

ELECTRICAL STABILITY OF DETONATION PRODUCTS OF CONDENSED EXPLOSIVES

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The development of the various areas of experimental physics and technology requires the creation of high-power, high-speed switching devices [1]. The most promising from the point of view of obtaining the necessary switching parameters are commutators based on the use of condensed explosives. A study of the electrical properties of the detonation products of explosives, filling the gaps in the electrical chain and defining the switching characteristics of circuit breakers, has been stimulated by the creation of the optimum design of an explosive switch.

In [2], the electrical stability of the detonation products of a charge of PETN (pentaerythrityl tetranitrate), located between the ends of cylindrical electrodes, was investigated. It is shown that, with the experimental accuracy, the stability of the gap up to a specified stage of expansion of the detonation products is constant ($E=100-120$ kV/cm). Later, the stability falls rapidly. Comparison of the experimentally obtained dependence of the electrical stability of the gap on the time in the section of rapid decline with the pressure dependence in the products has permitted the following assumption to be made: The electrical stability of the detonation products at a given stage of expansion is determined mainly by their density.

In the present paper the principal experimental results of an investigation of the electrical stability of the expanding detonation products of condensed explosives under the condition that their density is considerably lower than the density in the detonation wave and also of the static stability of the products in the pressure range 1-11 atm are given.

1. Electrical Stability of the Dispersing Detonation Products

A cylindrical charge of the explosive being studied was ignited with a high-voltage pulse in a metal case. After emergence of the detonation wave at the end of the charge, the detonation products started to expand into a tube with internal diameter 10 mm and then into a channel with dimensions 4×48 mm, in which electrodes with a diameter of 10 mm and having a fixed gap were installed flush with the walls. The distance between the electrodes was 4 ± 0.1 mm. A shock wave was formed in the air ahead of the products. After the shock wave passed the electrodes, a voltage pulse was applied to them at different times; the pulse had a front rise of less than 10^{-6} sec and a subsequent exponential decay of $9 \cdot 10^{-3}$ sec. The amplitude of the voltage wave was increased from experiment to experiment, until breakdown coinciding with the instant of application of the voltage occurred. Then a time step was performed on the delay in application of the voltage to the electrodes, and the experiments were repeated until the maximum electrical stability of the detonation products for a given type of explosive no longer developed.

The voltage on the gap was applied from a multiplier circuit. The voltage amplitude on the capacitors in the multiplier circuit was recorded with an S-96 kilovoltmeter and that on the electrodes by means of a capacity divider on an S1-42 oscillograph. The accuracy in determining the voltage amplitude amounted to 3%.

The charge parameters were as follows: PETN and Hexogen - diameter 7 mm, height 45 mm, and density $1.0-1.1$ g/cm³; Trotyl and ammonite (6ZhV) - diameter 9 mm, 7-8 mm PETN for ignition of the main charge, and 50 mm of the explosive being studied (with a density of $1.0-1.1$ g/cm³).

The results of processing the experiments to find the electrical stability of the expanding detonation products are shown in Fig. 1 [1] Trotyl; 2) ammonite (6ZhV); 3) PETN; 4) Hexogen; 5) PETN with the addition of Teflon; it can be seen, first of all, that the stability increases, reaches a maximum, and then falls. In addition to pure explosives, PETN with different additives was also investigated. For example, the addition of NaCl in amounts up to 40% of the charge weight did not increase the stability. The experiments were conducted

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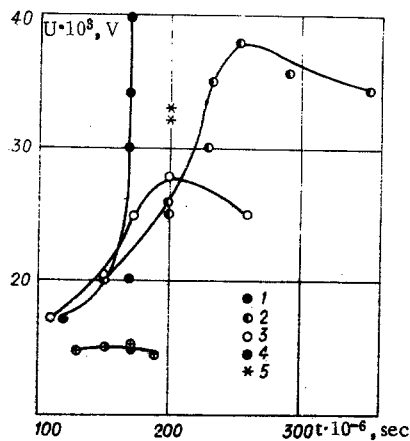


Fig. 1

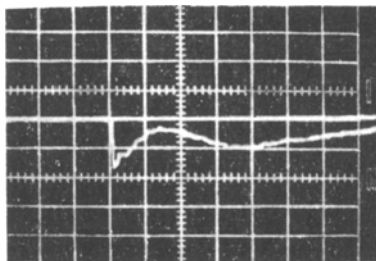


Fig. 2

at the maximum voltage for pure PETN, and breakdown was always observed. The addition of a Teflon chip led to an increase of stability by 25%. No quantitative estimates of the percentage content of fluorine were made.

It was not possible to find the maximum electrical stability of the Trotyl detonation products on this facility, since it is not clear to what the onset of breakdown at a potential of 44 kV belongs, i.e., to the breakdown of the Trotyl detonation products or to the breakdown over the surface of the dielectric in the channel. By inserting plates of Perspex between the electrodes, having the same dimensions as the channel, breakdown over its surface occurred at a voltage amplitude of 36–38 kV. In the experiments with Trotyl, the products did not breakdown even at 40 kV. Moreover, on the oscillograms for Trotyl at voltage amplitudes of 39–40 kV, no breakdown was observed with a delay, which is characteristic for other explosives, and for which the magnitude of the delay decreased with increase of the voltage amplitude.

In order to determine the nature of the change of the detonation product parameters on the time in the region of the electrodes, pressure measurements were carried out. The probe described in [3] was used in the experiments. The signal from the probe and the attached capacitor ($C = 7.5 \cdot 10^{-9}$ F) was applied to the input of the C1-42 oscilloscope. Static calibration of the probe was carried out on a hydraulic press by means of a U5-6 electrometric amplifier. The principal error in determining the pressure is the oscillographic error. The accuracy of the pressure amplitude value amounted to 10–15%.

An oscillogram of the pressure of the Trotyl detonation products is shown in Fig. 2. The oscillograph was triggered simultaneously with the application of the initiating pulse. The scale value is 25 μsec /division horizontally and 100 tech. atm /division vertically. The initial peak on the oscillogram corresponds to the pressure at the shock front. The subsequent pressure drop is explained by the flow nonuniformity. When the shock emerges from the tube into the channel of larger cross section, the lateral relief waves reduce the pressure behind it. Then the pressure of the detonation products increases until no relief wave arrives at the electrodes from the end of the charge, after which it falls. When the pressure oscillograms and the graphs of the electrical stability of the gap are compared, it is observed that the start of increase of the pressure coincides with the increase of electrical stability. It should be noted that the pressure of the detonation products in the region of the electrodes changes considerably more strongly than their stability. Moreover, according to the oscillograms, the pressure maxima for the detonation products of PETN and ammonite begin 25 and 40 μsec earlier

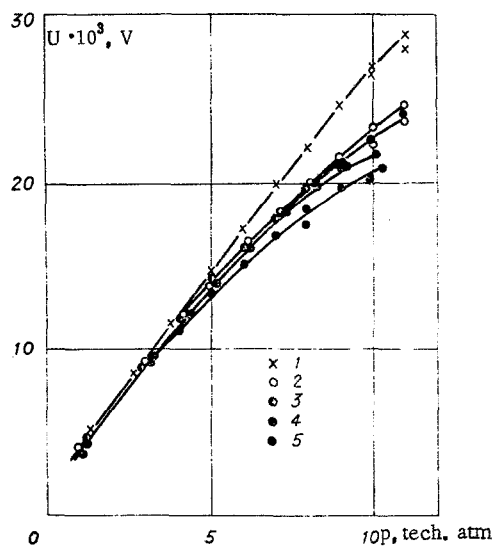


Fig. 3

than the corresponding maxima of their electrical stability. The noncoincidence of the maxima of stability and pressure can be explained, if it is assumed that the stability of the detonation products, together with the total concentration of particles and the temperature, depends on the concentration of the intermediate products, (which have a low ionization potential and burn-up during dispersion).

The results obtained do not contradict the data of [2] (where the maximum of the stability of the products was not clearly expressed and only saturation was observed), since there the density of the detonation products between the electrodes always decreased with time. This can also explain the lower magnitude of the maximum electrical stability of PETN detonation products in this case ($E = 70$ kV/cm) by comparison with [2] ($E = 100-120$ kV/cm) since they correspond to different density values.

The increase of the electrical stability of PETN detonation products with the addition of Teflon to the explosive can be explained by a reduction of the concentration of free electrons in the products as a result of the high affinity of fluorine for electrons.

2. Static Stability of the Detonation Products

The detonation products were produced in a special explosion chamber, which allowed residual pressures after explosion of the charge of up to 15 tech. atm. The chamber was connected with a discharger (spark-gap), whose volume was much less than the volume of the chamber; this made it possible to conduct the experiments on the detonation products of a given charge several times. The pressure in the discharger was measured with a manometer having an absolute error of 0.1 tech. atm. The discharger was calibrated with air. The distance between the electrodes in the experiments was 0.95 ± 0.05 mm. In order to reduce the percentage content of air in the detonation products, the chamber was evacuated down to a pressure of 10^{-1} to 10^{-2} mm Hg prior to the explosion.

The discharger was connected to the explosion chamber, blown out, and filled with detonation products up to a pressure of 11 tech. atm 20-30 minutes after the detonation of the explosive charge. Then a slowly increasing voltage was applied to the electrodes. The magnitude of the voltage was recorded at breakdown of the gap; the accuracy in determining this was 3%. The experiments were conducted at one and the same pressure several times in order to determine the dependence of the breakdown stability of the gap on the number of breakdowns. Afterward, the pressure was reduced to 1 tech. atm and the experiments were repeated. In this way, the Paschen curves were plotted (asymptotic stability with a large number of breakdowns) for each portion of detonation products, and then these curves were averaged.

Figure 3 shows the Paschen curves of the detonation products after the explosion of the charge [1] air; 2) PETN; 3) Hexogen; 4) ammonite (6ZhV); 5) EVV-8G; the static stability of the Trotyl detonation products coincides with the stability of the Hexogen detonation products]; it can be seen that the calibration curve for air at pressures greater than 9 tech. atm starts to deviate from a straight line. This can be explained by the strong nonuniformity of the field in the vicinity of the opening in the electrode, through which filling of the dis-

charger with the detonation products is effected. In the experiments at increased pressure, a displacement of the cathode spots to the region of large electrode curvatures was observed.

The lower electrical stability in comparison with air and the increase of this difference with increase of pressure are common for the detonation products of all the explosives investigated. It should be noted that the electrical stability of the detonation products for the first breakdowns after filling the discharger is lower than for subsequent breakdowns. For example, with Trotyl 20-30 min after explosion, it was 25% less than the asymptotic stability for a large number of breakdowns. Over 24 h, this difference amounted to 15%. Similar experiments with ÉVV-8G gave, respectively, 50% lower stability 20-30 min after explosion of the charge and 25% after 24 h. The same tendency for the other explosives investigated is expressed to a considerably lesser degree (order of experimental accuracy 5-7%).

The dependence of the electrical stability of the detonation products on the time between the explosion of the charge and the application of the voltage to the discharger, and also the increase of stability of the gap with increasing number of breakdowns, can be explained by the continuing chemical reactions in the detonation products. The intermediate products, having a lower ionization potential by comparison with the final detonation products, burn up with the passage of time, and in the spark this same process occurs more rapidly. The weaker decrease of stability of the dispersing detonation products [2] after explosion of the charge as compared to the corresponding measurements of their density can also be explained by this.

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PROBLEM OF DETERMINING ION COLLECTION EFFICIENCY IN LIQUID IONIZATION CHAMBERS

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In certain areas of physics, in particular, in ionizing radiation dosimetry employing liquid ionization chambers, the necessity of measuring the ion collection efficiency in liquids is encountered. Measurement of the ionization current is carried out by means of complex measurement devices. The saturation current of a liquid is difficult to obtain even with voltages which are close to breakdown, and therefore its determination is frequently carried out by an extrapolation method.

It is possible to determine the ion collection efficiency in dielectric liquids by a method using the ponderomotive forces (PMF) of an electric field. For this purpose, a pair of electrodes of known width a , height h_e , and fixed interelectrode separation d is partially immersed in the dielectric liquid, poured into a vessel (see Fig. 1). This system, which has a certain capacitance C and high dielectric properties, is charged from an electric voltage source to a certain potential difference U_0 . In consequence of the action of the PMF, in the interelectrode gap a rise of the liquid dielectric to a certain height h_0 is observed, determined by the equation [1]

$$h_0 = \frac{\epsilon_0(\epsilon_L - \epsilon_g)U_0^2}{2\rho g d^2 \cos \varphi},$$

where ϵ_L and ϵ_g are the relative dielectric constants of the liquid and gaseous dielectrics, respectively; ρ is the density of the liquid dielectric; ϵ_0 is the electrical constant; g is the acceleration of gravity; and φ is the angle between the longitudinal axis of the electrodes and the direction of the force of gravity.

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