The existing theories on the electrical breakdown of liquid dielectrics containing water, which were proposed by Hemant and Boning [1, 2], are based on relatively old experimental studies. Of the new experimental and theoretical studies in this field, mention should be made of [3, 4, 6-9]. The lack of any practical confirmation of these theories for many liquid dielectrics, as well as the major disagreement in results from experimental determinations of the relation \( E_{br} = f(\% \text{H}_2\text{O}) \) for identical dielectrics by different authors [1-5], is explained in particular by differences in the temperature of the dielectric during the experiment, since increases in temperature lead to conversion of water from the emulsified state to the dissolved state.

The aim of the present work is a further development of the existing views on the physics of electrical breakdown of liquid dielectrics containing water. The studies were conducted on Balakhany heavy crude oils. The following experiment was performed to study the relation between dielectric strength and dissolved water content. Water was placed in the bottom of a flask, which was then filled with crude oil that had been dehydrated in a Dean and Stark apparatus. The flask was heated while stirring the crude oil continuously, but without allowing any mixing of the oil with the water. The crude oil, at the temperatures indicated in Fig. 1, was poured into the cup of an AIMTI-60 oil breakdown apparatus, where \( E_{br} \) was measured, and a sample was taken for determination of water content by the Karl Fischer method. The measurements showed the independence of \( E_{br} \) or dissolved water content (Fig. 1, curve 1). In order to determine the dependence of \( E_{br} \) of the crude oil on the amount of emulsified water in the oil with a definite quantity of dissolved water, i.e., saturated with water at the given temperature, a natural water-in-oil emulsion (taken from commercial crude oil tanks) was added. The resulting emulsion, with a known concentration, was mixed thoroughly. The measurements showed that the relation between \( E_{br} \) and the amount of emulsified water was near-exponential (Fig. 1, curve 2). As a result of the experimental study of the relation between breakdown strength of the crude oil and the amount of water in the oil, taking into account the state of the water, the curve shown in Fig. 1 was plotted by combining the two relationships for dissolved and emulsified water. It should be noted that an analogous representation of the dependence of \( E_{br} \) of liquid dielectrics on the amount of water present, taking into account the state of the water, was given in [9] somewhat later than in our work [12].

Our measurements showed that, for an emulsion, \( E_{br} \) is independent of diameter of the dispersed water drops over the range from 0.5 to 50 \( \mu \), this range being obtained by adding emulsions drawn from valves located at different heights in a tank containing a polydisperse crude oil emulsion that had been allowed to settle for a prolonged period of time.

This conclusion, which also agrees with that of Fries [1] and Brounshtein [10], points out the incorrectness of the theory of Hemant and Boning, according to which \( E_{br} \) depends on the diameter of the water globules.

The independence of \( E_{br} \) of water drop diameter can be explained by dispersion of large drops into fine emulsified droplets under the influence of the electric field when it reaches a certain critical strength thus forming an emulsion that is close to one and the same degree of dispersity. These conclusions of ours are confirmed by the work of V. G. Ben'kovskii [7] and also by research conducted at the V. I. Ul'yanov (Lenin), Leningrad Electrical Engineering Institute and at the Vrotslavskii Polytechnic Institute (Poland).

When the crude oil was cooled during the time of making the measurements, transition of the water from the dissolved state to a microemulsion led to a sharp reduction in \( E_{br} \) (Fig. 1, curve 3).

The differences between emulsified and microemulsified water in their effect on the dielectric strength of the liquid dielectric is explained by their high cataphoretic mobility and also by the fact that nonuniformity of the electric field caused by surface roughness of the electrodes (which according to [4] serves as the source of "bridge" formation) is significant to microparticles with size of the same order as the magnitudes of the roughness, whereas...
such nonuniformity is of no significance in the case of emulsified particles that are larger by three to four orders of magnitude.

Thus, the disagreement among the results of various authors should be explained by their use of different methods of adding water to the dielectric; in some cases the water was present in the form of a microemulsion [5, 6] and in other cases in the form of an emulsion [8].

We carried out further investigations in a test stand [11] with special devices for static and dynamic measurements. Standard electrodes were installed in the device for static measurements. Coaxial cylindrical electrodes (14 mm O.D., 10 mm I.D., 22 mm long) were used in the device for dynamic measurements. Data are shown in Fig. 2 relating the breakdown voltage of crude oils with different water contents as a function of pressure, at a temperature of 22°C: these data indicate that an increase in $U_{br}$ with increasing pressure is observed with water contents of 0-1%.

Data are shown in Fig. 3 relating conduction current to applied voltage with different contents of water, at a temperature of 22°C and a pressure of 6 kg/cm². The final points on the curves of $I = f(U)$ correspond to the pre-breakdown values.

Analysis of these curves shows that, with water contents from 0 to 0.85%, the relation between electric conductivity of the crude oil and the electric field voltage has a bend in the curve, analogous to the region of saturation.