b) small inhomogeneities, whose spatial frequencies are greater than $\eta_* + \Delta \simeq 3.2a^{-1}$, make no contribution to the value of the scattering of the signal of the instrument;

c) inhomogeneities, whose spatial frequencies are small in comparison with $\eta_* \simeq 1.8a^{-1}$, do not, in practice, have any effect on the scattering of the signal.

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LAG TIME OF THE BREAKDOWN OF PRESSED LEAD AZIDE

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Data are obtained on the lag time of the breakdown and the dielectric strength of a solid porous dielectric with a porosity of 0.4 (pressed lead azide) with different durations of a rectangular voltage pulse from 10^{-8} to $2 \cdot 10^{-6}$ sec.

Important characteristics of the pulsed breakdown of dielectrics are the lag time of the breakdown and the dielectric strength. A lag of the breakdown is observed both for gases and for solid dielectrics. It consists of the statistical lag and the time of formation of the discharge. In gases a lag of the breakdown of 10^{-4} sec and more has been observed [1-3]. In solid dielectrics, the lag of the breakdown is considerably less $(1-8) \cdot 10^{-8}$ sec [4, 5]. With such small exposures, in solid dielectrics an increase in the electrical strength has been observed [6]. While in gases a considerable part of the lag time of the breakdown consists of the statistical lag, and only with strong ionization of the spark gap will the lag time consist only of the time of formation of the discharge, in solids the lag time consists mainly of the formation time of the discharge.

Data on the lag time of two-phase dielectrics consisting of a solid body and a gas are of interest. A representative dielectric of this type is pressed lead azide, consisting of crystalline lead azide and air, which is investigated in the present work. A study of the breakdown of lead azide and an explanation of its mechanism is also of interest for a study of its sensitivity to an electric spark.

Method of Experiment

Powdered lead azide with a crystal size of 1-3μ was pressed between steel electrodes to a density of 2.8 g/cm^3. Under these circumstances, in the solid dielectric a porosity of 0.4 was set up (40% of the

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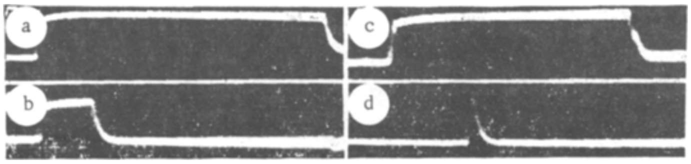

Fig. 1

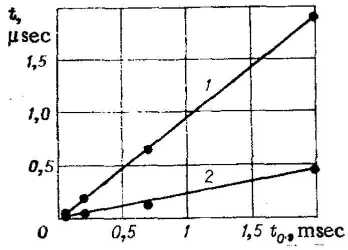

Fig. 2

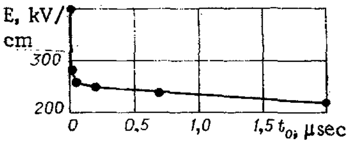

Fig. 3

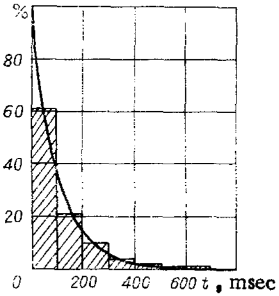

Fig. 4

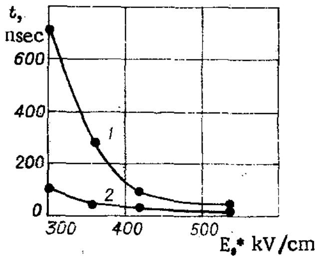

Fig. 5

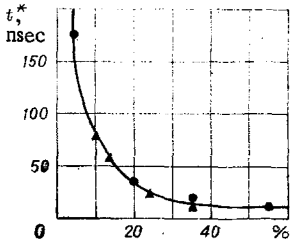

Fig. 6

volume was occupied by air). In the samples the radius of the rounding-off of the electrodes was considerably less than the distance between the electrodes, so that, in the thinnest point of the spark gap, a field was set up which was close to homogeneous.

The breakdown of the samples was effected in pulses of rectangular form with different durations. The voltage in a sample was raised stepwise. Figure 1 shows typical oscillograms: a) voltage pulse with a duration of $7 \cdot 10^{-7}$ sec; b, c, d) breakdown with a lag of $5.9 \cdot 10^{-7}$, $1.3 \cdot 10^{-7}$, 10^{-8} sec.

The electrical strength E was determined for different durations of the rectangular pulse, from the values of the breakdown voltage and the distance between the electrodes. With each duration of the pulse, the value of E was determined as the mean arithmetic value from 10 experiments; each sample broke down only once, since repeated breakdowns occur with higher voltages.

The lag time of the breakdown t was defined as the time interval from the moment when the voltage at the electrodes of the sample attains the value of the static breakdown voltage to the moment of actual breakdown, fixed by the start of a sharp drop in the voltage on the oscillogram.

Results of Experiments

With an increase in the duration of the rectangular voltage pulse in the interval $10^{-8} - 2 \cdot 10^{-6}$ sec, there is an increase in the mean arithmetical and the maximal lag time observed in the experiments for pressed lead azide with a porosity of 0.4. The maximal value of the lag time of the breakdown can reach almost the total duration of the pulse (Fig. 2, which shows the dependence of the lag time of the breakdown t on the duration of the pulse t_0, 1 is the maximal value, and 2 is the mean value). The mean arithmetic value of the lag time of the breakdown is less than half of the duration of the pulse. The dependence of the electrical strength of pressed lead azide E on the duration of the rectangular pulse t_0 is shown in Fig. 3. With a decrease in the duration of the rectangular voltage pulse, there is at first only an insignificant rise in E. Starting from a duration of the voltage pulse equal to $2-3 \cdot 10^{-8}$ sec, with a further decrease in the duration of the pulse, there is a rapid rise in E.

Figure 4 shows a histogram of the distribution of the lag time of breakdown with a determined duration of the pulse ($7 \cdot 10^{-7}$ sec) and intensity of the field (300 kV/cm), with a breakdown probability of 90%. The solid line illustrates the exponential curve

$$f(t)=n_0 \exp(-k^* t), \tag{1}$$

where $n_0 = 100\%$; t is the lag time; $k^* = 1/t^*$; t^* is the mean arithmetic lag time (from an analysis of oscillograms of the breakdown of 200 samples, $t^* = 1.1 \cdot 10^{-7}$). From a comparison of the histogram of the distribution and the exponential curve it can be seen that, with a determined duration of the rectangular voltage pulse, the distribution of the lag time is described by an exponential law.

Figure 5 shows the dependence of the lag time of the breakdown of pressed lead azide on the prebreakdown intensity of the electrical field, with a duration of the voltage pulse of $7 \cdot 10^{-7}$ sec (1 is the maximal observed value; 2 is the mean arithmetical value). An increase in the intensity of the field in the pulse leads to a situation in which there is a decrease in the mean and the maximal observed lag time. The dependences $t = f(E)$ have the form of exponents.

The dependence of the mean arithmetic lag time of the breakdown t^* (nsec) on the overvoltage (%) is shown in Fig. 6. The triangles correspond to a duration of the pulse of $2 \cdot 10^{-7}$ sec, and the circles to $7 \cdot 10^{-7}$ sec. The mean arithmetic lag time of the breakdown decreases with an increase in the overvoltage (or the intensity of the electrical field). The points for the above two durations of the pulse lie on one curve.

Discussion of Results

A porous dielectric in which a large part of the volume is occupied by the solid body (pressed lead azide with a porosity of 0.4), with respect to the value of the lag time of the breakdown ($2 \cdot 10^{-6}$ sec) and the law of the distribution of the lag time (the exponent), is similar to air [7]. In a solid dielectric, the lag time of the breakdown is considerably less [4].

The distribution of the lag time of the breakdown, which consists of the statistical lag time and the time of formation of the breakdown, obeys an exponential law (1), which indicates that the lag time of the breakdown with a length of the voltage pulse of $7 \cdot 10^{-7}$ sec consists of the statistical lag time.

The exponential law of the distribution of the lag time of the breakdown follows from the fact that the appearance of an electron anywhere near the cathode in the air gap, required for the start of the breakdown, is a random phenomenon. The probability w(t) that the breakdown will set in not earlier than after a given interval of time t is expressed by the exponential function [7]

$$w(t)=\exp(-k^* t),$$

where k^* is a constant, equal to the reciprocal of the mean lag time of the breakdown. The number of samples n, breaking down with a lag in the interval from t_1 to t_2, out of the total number of samples tested N, has the form

$$n=N[\exp(-k^* t_1) - \exp(-k^* t_2)].$$

The time of formation of the discharge can be evaluated from the dependence of the electrical strength E on the duration of the action of the electrical field, if it is assumed, as is done for liquid dielectrics [8], that a sharp rise in E starts when the lag time of the breakdown is approximately equal to the time of formation of the discharge. From Fig. 3, it can be assumed that the formation time of pressed lead azide with a thickness of 0.2 mm is approximately $2 \cdot 10^{-8}$ sec.

The decrease in the lag time (maximal and mean) with an increase in the intensity of the electrical field (see Fig. 5) is connected with a decrease in the statistical lag time. The formation time of the discharge also, of course, decreases, but its fraction in the total lag time of the breakdown is not great. The shortening of the statistical lag time with an increase in the intensity of the field in the pulse E^* obviously takes place since, with an increase in E^*, there is an increase in the probability of the appearance of a precursor electron at the required place (for example, due to an increase in the current of the field emission).

With a determined intensity of the field, the mean lag time does not depend on the duration of its action, if it is greater than the formation time of the discharge, which can be seen in Fig. 6, where the points with a duration of the pulse of $2 \cdot 10^{-7}$ and $7 \cdot 10^{-7}$ sec lie on one curve.

An evaluation of the mean rate of propagation of the discharge, using the formula $v = d/t_f$ (d is the distance between the electrodes, t_f is the formation time of the discharge) gives a value of $v = 10^6$ cm/sec. This value of the rate is considerably less than the rate of propagation of an electron avalanche or a streamer under experimental conditions [9, 10]. It is approximately equal to the rate of propagation of positive ions in the air pores of a substance.

The experimental data and the evaluation of the rate of propagation of the discharge provide a basis for the assumption that the breakdown of a porous dielectric with open porosity starts with the appearance of an electron at the cathode and ends when the positive ions, formed in the air pores at the anode with shock ionization, reach the cathode and effect the formation of a plasma filament.

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VERIFICATION OF THE CASE OF THE ORIGIN OF BALL LIGHTNING

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In [1] there is a description of a case of the origin of a luminescing sphere in an S-shaped bend of a lightning rod. Under these circumstances, it is assumed that this sphere was ball lightning.

The present author has made a model verification of this observation, in a three-cascade pulse voltage generator, with a working voltage of 150 kV in an air atmosphere at a pressure of 730–750 mm Hg. Under these circumstances, the S-shaped bend was effected by installing dielectric bodies made of vinyl plastic and celluloid in a discharge gap of the "rod–rod" type; the bodies are bent according to the law $x = e^{-\alpha y^2}$. The electrodes of the discharge gap were arranged at the axis. For control of the initial breakdown, in the plane of the electrodes, along the surface of the body and its apex, there was led a graphite line with a thickness of 0.001 m, falling short of the electrodes by 0.01–0.015 m on each side.

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