SENSITIVITY OF PETN TO AN ELECTRIC SPARK

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The study of the sensitivity of explosives to the action of various kinds of initiating impulses is of both scientific interest (the study of the mechanism of the initiation of an explosion) and practical importance (the development of safety measures and recommendations for the practical use of explosives).

A number of papers have appeared on the sensitivity of secondary materials to an electric spark and to the explosion of a fine wire [1, 2].

We present the results of an experimental study of the sensitivity of PETN to an electric spark. The effects of particle size, density, temperature, and moisture content on the sensitivity of PETN to an electric spark have been studied. The effects of the interelectrode distance and the inductance of the discharge circuit on the magnitude of the energy necessary to initiate an explosion have also been investigated.

Experimental Procedure. The sensitivity to an electric spark was determined by pressing PETN into a 6 mm diameter chamber with pointed electrodes.

An explosion was initiated by the discharge of a capacitor connected in parallel with a spark gap at the breakdown between the electrodes in the PETN. It was determined from the current and voltage oscillograms that for a discharge circuit having an inductance of 0.05 μH and a resistance of 0.01 Ω 90% of the energy stored in the capacitor was released in the spark gap in a time of 10^{-8} sec. The same result was obtained in [3] for breakdown in air.

The capacitor connected in parallel with the spark gap of the sample was charged from a previously charged capacitor through a controllable commutator and an inductance of such a magnitude that the make-up of the discharge by the current from the reservoir capacitor did not exceed 2-3% during the time interval preceding the detonation of the sample. Therefore the make-up energy can be neglected in estimating the sensitivity of PETN. To within 10% the energy released in the spark gap is

$$W = {}^1/_2\, CU^2$$

where C is the capacitance of the capacitor, and U is the breakdown voltage measured by the oscillograms (Fig. 1).

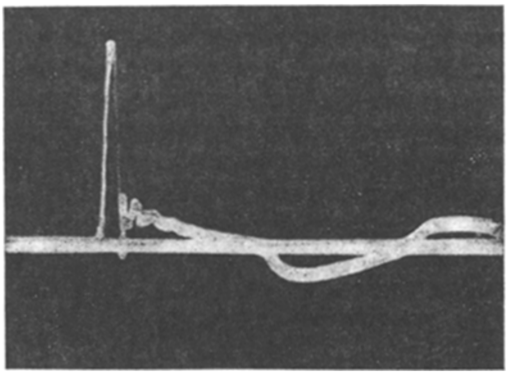

Fig. 1

The dependence of the frequency of explosions on the energy released in the spark gap was determined experimentally. The value of the energy at which explosions were observed 50% of the time (W_{50} in mJ) was taken as a measure of the sensitivity of the PETN. The lower this energy the more sensitive the PETN.

Experimental Results. The PETN used in the experiments had average grain sizes of 2.4, 4.8, 7.9, and 100μ, and was pressed to a density of 1.1 g/cm^3 into samples with a distance of 0.7 mm between electrodes. The results of the experiments are shown in Fig. 2. It is clear from the figure that the energy W_{50} increases with increasing grain size.

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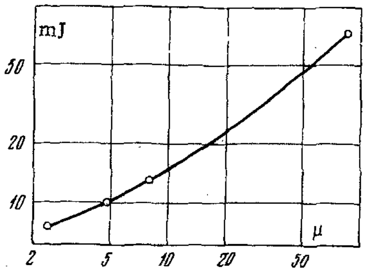

Fig. 2

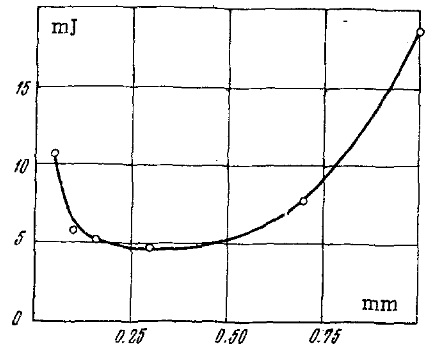

Fig. 3

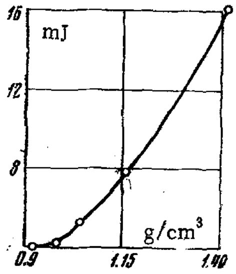

Fig. 4

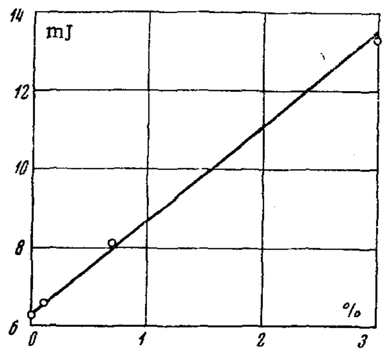

Fig. 5

To determine the dependence of the energy W_{50} on the distance between electrodes, PETN with an average grain size of 2-3 μ was pressed to a density of 1.1 g/cm^3 into samples with a distance of 0.05 to 1 mm between electrodes. The experimental results are given in Fig. 3 which shows that W_{50} is minimum for an interelectrode distance of 0.2-0.3 mm.

The dependence of the energy W_{50} on density was determined for PETN with an average grain size of 2-3 μ pressed into samples with a distance of 0.2 mm between electrodes. The experimental results plotted in Fig. 4 show that W_{50} increases with increasing density in the density range investigated.

The measured values of the energy W_{50} for PETN with an average grain size of 2-3 μ pressed to a density of 1 g/cm^3 into samples with an interelectrode distance of 0.2 mm are listed in Table 1 for various temperatures. It is clear that W_{50} decreases as the temperature increases.

The effect of the inductance of the discharge circuit on W_{50} was determined for samples with interelectrode distances of 0.2 mm in which PETN with an average grain size of 2-3 μ was pressed to a density of 1 g/cm^3. The experimental results shown in Table 2 indicate that an increase in the inductance of the discharge circuit leads to an increase in the energy necessary to initiate an explosion of PETN.

The dependence of the energy W_{50} on moisture content was determined for PETN with an average grain size of 2-3 μ pressed to a density of 1 g/cm^3 into samples with a 0.2 mm distance between electrodes (Fig. 5). The energy W_{50} increases with increasing moisture content of the PETN.

Discussion of Results. The spark breakdown in air is accompanied by a shock wave [4-7]. The theory of the development of a spark discharge is based on a consideration of shock hydrodynamic processes [7]. It was established that the rate of expansion of the spark channel and the velocity of propagation of the shock wave in air are closely related to the rate of introduction of energy into the discharge. The rate of introduction of energy into the discharge depends on the parameters of the discharge circuit, particularly the inductance. A decrease in the inductance leads to an increase in the rate of release of energy, and consequently to an increase in the velocity of the shock wave. The velocity of the shock wave in air at atmospheric pressure is 1-5 km/sec [4], in nitrogen at 20 atm it is 60 km/sec, and in hydrogen at 20 atm it is 80 km/sec [8]. These velocities are close to or exceed the detonation velocities of explosives. The spark temperature can reach 10,000°K [9].

TABLE 1. Energy W_{50} at Various Temperatures

№	Temperature	W_{50}, mJ
1	203	27.0
2	293	6.5
3	323	4.5

TABLE 2. Energy W_{50} for Various Inductances of the Discharge Circuit

№	Inductance of discharge circuit in μH	W_{50}, mJ
1	0.05	6.5
2	0.30	15.0
3	0.68	500.0

The initiation of the detonation of PETN is a complex process. Apparently the process involves both the shock wave produced in the intense spark discharge and thermal processes in the electrical breakdown in powdered PETN which is part PETN granules and part air.

In connection with the role of the shock wave it should be pointed out that the energy W_{50} increases with increasing inductance of the discharge circuit, leading to a decrease in the velocity of the shock wave [5]. To obtain the shock-wave velocity necessary to initiate an explosion for a large inductance the energy stored in the capacitor must be increased. The penetration of the shock wave through matter leads to an increase in the pressure and temperature [10]. The heating of the granules on the shock front leads to the chemical decomposition of the explosive. The explosive appears to be heated by the interstitial air pockets which are heated by the shock wave. The size of the pores affects the energy necessary to initiate the explosion: W_{50} decreases with a decrease in density, i.e., for an increase in the size of the air pores. With a decrease in grain size for the same volume fraction of air pores the relative surface of the granules is increased. As a consequence a larger surface and a larger mass of explosive are involved in the disintegration reaction and there is an energy makeup of the shock wave which leads to a decrease in the energy necessary to initiate an explosion. This agrees with [11] but not with [12].

The thermal processes involved in the electrical breakdowns cause W_{50} to be increased: 1) when the temperature is lowered, since at a lower temperature a larger amount of heat is required to raise the temperature of the PETN to the value at which rapid chemical disintegration occurs; 2) for increased moisture content, since the greater the moisture content the thicker the layer of water on the PETN granules; heat is consumed not only in heating the granules but also in heating the water; 3) for a decrease in the interelectrode distance to less than 0.2 mm, since part of the energy is spent in heating the electrodes [13].

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