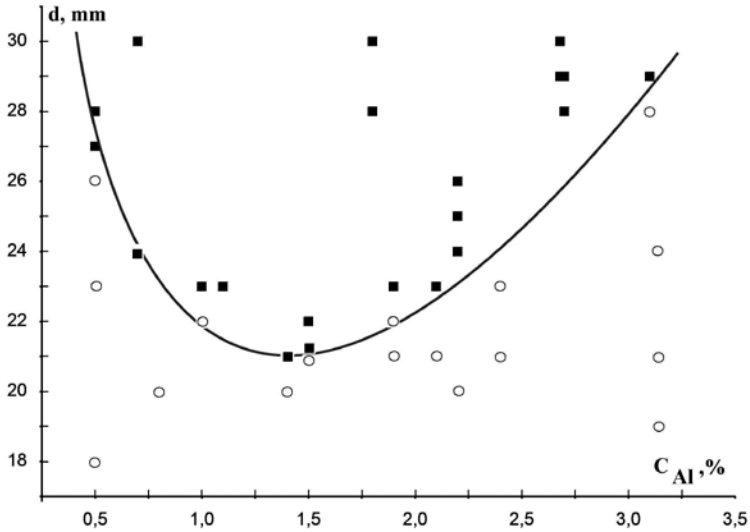

Figure 3. Detonability of mixtures on a base of nonporous granular AN with aluminum powder PAP-2.

Detonation velocity of mixtures on a base of nonporous granular AN with aluminum powder PAP-2 (98/2) was measured by means of ionization sensors [13]. It was D = 1027 ±38 m/s at diameter d = 28-30 mm and density ρ = 0.89 g/cm^3. This value is near four times less than calculated value by means of method [14]. It could be explained by heterogeneity of mixtures and by closeness of charge diameter to d_f of mixture.

Conclusion

Detonability of the mixtures on base fine (particle size was near 20 microns) and granulated ammonium nitrate (AN) with some organic fuels and aluminum powder was experimentally investigated. One can see that all of them represent explosive systems, and detonability of some of them (e.g. mixture AN/mipora at low density) can be very high. This is the most essential argument for a criminal case investigators.

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