Journal of Hazardous Materials, 4 (1980) 113–119

EFFECT OF AMMONIUM PERCHLORATE PARTICLE SIZE ON ITS DETONATION CHARACTERISTICS WHEN SENSITIZED WITH SMALL AMOUNTS OF NITROGUANIDINE

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ABSTRACT

Sympathetic detonation has already been achieved in ammonium perchlorate by adding small amounts of nitroguanidine. Although it appeared that the ammonium perchlorate was detonating at the ideal detonation velocity of the nitroguanidine additive, the effects of confinement, charge diameter, and ammonium perchlorate particle size were not assessed. The effects of confinement and charge diameter were subsequently investigated. In all these studies, however, the particle size of the ammonium perchlorate remained unchanged--nominally 200 micron Class C mil spec ammonium perchlorate. The present effort investigated the effect of variable ammonium perchlorate particle size upon the detonation characteristics of a typical ammonium perchlorate composite system: one sensitized with 5 percent nitroguanidine. Three particle size ranges--designated coarse (149 to 500 micron), medium (44 to 149 micron), and fine (0 to 44 micron)--were investigated. Screen-sieve separation was used. Although the results did confirm a general increase of detonation velocity with a decrease in ammonium perchlorate particle size, some anomalous behavior was also identified. A more comprehensive study will be needed to elucidate the effects of particle size or, more generally, the particle size distribution.

INTRODUCTION

The detonation velocity of explosives is a function of the chemical energy released, the rate at which this energy is released, the initial density of the explosive, the explosive charge diameter, and the degree of confinement. When the charge diameter is adequate, however, the detonation velocity is solely a function of initial explosive density and is completely determined by the thermohydrodynamics of the explosive. Such detonations, termed ideal detonation velocities, are constant and unique for each explosive at constant density. Figure 1 illustrates the empirical linear relationships of ideal detonation velocity as a function of density for both nitroguanidine and ammonium perchlorate (Ref. 1,2). By definition, and as can be experimentally demonstrated, the ideal detonation velocity is independent

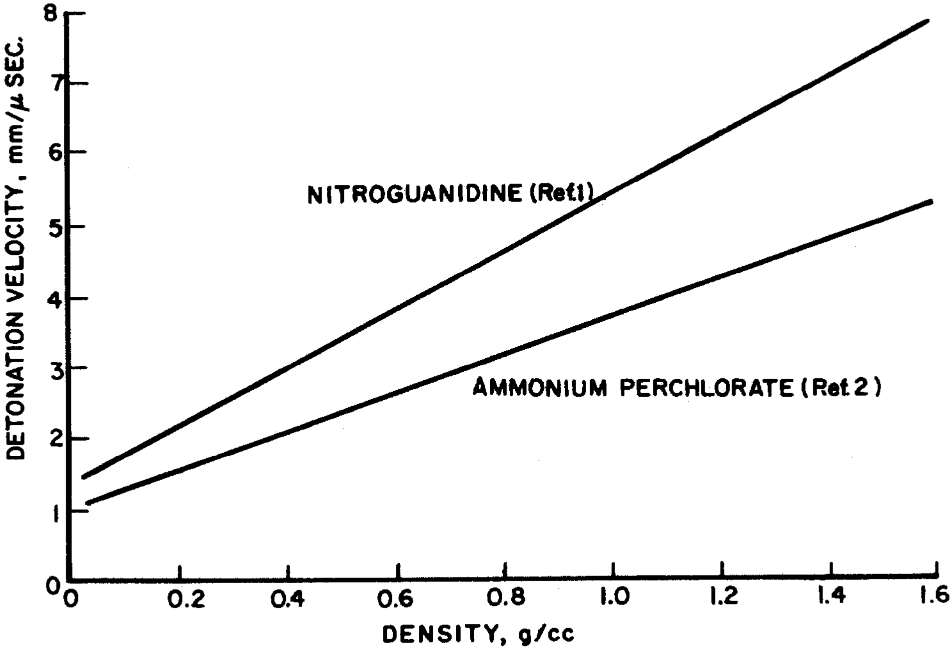


Fig. 1. Empirical linear relationship of ideal detonation velocity as a function of density for nitroguanidine and ammonium perchlorate (Ref. 1,2).

of particle size. The relationships between ideal detonation velocity, D_i, and density, ρ, illustrated in Figure 1 are derived from:

Nitroguanidine: $D_i = 1.440 + 4.015\ \rho$ (1)

Ammonium perchlorate: $D_i = 1.012 + 2.688\ \rho$ (2)

Ammonium perchlorate, although detonable, is generally not considered an explosive In previous work (Ref. 3) we investigated the stable sympathetic detonation of ammonium perchlorate by sensitizing it with a small amount of nitroguanidine. Under the conditions investigated, the ammonium perchlorate by itself could not detonate. It was our conclusion (Ref. 3) that the small amount of nitroguanidine was detonating at or near its ideal detonation velocity and that the ammonium perchlorate was induced to detonate sympathetically at the same detonation velocity.

Explosives, and particularly explosive composites, can detonate at velocities other than the ideal detonation velocity. This generally occurs when factors such as critical diameter, confinement, and sometimes particle size, are critical. Such detonations are termed nonideal. The range of nonideal detonations can be extensive, especially for fuel-oxidizer composite explosives. There is evidence to suggest that for certain fuel-oxidizer composites propagation rates can vary as a continuum from detonation velocities of km/sec to deflagration velocities of cm/sec. Hence the possibility that many typical pyrotechnics such as boron/potassium nitrate or aluminum/ammonium perchlorate can detonate. This has, in fact, been demonstrated (Ref. 4,5).

The present paper, however, investigates only the effects of ammonium perchlorate particle size when ammonium perchlorate is sensitized with a small amount of nitroguanidine. The resultant detonation velocity is presumed to be the ideal detonation velocity of the nitroguanidine based on its effective density, except when exceeded by the nonideal detonation velocity of the ammonium perchlorate under the restrictive conditions of charge diameter, confinement, density, and particle size.

EXPERIMENTAL

The experimental device employed in this and in previous work (Ref. 3,6) is illustrated in Figure 2. Steel confinement was used in this study and two charge diameters were investigated - 6 and 12 mm--for comparative purposes. An ammonium perchlorate system sensitized with 5 percent nitroguanidine was used as a standard. Because of the significant effect of ammonium perchlorate particle size on overall bulk density, this latter factor must be taken into consideration in the interpretation of the results of these experiments.

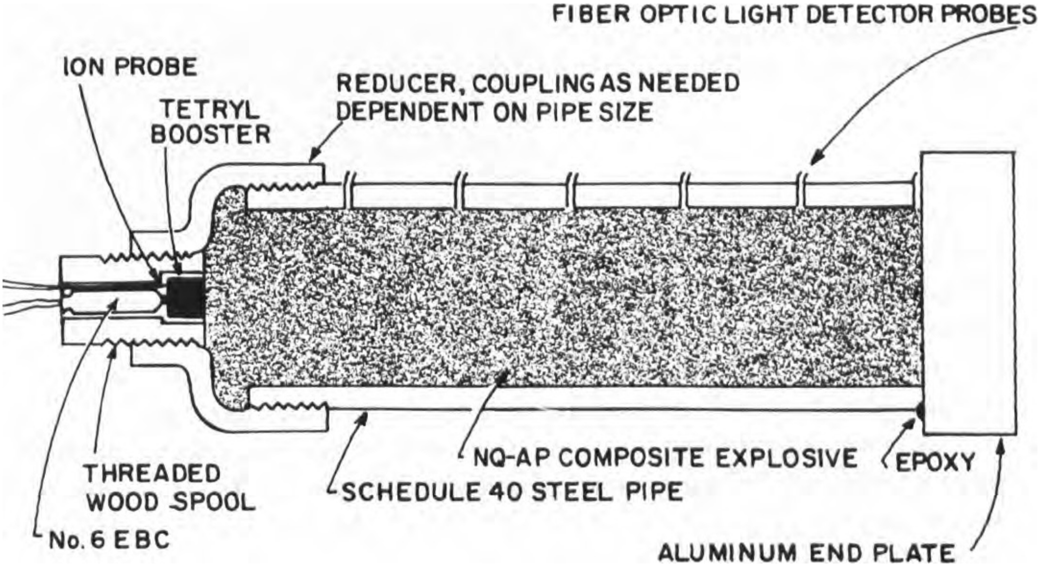


Fig. 2. Experimental test device utilized to monitor detonation velocities of explosive compositions.

As Figure 2 illustrates, the nitroguanidine-sensitized ammonium perchlorate samples were simply loaded into the pipe device. A No. 6 EBC was used in conjunction with a tetryl booster pellet to initiate detonation. The detonation velocity was monitored by light output from the detonation front as it passed the fiber optic stations of the pipe. Figure 3 shows a typical oscillograph output. Use of multiple stations substantiated whether a stable propagation velocity was or was not achieved.

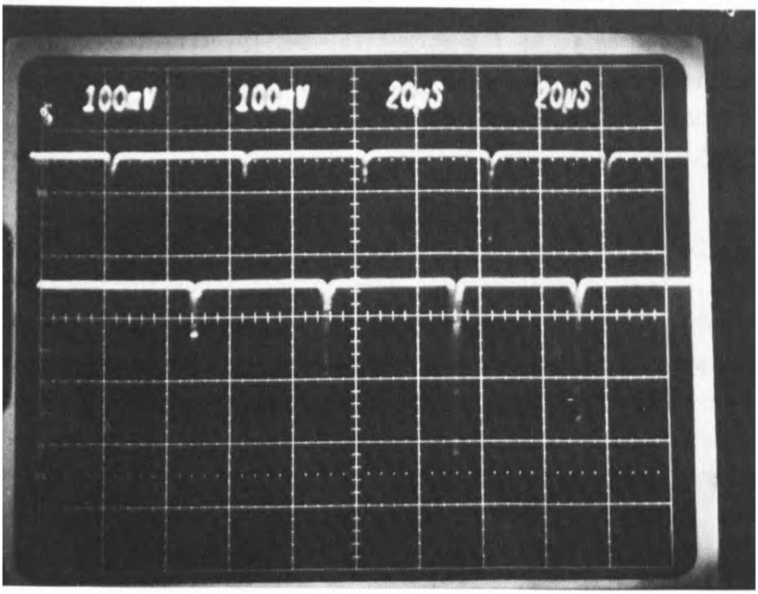
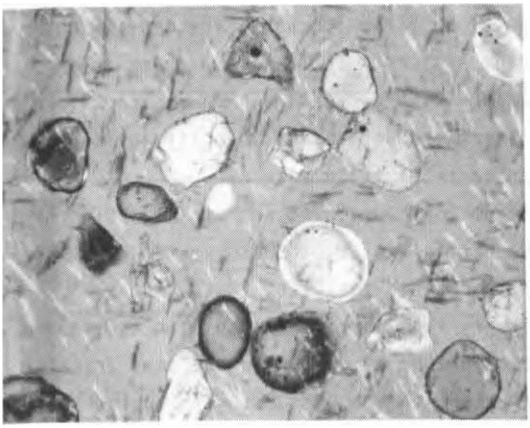


Fig. 3. Typical detonation velocity fiber optic light detector oscillograph record. Probe separation 76.2 mm - detonation velocity 1900 m/sec.

The three particle size ranges of ammonium perchlorate--designated as coarse (149 to 500 micron), medium (44 to 149 micron), and fine (0 to 44 micron)--were obtained by screen-sieve separation. Figures 4 through 6 illustrate photomicrographs of these particle size ranges. Nitroguanidine, the needle-type crystals in the figures, remained unchanged in all three systems. Note that the number of nitroguanidine crystals, which were generally 100 to 200 microns long, far exceeded the number of ammonium perchlorate crystals--even in the fine ammonium perchlorate case--although the nitroguanidine constituted only 5 percent of total mass.



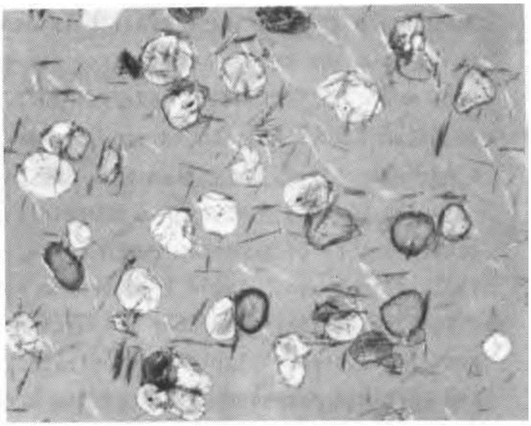


Fig. 4. Photomicrograph of coarse ammonium perchlorate mixed with 5 percent nitroguanidine.

Fig. 5. Photomicrograph of medium ammonium perchlorate mixed with 5 percent nitroguanidine.

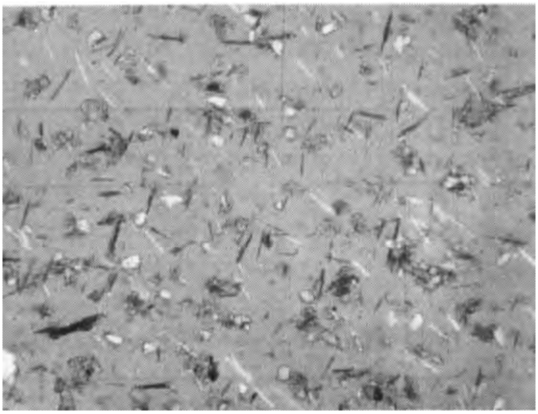


Fig. 6. Photomicrograph of fine ammonium perchlorate mixed with 5 percent nitroguanidine.

RESULTS

The results of these experiments are summarized in Table 1. As expected, the detonation velocity increases significantly with decreased ammonium perchlorate particle size between the medium and fine systems. The overall bulk density variation here should cause a decrease in detonation velocity with an overall decrease in bulk density. The effect of particle size evidently far exceeds the opposing effect of the overall bulk density. On the other hand, the case is not quite so clear between the coarse and medium systems. In this case there is a very moderate decrease in overall bulk density with decreasing ammonium perchlorate particle size. This could account for a decreased detonation velocity, evidently a stronger effect here than ammonium perchlorate particle size.

While Figures 4 through 6 certainly attest to the significant variation in the particle size of ammonium perchlorate, the particle size of these systems was nonetheless analyzed. Table 2 gives the results of this analysis. Note that the coarse system has a greater proportion of very fine particles than both the medium and fine systems. Table 3 illustrates this further by comparing the mass fraction and particle fraction ranges of the three particle size systems. The coarse system, with 94.2 percent by mass of the larger particles, has a larger percentage of fine particles than either the medium system, which has 98.2 percent by mass of medium range particles, or the fine system, which has 96.5 percent by mass of fine range particles. The question arises: which is of greater importance: the amount or the mass of particle sizes in a specific mechanism? A recent study of the effect of particle size on the shock initiation of molecular powdered explosives (Ref. 7) concluded that larger particle sizes are more sensitive than smaller particle sizes.

TABLE 1

Ammonium perchlorate sensitized with five percent nitroguanidine

Particle Size Range μm	Diameter mm	Density g/cc	Detonation Velocity* m/sec
149 to 500	12	1.24	2160
44 to 149	12	1.21	2030
0 to 44	12	1.06	2820
149 to 500	6	1.20	1900
44 to 149	6	1.04	1550
0 to 44	6	0.88	2350

*Detonation velocity of nitroguanidine at above density: 1660 m/sec
Detonation velocity of ammonium perchlorate at above density: 4000 m/sec

TABLE 2

Ammonium perchlorate particle size analysis

Type	Percent of μm size						
	<8.1	8.1-16	16-41	41-81	81-168	168-315	315-525
Coarse	31.4	33.9	27.0	3.9	1.1	2.3	0.37
Medium	5.9	2.7	15.3	19.8	43.2	13.1	0
Fine	22.3	28.4	32.0	16.6	0.54	0.01	0

TABLE 3

Ammonium perchlorate particle versus mass distribution

Type	Sieve Size	Mass		Particles	
		%	Range	%	Range
Coarse	149-500	94.2	168-525	92.3	0- 41
Medium	44-149	98.2	81-315	63.0	41-168
Fine	0- 44	96.5	16-168	82.7	0- 41

Once initiated, however, the smaller particles attain stable propagation more readily.

SUMMARY

The objective of this work was to investigate the effect of ammonium perchlorate particle size upon the detonation characteristics of an ammonium perchlorate system sensitized with a small amount--5 percent--nitroguanidine. It can be safety concluded that reducing the ammonium perchlorate particle size, which is already known to increase the propensity of ammonium perchlorate to detonate, increases the overall detonation velocity of the ammonium perchlorate-nitroguanidine system. The effects of varying the overall bulk density, which is also known to increase detonation velocity as density increases, can be accounted for to some extent. There is no satisfactory explanation for a possible reversal in anticipated results between the coarse and medium systems. It may be attributed to the particle size distribution, which produces a greater number of fine particles on a relative basis in the coarse system than in either the medium or fine system. However, this matter can only be resolved by a more definitive study requiring both better particle size separation and perhaps an analysis of the effect of bimodal particle sizes on detonation velocity and ignition.

REFERENCES

1. M.D. Hurwitz, OSRD 5611, (1945).
2. W.H. Anderson and R.E. Pesante, Eight Int. Symp. Combust., Williams and Wilkins, (1962), pp 705-710.
3. A.J. Tulis, Sixth Int. Detonation Symp., (1976), pp 173-182.
4. A.J. Tulis, Tenth EED Symp., Proceedings in press, (1979).
5. A.J. Tulis, unpublished work.
6. A.J. Tulis, J. Hazardous Mat., 2 (1977/1978), pp 171-181.
7. C.L. Scott, Fifth Detonation Symp., ACR-184, (1970), pp 259-266.