CRITICAL DETONATION DIAMETER FOR AN EXPLOSIVE CONTAINING AN INERT ADDITIVE

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Measurements have been made of the critical detonation diameters for explosive compositions based on Hexogen, Octogen, and Trotyl containing various amounts of inert solid fillers and air. The effects of density and porosity on the detonation have been examined. Porosity affects the results because the explosive particles may be ignited by gaseous reaction products [1]. It has previously been observed [2] that hot gases have an effect in the excitation of detonation by transmission through an air gap. It was found that a layer of phlegmatizer on the explosive grains can substantially reduce the detonation transmission distance, and the same occurs if a layer of water is placed at the end of a passive charge. It might be supposed that the detonation excitation mechanism, which is somewhat analogous to Apin's explosive-combustion mechanism [1], might be observed in the explosive systems used here.

The critical detonation diameters were examined using explosive powders of mean particle size 0.1 mm; the explosive content per unit volume was always 1 g/cm^3. The inert filler entered into the free space, the amount varying from a few percent up to almost the entire free volume in the charge. The density and porosity varied correspondingly. This meant that one could obtain charges of structure ranging from loose powders to maximally compacted systems at a constant explosive content.

The inert fillers were wax, talc, aluminum powder, and polymethyl methacrylate powder (the last of particle size about 1 μ).

The wax was deposited on the explosive grains from solution in petroleum and covered the entire surface; it should prevent the grains from being ignited by hot gases. Talc as a good lubricant allowed one to vary the density of the system as well as the porosity and gas permeability, but did not cover the surfaces of the grains entirely. The grain size of the polymethyl methacrylate was very small, so the gas permeability should be much less for a given volume content than in the case of talc, although it resembled talc in not shielding the particles entirely. Also, the density of talc is about 2.5 times that of wax and polymethyl methacrylate, and, consequently, the density should be substantially different for the same volume content. The range of properties available in the additives allowed us to distinguish clearly the effects of factors such as density, porosity, and gas permeability on the critical diameter and critical detonation speed.

Charges of these mixtures were packed into cellophane shells of length not less than 10 times the diameter. The detonation speed was recorded with an SFR-2M camera.

Table 1 gives the characteristics of the charges and the results; Fig. 1a shows how the critical detonation diameter varies for: 1) Trotyl, 2) Octogen, and 3) Hexogen in relation to the content of paraffin. The abscissa is the porosity instead of the content of the inert additive. Figure 1b shows similar curves for explosives containing the powder additives: 1) Trotyl + polymethyl methacrylate, 2) Trotyl + talc, and 3) Hexogen + talc. The points denoted by plus signs correspond to mixtures of Trotyl with aluminum, which was an additional system, in which the density of the aluminum was equal to that of the talc, and the particles were similar in size. These points fall almost exactly on the curve for Trotyl + talc. The mixtures of Octogen with talc did not press at all well, so the entire curve could not be recorded, but only certain points, which lie near the curve for Hexogen +

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TABLE 1. Effects of Inert Additives on d_{cr} and D_{cr} for Explosives

Composition, %		Density, g/cm³	Porosity, %	d_{cr}, mm		D_{cr}, m/sec
explosive	inert material			detonation occurs	detonation dies out	
Hexogen–talc						
90	10	1,10	40,4	4,0	3,0	5050
80	20	1,25	35,2	5,0	4,0	5100
75	25	1,33	32,2	7,0	6,0	5100
70	30	1,43	28,6	8,0	7,0	5070
60	40	1,66	20,0	9,0	8,0	5900
55	45	1,80	14,5	3,3	—	
50	50	2,0	7,5	3,3	—	
Hexogen–wax						
95	5	1,05	38,7	5,0	4,0	5250
90	10	1,10	32,3	5,0	4,0	5250
80	20	1,25	16,7	5,0	3,8	6200
76	24	1,32	9,4	5,0	3,8	6730
72	28	1,39	1,2	5,0	3,8	7300
Octogen–talc						
70	30	1,43	31,1	8,0	7,0	5090
58	42	1,72	20,0	7,0	6,0	6170
50	50	2,05	3,8	3,8	—	6300
Octogen–wax						
90	10	1,10	36,0	7,0	6,0	5200
78	22	1,28	21,0	8,0	7,0	5850
70	30	1,42	0	9,0	8,0	6800
Trotyl–talc						
90	10	1,1	40,0	8,0	7,0	4100
75	25	1,33	28,0	9,0	8,0	4100
70	30	1,43	24,0	9,0	8,0	4000
65	35	1,54	20,0	10,0	9,0	4450
60	40	1,66	15,0	7,0	6,0	4550
55	45	1,80	10,0	7,0	6,0	4970
Trotyl–aluminum (APP-3)						
90	10	1,1	40,0	8,0	7,0	4100
65	35	1,54	20,0	10,0	9,0	4600
60	40	1,66	15,0	7,0	6,0	—
55	45	1,80	10,0	7,0	6,0	5390
Trotyl–polymethyl methacrylate						
95	5	1,05	36,0	12,0	10,0	4070
85	15	1,16	26,0	18,0	15,0	4880
80	20	1,25	19,0	12,0	10,0	4800
78	22	1,28	17,0	10,0	9,0	—
75	25	1,33	12,0	9,0	8,0	4880
70	30	1,43	3,4	8,0	7,0	5800

Note. Explosive grain size 0.1 mm.

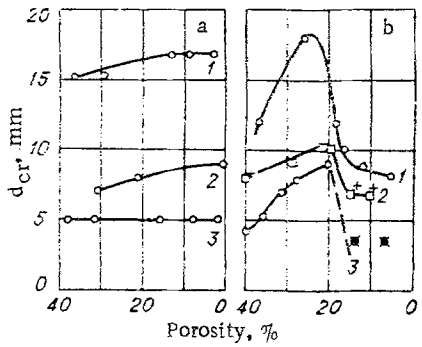

Fig. 1

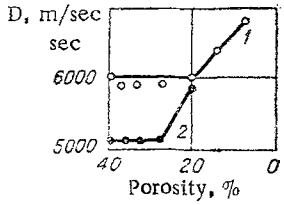

Fig. 2

talc (Table 1). It proved impossible to determine the critical diameter at porosities less than 20% for Hexogen + talc, but it was found that the values were less than 3.3 mm, since detonation occurred in charges of this diameter (points shown by crosses in Fig. 1b).

Figure 1 shows that the variation in d_{cr} with the content of inert additive is dependent on whether the latter is a powder or coats the grains (wax). In the case of the wax, there is a weak (smooth) dependence of the critical detonation diameter on the content of the inert additive, whereas the trend for the powder additives is more complex. The rise in d_{cr} with the content of the powder goes as far as a peak, evidently because the explosive grains are ignited by gaseous reaction products. The permeability decreases as the proportion of inert additive increases, so the hot reaction products can less readily reach the explosive particles, which means that the conversion time for the explosive increases, and hence the critical diameter also rises. This explains why larger critical diameters are found for mixtures of Trotyl with polymethyl methacrylate (curve 1 of Fig. 1b), as compared with Trotyl + talc or aluminum (curve 2), since the particles of polymethyl methacrylate were much smaller than those of talc, and hence the gas permeability was lower.

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_{γ} (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_{γ} 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 wi 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

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DETONATION CAPACITIES OF PERCHLORATE EXPLOSIVES

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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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