

## INCREASE OF DIELECTRIC STRENGTH OF WATER IN A SYSTEM WITH "DIFFUSION" ELECTRODES

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Results are presented of an investigation of the dielectric strength of pure water when the electrodes are shielded with thin conducting layers. It is established that shielding the electrode surfaces greatly increases the electric strength of water.

It is known that the breakdown of a liquid usually starts at the surface of the electrode [1]. One of the possible causes of surface breakdown may be, e.g., the presence on the surface of inhomogeneities that tend to increase the electric field. In this case experiments on liquid breakdown yield results not so much on the electric strength as on the processes near the electrodes.

To eliminate the influence of phenomena at the electrodes on the breakdown of liquid dielectrics, Ryutov [2] proposed to produce on the electrode surfaces conducting layers having a conductivity that decreases smoothly towards the interior of the liquid, and having an effective thickness greatly exceeding the microinhomogeneities, but much smaller than the distance between the electrodes. Realization of this proposal permits the study of the real volume breakdown of liquids under purer conditions.

We present here the results of an investigation of the electric strength of pure water ( $\rho \sim 10^6 \Omega\text{-cm}$ ) in a homogeneous field, with the electrodes shielded by thin conducting diffusion layers. A step voltage pulse of amplitude  $U = 60$  to  $200$  kV and with a rise time  $\tau \sim 0.3 \mu\text{sec}$  was applied from a pulse generator to a planar gap of length  $d = 3$  mm and with electrode diameter  $D = 30$  mm. We used in the experiments solid and porous (pore dimensions  $\sim 2 - 5 \mu$ ) of stainless steel. The diffusion layers were shaped by slowly pressing (to prevent stirring of the liquid) of solutions through the porous electrodes.

The danger that convection currents might be produced as a result of the Rayleigh-Taylor instability of the boundary of liquids with different densities in the gravitational field was eliminated in the following manner: an aqueous solution of  $\text{CuSO}_4$  with density somewhat larger than the density of the water was introduced through the lower electrode, and a solution of  $\text{FeCl}_3$  with density somewhat lower than that of the water was introduced through the upper electrode.

Inasmuch as density gradients of the refractive index were produced in the vicinities of the electrodes in the presence of the conducting layers, the layer thicknesses could be monitored by the Toepler method.

The ponderomotive forces due to the applied electric field are capable of destroying the layers<sup>1)</sup>. It follows, however, from simple estimates (see [2]) that under the conditions of our experiments the characteristic layer-disintegration time exceeds 100 microseconds and cannot affect the breakdown-delay time, which did not exceed 5 microseconds under typical conditions.

As noted in [1], breakdown is initiated from the positive electrode in a homogeneous field at times  $t \leq 1 \mu\text{sec}$ . The first experiments were therefore devoted to a study of the breakdown with only the anode shielded by the conducting layer<sup>2)</sup>. The cathode was then a solid electrode. The layer thickness was approximately  $0.2 - 0.3$  mm. The breakdown electric field intensity was determined with the aid of the Kerr effect in water. The light source was an LG-75 helium-neon laser ( $\lambda = 6328 \text{ \AA}$ ); the Kerr patterns were registered with an FEU-30 photomultiplier, the signal from which was fed to an I2-7 oscilloscope. The field intensity calculated in this manner agrees satisfactorily with the value determined from the voltage on the electrodes and from the effective gap length determined by the Toepler method.

Integral photographs of the breakdown were taken simultaneously. One of them is shown in Fig. 1. It can be concluded from the direction of the branches of the streamer formation that if a diffusion layer is present at the anode, the breakdown is initiated at the cathode. The photograph shows clearly the boundary of the layer at the anode, in the form of a bright band parallel to the plane of the electrode.

Experiments in which a conducting layer was produced only at the cathode have revealed no noticeable changes in the character of the breakdown. It can be concluded on the basis of these results that in the case of a gap bounded by solid electrodes the cathode processes do not

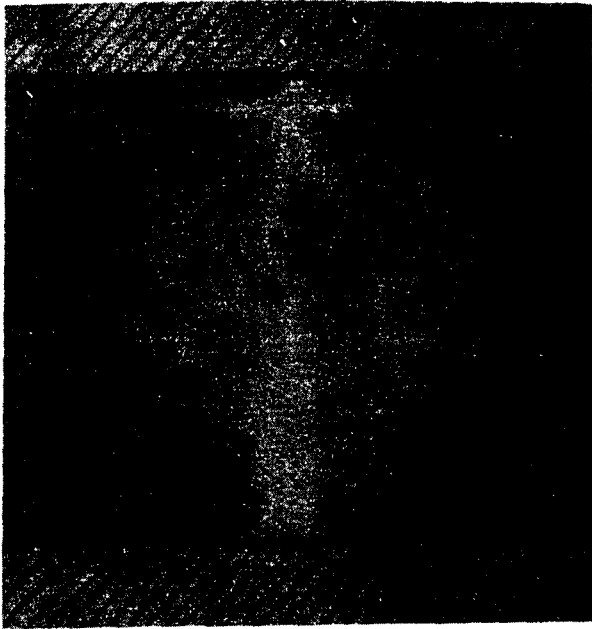


Fig. 1

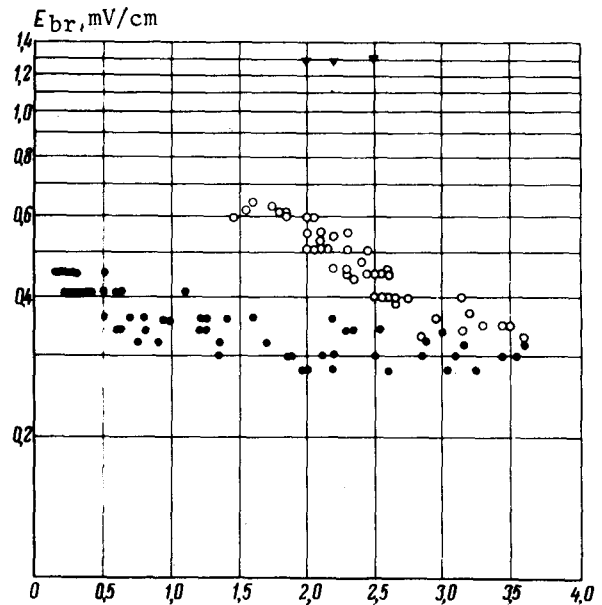


Fig. 2. Breakdown delay time vs. electric field intensity in gap: ● - solid metal electrodes; ○ - anode shielded by conducting layer; ▼ - both electrodes shielded.

influence the initiation of the breakdown at the anode.

Figure 2 shows the measured breakdown field as a function of the breakdown delay time. As seen from the figure, at a breakdown delay time  $t \leq 3$   $\mu\text{sec}$  the breakdown field intensity is much higher when one diffusion layer is used (at the anode) than in the case of solid metal electrodes. The volt-second characteristics come closer together when the delay time is increased.

The loss of the strengthening effect at  $t \geq 3$   $\mu\text{sec}$  in experiments with a single anode layer agrees with the integral photographs of the breakdown of a gap bounded by solid electrodes at the same delay-time interval. These photographs show the development of the breakdown, and accordingly the shortening of the gap on both the cathode and anode sides.

The upper part of Fig. 2 shows preliminary results on the breakdown of water when two diffusion layers are produced. The effective gap in these experiments was approximately 1.5 mm. As seen from the figure, the shielding of both electrodes greatly increases the electric strength of the water, thereby increasing by more than one order of magnitude the energy density in high-voltage energy-storage devices.

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