DENSITY DEPENDENCE OF THE CRITICAL DIAMETER AND DETONATION VELOCITY OF EXPLOSIVE CHARGES

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It is shown that the dependence of the critical diameters of ammonium–nitrate and homogeneous explosives on density is qualitatively the same.

For homogeneous explosives the initial density from which the critical diameters increase as the density increases is close to the density of the single crystal, whereas for ammonium-nitrate (AN) explosives it is less than unity.

The detonation velocity of charges of homogeneous explosives of near-critical diameter, like the detonation velocity of AN explosives, increases with increase in density to a limiting value of the latter, after which it decreases.

The value of the limiting density starting from which the detonation velocity of charges of pressed TNT begins to decrease almost coincides with the value of the density starting from which the critical diameter of the same explosive increases and is equal to $\sim 1.63-1.64$ g/cm^3.

It is known [1, 2] that as the density increases the detonation velocity of D-charges of AN explosives increases only up to a certain value of the density, after which it begins to decrease. If the density exceeds a certain limit, detonation is quenched. Belyaev [3] and Petrovskii [4] have shown that this applies only to charges of near-critical diameter.

We assume that the detonation velocity of charges of homogeneous explosives with near-critical diameters varies in the same way as for charges of AN explosives, i.e., as the density increases the detonation velocity should increase to a certain limiting value of the density, after which it should decrease.

So far, the existence of a limiting density for homogeneous explosives has remained undetected, since only charges with densities obtainable by ordinary pressing have been investigated, whereas the limiting density of homogeneous explosives should be sought in the range of the single-crystal density.

We also assume that the curve representing the dependence of the critical diameters d_* on density ρ_0 of both homogeneous and mixed (in particular, AN) explosives has a minimum. This assumption is justified by the data of [5] and the unpublished data of Apin, who has demonstrated the existence of a minimum of the $d_* = f(\rho_0)$ curve for RDX.

In order to test these assumptions we selected TNT and ammonite 80/20, since these explosives are in common use. Moreover, TNT has the greatest d_* of the ordinary homogeneous explosives and is easier to experiment with than more powerful explosives.

1. Experiments with TNT charges at $\rho_0 > 1.62$ g/cm^3.

For making the TNT charges we regularly employed TNT with a solidification point of 80.2° C.

Before pressing we heated the TNT together with the mold to 72–76° C and added a little acetone. During pressing, the charges were placed under a pressure of 3000–3500 kg/cm^2 for a period of 2–3 min. The TNT employed had a particle size of less than 0.002 mm. The unit charges were not more than 5 mm thick.

After preparation the unit charges were kept for 30 days at room temperature in order to allow the acetone to evaporate completely; then we determined the density of each charge and sampled the volatiles content, which was not higher than that of the starting TNT.

Table 1

Detonation Velocity of Pressed TNT Charges (with density close to that of the single crystal) as a Function of Density

d, mm	ρ_0, g/cm^3	D, m/sec	n	σ_i, m/sec
13	1.59	6850	5	+100 —40
13	1.6	6870	4	+30 —40
13	1.61	6870	4	+20 —90
13	1.62	6900	4	+25 —35
13	1.64	6950	3	+30 —50
13	1.65	6800	3	+50 —40
10	1.61	6790	3	+60 —90
10	1.62	6830	3	+25 —61
10	1.64	6790	3	+50 —100
10	1.642—1.646	6725	1	—
10	1.647—1.65	6730	1	—
8	1.61—1.62	6650	3	+30 —
8	1.62—1.63	6670	3	+40 —60
8*	1.63—1.64	6480	3	+70 —50
8*	1.639—1.641	6350	1	
8*	1.644—1.645	6350		
8†	1.645—1.65			
8†	1.642—1.644		1	
8†	1.640—1.65		1	
8†	1.64—1.645		2	
8†	1.64—1.645		1	
8†	1.65—1.659		1	
6†	1.63—1.64			

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*In a series of experiments at ρ_0 = 1.63 − 1.645 we observed the quenching of detonation. Quenching was also observed when detonation was initiated by intermediate pressed TNT detonators with d = 8 mm, h = 15 mm, and ρ_0 = 1.6.

† Failure to detonate.

Table 2

Detonation Velocity as a Function of the Diameter of Pressed TNT Charges at Densities Close to the Density of the Single Crystal

ρ_0, g/cm^3	d, mm	D, m/sec
1.625	8	6670
	10	6830
	13	6910
1.630	8	6580
	10	6830
	13	6930
1.635	8	6480
	10	6820
	13	6945

Table 3

Results of Experiments to Determine the Critical Diameters of Ammonite 80/20 Charges

d, mm	ρ_0, g/cm^3	Result of expt.
7	0.523	—
7	0.568	—
8	0.623	+
8	0.495	+
7	0.95	+
7	0.9	+
7	1.0	—
7	1.16	—
8	1.07	—
8	1.1	+
9	0.926	+
9	1.03	+
8	1.18	—

The density was determined from calculations based on data obtained by weighing on an analytical balance correct to 0.002 g and on micrometer measurements correct to 0.002 mm. As a check we made spot determinations of the density by the hydrostatic method, taking into account the loss of weight of the wire (from which the charges were suspended) in the water.

The discrepancy between the densities determined by the hydrostatic method (for the same charges) did not exceed 0.003 g/cm^3.

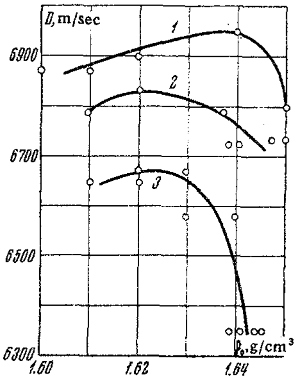
Unit charges with the same calculated density were used to form a single composite charge.

In the case of experiments on composite charges consisting of unit charges of different density the maximum density fluctuation has been indicated (see Table 1).

Before being tested the unit charges were arranged in a groove in a wood plank 2−3 mm thick. The width of the groove was 3−5 mm, the depth 1 mm. Copper wire 0.12 mm thick was wound around the unit charges with a pitch of 5 mm, so that it was not necessary to cement the ends. The charges were exploded by means of intermediate tetryl or flegmatized PETN detonators of the same diameter as the test charges and 16−20 mm long. In certain experiments intermediate detonators of pressed TNT 8 mm in diameter and 15 mm long with a density of 1.6 were used to initiate detonation in the 8-mm−diameter charges.

The results of the experiments to determine the dependence $D = f(\rho_0)$ are presented in Table 1. Here D are the mean detonation velocities, ρ_0 the density, n the number of experiments, and σ_i the maximum deviation from the mean value of D.

The dependence of the detonation velocity on density is also shown in the figure for TNT charges 13, 10, and 8 mm in diameter.



Detonation velocity of TNT charges as a function of density at densities greater than 1.61: 1) for charges 13 mm in diameter; 2) for charges 10 mm in diameter; 3) for charges 8 mm in diameter.

Clearly, for small-diameter TNT charges the detonation velocity increases with increase in density only up to a certain limit, after which it falls. For a given diameter this limit (or critical density) is smaller, the smaller the diameter of the charge.

For charges with a diameter of 13 mm it is equal to 1.64, for 10-mm charges to about 1.63, and for 8-mm charges to about 1.62.

Charges 6 mm in diameter do not detonate at a density of 1.63–1.64, i.e., the critical diameter at a density of 1.63–1.64 is greater than 6 mm, whereas at a density of 1.62 it is less than 2 mm.

Using the $D = f(\rho_0)$ curves with d = const for various diameters, shown in the figure, it is possible to obtain data for determining $D = f(d)$ at ρ_0 = const.

The data thus obtained are presented in Table 2.

It should be noted that the spread of the measured detonation velocities was quite considerable and in individual cases reached 100 m/sec. Therefore the absolute mean values of the detonation velocities indicated in the figure for charges 13 and 10 mm in diameter, for which the variation of velocity with density is of the same order as the possible experimental error, are only orientational. However, for charges 8 mm in diameter the decrease in velocity obtained is much greater than the possible experimental error.

On the basis of the experiment with charges 8 and 6 mm in diameter there is also no doubt that the critical diameter increases with increase in density.

2. Experiments with ammonite 80/20 charges. As already mentioned, it is to be expected that the critical diameter of ammonite 80/20 will decrease with decrease in density to a certain value of the latter, after which it will increase. In order to test this assumption we performed experiments to determine the critical diameters of low-density charges of ammonite 80/20 in cartridge-paper cases.

The ammonite was prepared from AN and TNT with particle sizes of less than 0.3 mm.

Mixing was combined with grinding with a porcelain pestle in a porcelain mortar for 25-30 min. The moisture content of the finished product was not greater than 0.02%. The charges were mounted on brass plates and exploded with a KD-8 cap.

The experimental results are presented in Table 3. In this table a plus sign indicates complete detonation, a minus sign failure to detonate.

As may be seen from Table 3, $7 < d_* < 8$ at a density 0.5–0.6, $d_* < 7$ at a density 0.9, and $d_* \approx 8$ mm at a density 1.0–1.16.

Charges 7 mm in diameter detonate only at a density of 0.9–0.95 and do not detonate at $0.6 > \rho_0 > 1.0$. Thus, for the ammonite 80/20 tested the minimum value of d_* corresponds to a density of 0.9. The fact that d_* increases with increase in density was previously known. What is new is the experimentally established existence of a minimum of d_*.

The small absolute value of the values of d_* obtained is attributable to the thorough grinding and mixing of the product.

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