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SOME FEATURES OF DETONATION INITIATION IN LOW-DENSITY CHARGES

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Many powdery explosives (E.E.), especially industrial ones, are often used in charges whose density is considerably less than the specific gravity of the explosive itself. The study of the features of detonation initiation in low-density charges therefore has not only scientific but also practical significance. I. F. Blinov and one of the authors, in investigating the explosibility of aromatic dinitro compounds, discovered a new phenomenon that at the time remained unexplained: at low density (0.4–0.6 of the specific gravity) these explosives detonated in a small-diameter metal tube from a No. 8 blasting cap and did not explode from it in a large-diameter tube. When the initial impulse was strengthened (a charge of tetryl or RDX of bulk density as an intermediate detonator), detonation was regularly initiated both in the narrow and in the wide tube. It remained unclear whether this phenomenon represented a peculiarity of difficult-to-initiate dinitro compounds or whether it had a general character. To clarify this question and to establish the principal characteristics of the phenomenon, the present investigation was undertaken.

The first series of experiments was carried out with collodion cotton*. At a density of 0.23–0.26 g/cm^3 the critical detonation diameter of this explosive, determined by explosions of conical charges in a paper casing, was 10 mm. In subsequent experiments, charges of various densities were exploded in tubes with an internal diameter of 10–10.5 (hereinafter, small diameter) and 21–30 mm (hereinafter, large diameter)**. As the initiator, charges of lead azide with a density of about 2 g/cm^3 in glass tubes of different diameters were used***. The length of the lead azide column was 5–10 diameters. The tube with azide was immersed 2–3 mm into the charge being initiated. By changing the diameter of the tube and, correspondingly, of the lead azide column, it was easy to change the size of the region in the charge under study on which the initial impulse acts. In what follows, we call this region the initiation site. The results of experiments with collodion cotton are given in Table 1.

As is evident from the data of Table 1, with a constant size of the initiation site, failures in large-diameter tubes cease if the charge density exceeds a certain limit, which for an initiator 4 mm in diameter is about 0.6 g/cm^3. If the size of the initiator is reduced, then even at this density detonation occurs in small-diameter tubes, but not in wider tubes.

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* Nitrogen content 12.06%, moisture 0.1%, sieved through a sieve with 0.5 mm openings.
** Brass tubes with a wall thickness of 0.5 mm and glass tubes with a wall thickness of 1-2 mm were used. With this wall thickness the resistance to scattering offered by the glass tube is so great that the difference between metal and glass did not appear in our experiments.
*** When collodion cotton charges were initiated by a No. 8 blasting cap, complete detonation was observed in tubes of both diameters at all densities tested.

When a charge is not enclosed in a casing, even one made of glass, no difference is observed between charges of large and small diameter. Collodion-cotton charges of both 12 and 30 mm diameter in a thin paper casing, at a density of 0.25 g/cm^3, did not detonate with a tube diameter containing lead azide of 4 mm. With a more powerful initial impulse, stable detonation occurs in both cases. The following series of experiments was carried out with finely dispersed tetryl, prepared by the method described by Ya. I. Leitman ([1]).

Table 1

Results of experiments on initiating detonation of collodion-cotton charges in tubes of different diameter (+ detonation, − failure or burning of the charge)

Charge density, g/cm^3 of collodion cotton	Diameter of initial lead azide charge, mm	In a tube, diameter 10-10.5 mm	In a tube, diameter 21-30 mm
0.24-0.26	4	+++	−−−−
0.40-0.42	4	++	−−−
0.50-0.51	4	++	−−
0.58-0.65	4	+	++
0.58-0.65	2	++	−−

At a density of 0.30-0.35 g/cm^3 the critical detonation diameter (paper cartridge) was about 6 mm. With small dimensions of the initiating source (lead azide charges 0.85-1.00 mm in diameter), stable detonation was observed in brass tubes 10 mm in diameter, while in tubes 15 and 23 mm in diameter there were systematic failures.

Similar results were obtained in experiments with a mixture of 4% nitroglycerin and 96% ammonium nitrate at a density of 0.5 g/cm^3 (tubes 10 and 30 mm in diameter, initiation by a lead azide charge 2 mm in diameter), and with a powder obtained by grinding nitroglycerin powder. In the latter case, at charge densities of about 0.5 g/cm^3 and an initiator diameter of 4 mm, detonation was observed in tubes 10 mm in diameter and failure in tubes 20 mm or more in diameter. For all the substances studied, the phenomenon described was observed only when the density of the charges was below a certain limit. The magnitude of this limit, as we saw from the example of collodion cotton, depends to some extent on the dimensions of the initiating source; however, in all the cases studied the limiting density did not exceed 0.7 of the specific gravity.

On the basis of the general concepts developed concerning the detonation ability of condensed high explosives, Yu. B. Khariton ([2]) showed that stable detonation can arise if the size of the source exceeds a certain minimum, of the order of magnitude close to the critical diameter of the given explosive. From this point of view, if a given initiator can produce detonation in a charge of small diameter, then all the more can it be produced in a charge of larger diameter.

In low-density charges enclosed in a dense casing, as the experiments described above show, the results may be substantially different. The low relative density makes possible the compaction of the explosive under the action of comparatively small forces, while the size of the individual particles is considerably smaller than the critical diameter, so that detonation is possible only for an aggregate of such particles. Applying Yu. B. Khariton' s principle ([2]), the occurrence of an explosion in such a system may be represented as follows: in the initiating source there arises a reaction of explosive transformation which proceeds, apparently, in the form of burning over the surface of individual particles. Burning arises if the action of the initiator, characterized, for example, by the pressure in the front of the shock ···

waves, has an intensity exceeding some minimum. The degree of completion of the transformation in the reacting layer depends both on the magnitude of the pressure and on the duration of its existence, determined by the size of the initiation region and by the conditions of dispersal of the substance from it. In charges of low relative density, one may speak of "internal" dispersal of the substance from the zone encompassed by compression, due to compaction of the surrounding layers. The scattering of the compressed substance from a sufficiently small region occurs before the burning of the particles has propagated to its boundary, and the layers surrounding the initiation region behave like an inert shell. At low charge density the inertial resistance of this layer proves small; dispersal of the substance from the compressed layer proceeds rapidly, which leads to attenuation of the detonation. In a strong tube of small diameter the compression wave caused by the explosion of the initiator reaches the walls while still having sufficiently high parameters. The increase in pressure as a result of reflection of the wave prevents attenuation of the reaction in the initiation region. In a tube of large diameter, by the time it reaches the wall the wave has been weakened to such an extent that reflection can no longer effectively influence the completion of the explosive transformation reactions. Along with the phenomenon of reflection, the circumstance may also play a role that, as the tube diameter decreases, dispersal of the substance diminishes because of the reduction of the readily compacted layer between the boundaries of the initiation region and the walls.

As the charge density increases, the rate of pressure drop in the compression wave decreases, and a self-propagating reaction region can be created by the action of an initiator which, in a less dense charge, can excite a stable transformation only through the effect of reflection from the wall. An increase in the initial density also reduces the compactability of the layers surrounding the initiation region, which diminishes the internal dispersal.

It seems probable to us that the proposed mechanism of internal dispersal also determines a number of previously described, insufficiently explained phenomena in the explosion of weakly compacted charges—for example, the decrease, established by A. F. Belyaev et al. ([3]), in the thickness of the dispersed layer with increasing density of the charge being exploded. Consideration of this phenomenon is also necessary in solving many applied problems, in particular when assessing the explosibility of various substances in the form of low-density charges.

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Note: Figure translations are in progress. See original paper for figures.