

The marked reduction in the critical diameter near 20% porosity occurs for all powder additives and for all the explosives, which evidently means that there is a change in the grain ignition mechanism. One may reasonably suppose that the smooth and slight variation in the critical diameter with the paraffin content (Fig. 1a) indicates that the reaction propagation mechanism is the same at all charge densities.

The critical detonation speed also varies with the proportion of inert filler; Fig. 2 shows the limiting detonation speed D_l (curve 1) and the critical value D_{cr} (curve 2) for Hexogen-talc mixtures; at low talc contents (porosities over 20%) the detonation speed is constant and the difference between D_{cr} and D_l is 900-1000 m/sec. The constant value for D_{cr} (curve 2 of Fig. 2) coincides with the range of increasing d_{cr} (Fig. 1b). Note particularly the point at the upper end of curve 2 in Fig. 2, which corresponds to 20% porosity, where D_{cr} for the mixture (60:40 Hexogen-talc) has almost attained the limit. It would appear that there is a change in the detonation excitation mechanism at this point. The critical diameter falls considerably when the proportion of inert additive increases further. The rise in D_{cr} when the porosity falls to about 20% has been observed previously [3] and was explained as due to decomposition at foci accompanying combustion of grains from the surface under certain conditions (these foci are microscopic pores and other nonuniformities in the commercial grains). One supposes that the pressure in the detonation wave under critical conditions at this point attains values such as to produce reaction at the foci w_i in the grains, which results in a change in the mode of excitation, with ignition by hot gases giving way to a predominant effect from pressure and compression in the detonation wave.

LITERATURE CITED

1. A. Ya. Apin, Dokl. Akad. Nauk SSSR, 24, 992 (1939); 50, 285 (1945).
2. A. Ya. Apin, A. N. Afanasenkov, and G. V. Dimza, in: Blasting [in Russian], No. 75/32, Nedra, Moscow (1975).
3. G. V. Dimza, Fiz. Goreniya Vzryva, 8, No. 2 (1972).

DETONATION CAPACITIES OF PERCHLORATE EXPLOSIVES

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UDC 662.3

Most inorganic oxidants are weak explosives of low heat release; examples are ammonium nitrate and ammonium perchlorate (AN and APC). The energy of a mixture of such an oxidant with a combustible additive (nonexplosive) exceeds the energy of ammonium nitrate or perchlorate by a factor of 3-4, which means that almost all the energy is released by interaction of the oxidant decomposition products with the fuel. This makes such mixtures convenient for research. Although the interactions are more important at large diameters, there is no doubt that they still occur near the critical diameter. Explosive mixtures of oxidant-fuel type have several special features that begin to become apparent under critical conditions. For instance, the critical diameter is less than that for the pure oxidant, while the critical detonation speed is higher [1]. There are differences by comparison with the individual explosives as regards the critical diameter d_{cr} and critical detonation speed D_{cr} as functions of component grain size. One of these is that d_{cr} increases with the density, which has long been known, but which has not been fully elucidated. The reason is not simply that the diffusion processes become slower as the pressure increases [1].

We have examined the effects of component grain size, mixture composition, and nature of the fuel on the detonation under critical conditions. The tests were done with mixtures

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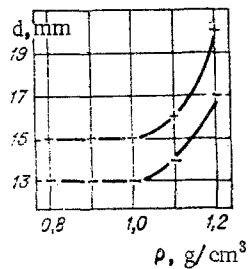


Fig. 1

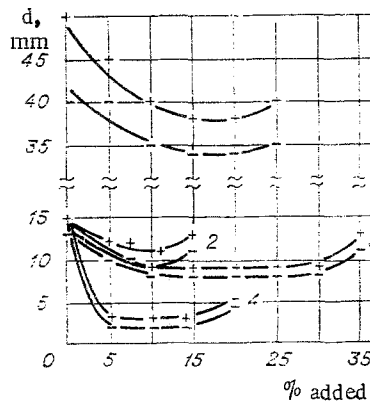


Fig. 2

Fig. 1. The ρ dependence of d_{cr} [+ detonation occurs; -) detonation dies out].

Fig. 2. Effects of d_{cr} for APC from addition of: 1) urea, $l = 130 \mu$; 2) carbon; 3) urea, $l \sim 5 \mu$; 4) urotropine.

of APC with urea, urotropine, carbon, and Octogen.

Figure 1 shows d_{cr} as a function of density for fine-grained APC ($l \sim 5 \mu$), which indicates how the detonation capacity of a mixture compares with that of pure APC. The critical diameter is constant at 14 mm for ρ of 0.8, 0.9, and 1.0 g/cm³, but d_{cr} begins to rise at higher densities. The decomposition products from the components interact most fully when the grain size of the mixed explosive is very small. This effect from the fuel additive is clear under critical conditions, as is readily seen from APC + urea (Table 1 and Fig. 2).

The critical detonation speed for a coarse-grained mixture is about 2.0 km/sec, as against 3.0 for a fine-grained one. The measurements show that coarse-grained urea reduces d_{cr} only slightly, whereas the fine-grained material is more effective, which is appreciable also from the critical detonation speed. The finely divided mixture detonates under critical conditions at speeds much greater than those for the coarse-grained material. Figure 2 and Table 2 give d_{cr} in relation to composition for mixtures of APC with urotropine and carbon, both ground to micron size. Even a small proportion of fuel reduces the diameter considerably. However, any further increase in the proportion of fuel up to the zero-oxygen balance point either has no effect at all on critical diameter or produces some increase on account of the marked dilution. A similar effect was reported in [2]. The critical diameters for APC mixed with 10 or 20% wax at specific gravities of 0.5-0.7 remain constant.

An additive that is nonexplosive and does not release gas (carbon) has least effect on the critical parameters under otherwise equal conditions (particle size and density), whereas an additive that produces gases (urotropine or urea) reduces d_{cr} much more considerably.

One naturally expects that an explosive fuel added to ammonium nitrate or perchlorate would have an even more marked effect, which is bound to influence the detonation characteristics under critical conditions. Mixtures of APC with Octogen were used to examine this effect for various ratios between the oxygen and fuel; we measured d_{cr} and D_{cr} in relation to composition and density. The APC had a particle size over 100 μ and the Octogen, over 50 μ . Table 3 and Fig. 3 give the results. Mixtures of APC with Octogen of particle size 1-10 μ are very highly reactive; for instance, a mixture containing 10 or 20% Octogen with a density ρ of 1.14 g/cm³ detonates in charges of diameter 3 mm with a speed of 3.0 or 3.2 km/sec, respectively. This shows that Octogen added to APC reduces the diameter considerably; for instance, 5% Octogen reduces the critical diameter for APC by a factor of 4 at $\rho = 1.2$ g/cm³.

The effects of charge density on d_{cr} are such that Octogen contents up to 15% result in mixtures that behave in the same way as mixtures of perchlorate with nonexplosive fuels, i.e., the critical diameters increase with the density. Mixtures containing 15 or 20% Octogen have critical diameters almost independent of the density. Higher Octogen contents

TABLE 4

Percent Hexogen	d_{cr} , mm, for $\rho = 1.0 \text{ g/cm}^3$
0	7.5 ± 0.5
10	7.5 ± 0.5
20	7.0 ± 0.5
30	—
40	5.75 ± 0.25
50	5.25 ± 0.25
70	4.25 ± 0.25
80	3.75 ± 0.25
90	3.5 ± 0.25
100	3 ± 0.25

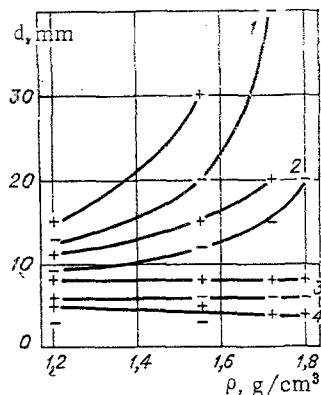


Fig. 3

Fig. 3. Density dependence of d_{cr} for APC mixed with Octogen: 1) 95:5; 2) 90:10; 3) 85:15; 4) 75:25.

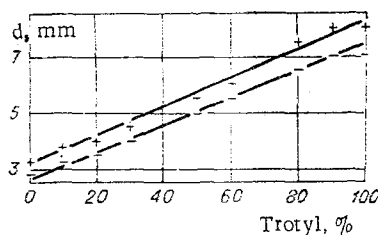


Fig. 4

Fig. 4. Composition dependence of d_{cr} for TH.

cause the critical diameter as a function of density to become similar to that for individual high-energy explosives, i.e., by varying the composition with the same components one can observe the density dependence of the critical diameter, on the one hand, characteristic of the weak individual substances and mixtures with fuels, while, on the other hand, one finds relationships such as are found with high-energy individual substances.

In each of these cases we found smooth variation in the critical diameter with the density; in no case did the critical diameter show a peak [3]. It has been found [1] that d_{cr} for APC + 32% Trotyl increases slightly but clearly with the density. On the other hand, Octogen added to APC in the same proportion reduces d_{cr} . Table 3 gives the critical detonation speeds and values for d_{cr}/D_{cr} , this ratio being proportional to the reaction time. The variation in this quantity is similar to that for the critical diameter. For instance, the ratio tends to increase slightly with the density for Octogen contents of 5 and 10%, which means that either the reaction time does not alter or else that it increases slightly. Any further increase in the Octogen content reduces the ratio, which is characteristic for individual high-energy explosives. Therefore, the $d_{cr} = f(\rho)$ curves for mixtures of APC with Octogen indicate that the APC participates vigorously in the explosive conversion reactions.

In fact, if one takes a mixture of a secondary explosive with an inert additive, for instance, Hexogen with talc, one finds that there is no increase in the quantity with the density for proportions of the inert additive up to 60%. For example, Hexogen + talc (40:60) has $d_{cr} > 50$ for $\rho = 1.44 \text{ g/cm}^3$; at $\rho = 1.86 \text{ g/cm}^3$, the detonation propagates in a charge of diameter 15 mm.

We also examine TH mixtures (Trotyl-Hexogen), whose components have negative oxygen balances, and thus the decomposition products from the components largely do not interact. The critical charge diameter was determined for TH mixtures of overall density $\rho = 1.0 \text{ g/cm}^3$;

the particle sizes of the component were less than 100 μ . Table 4 and Fig. 4 show that the critical diameter as a function of composition is represented by a straight line, and the additivity rule applies. The effects of the two components are different. The relation of critical diameter to composition for APC-Octogen mixture is clearly nonlinear, and the reduction in the critical diameter for such mixtures is larger than the linear law would imply. On the other hand, if the APC in the mixtures with Octogen is replaced by an inert additive of the same density (KCl) and the same grain size, there is an increase in the critical diameter.

Mixtures containing 70% KCl detonate stably at a diameter of 12 mm, as against 16 mm at 80% KCl, i.e., the inert additive replacing APC increases the critical diameter by about a factor of 2, which shows that APC behaves in an active fashion under critical conditions even when the conditions are severe, namely, in mixtures with powerful explosives.

LITERATURE CITED

1. L. N. Akimova, L. N. Stesik, and A. Ya. Apin, *Fiz. Goreniya Vzryva*, 3, No. 3 (1967).
2. D. Price, A. R. Clairmont Jr., and J. O. Erkman, *Combust. Flame*, 17, No. 3, 323-336 (1971).
3. V. K. Bobolev, Candidate's Dissertation, Institute of Chemical Physics, Academy of Sciences of the USSR (1947).

SHOCK-INDUCED ELECTRICAL POLARIZATION OF NITROGLYCERINE

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According to [1, 2] the electrical polarization induced in low-molecular-weight solids by a shock wave (shock polarization) is due to turning of asymmetric dipole molecules in the force field of the shock front. When the material leaves the interaction zone of the shock front, which has a duration of 10^{-21} to 10^{-13} sec in liquids, the induced polarization is destroyed by thermal motion of the molecules [3] and, if the compressed material becomes electrically conducting, by equalization of bound charges by free current carriers [4, 5]. Since the relaxation process does not have to depend on the means for producing polarization (turning of molecules in the field of the shock front or due to an externally applied electrical field), the relaxation times τ for the shock and dielectric polarization must be the same for materials which are still good insulators in the compressed state. Thus, an independent measurement of the relative statistical permittivity ϵ_s and τ in the compressed state by means of the high-frequency methods described in [6] makes it possible to reduce the number of unknown parameters in the phenomenological theories of shock polarization and to compute the specific polarization P_0 produced by the shock front.

In the present work we measure ϵ_s , τ , and the shock polarization voltage of nitroglycerine over dynamic pressures of 1.4-14.5 GPa. Based on the experimental data obtained we estimate the viscosity of the compressed material and compute P_0 .

Theoretical Considerations

As in [3-5], we shall assume that the material being studied is the dielectric in a plane condenser with initial thickness x_0 . As it moves from one plate to the other at velocity U the shock front causes polarization of the sample, which relaxes to its equilibrium value of zero. We shall assume that the dielectric obeys the Debye formulas with a

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