Pulsed Electrical Strength of Liquids and Solids at High Pressure

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Pressure effect on electrical breakdown of solid and liquids was investigated. Electrical strengthes E_b nondegassed oil, water, oil-water solution, rocks and polyethylen were measured at pressure up to 350 atm. It was found E_b of distillated water in plane-plane 0,8 cm gap are independent on pressure.

Electrical streugth of boring fluid (oil-water solution with solid particles) was increased insignificantly at pressure growth up to 50 atm, and then became invariable. Both unrefined and water E_b in inhomogeneous electrical fields at needle-plane electrodes with any polarity dont depend on pressure. Electrical strenthes of porous solid materials filled by oil-water solution were increased on pressure growth up to 20-50 atm.

1. Introduction

The pressure, under which the condensed insulating materials are placed, is one of the most important reasons of changing of their electric strength E_b [1]. Electric strength of liquids and solids increases with the rise of pressure. But the reasons of E_b probable increase and the quantity of its relative rising for liquids and solids are different.

The data about the dependence of electric strength from the pressure E_b (P) of porous less mono- and polycrystalline or amorphous materials are absent, the characteristics of porous materials - rocks in the liquids [2] and polymers in compressed gases [3-5] were only measured. It is supposed, that discharge initiation in the solids, placed in the compressed gases, takes place in the gas pores, and the developing discharge channels orient along them. The increase of one-impulse, and especially multi-impulse E_b (P) was connected with the rise of the discharge initiation voltage in the gas pores. That is why the rising of pressure up to 15-50 atm. causes the growth of the porous materials E_b to 10-40 % and then the electric strength doesn't practically depend on pressure [4,6]. Attempts to connect E_b (P) rising with the decrease of the activation energy of the charge carriers, and with a growth of their mobility [3] are hardly justified, because the obvious changes of the electron structure begin when the pressures more than 10^{6} atm.

The increase of E_B of porous materials in the liquids [2,4] is connected with the growth of the liquid pressure in the pores and delay of the discharge channels initiation in them, but the reliable quantity data about the influence of the degree on the heterogeneity of the field, the puls duration influence and the type of the material are absent.

It is considered that the decrease of the influence of the generating gas bubbles at initiation and propagation of discharge channels is responsible for the E_b (P) increase of liquids [1,8,10]. The increase of E_b was observed in the pure liquids, in homogeneous fields and on the time interval more than 10^{-6} c [1,7,8,11,12]. However in short gaps ($\leq 10^{2}$ m) in the water the double increase with the breakdown time lag $2{\cdot}10^{-7}$ c at P=150 atm was observed too [13]. The experimental data for liquids of technical refinement, having a high concentration of admixtures, in centimeters gaps and extremely inhomogeneous fields and the discharge time lag less $<10^{-6}$ c are absent or contradictory. That makes the choice of insulation of technological equipment more difficult.

A deficit of E_b (P) data for porous dielectrics and technical liquids, in centimeters gaps and inhomogeneous fields, which are necessary for designing the electrode systems of discharge technologies, in particular of the deep discharge drilling, stimulated the realization of these investigations.

2. Experimental method

The measurements of pulsed breakdown voltage U_b were performed in a steel 6-litre chamber with the polycarbonate input. The chamber allows to test the conductivity, and U_B of the liquids and solids at the voltage up to 400 kV and pressure up to 400 atm.

The samples of rocks with the thickness of 18-23 mm were cut from one block of the rock, the polyethylene samples had thickness of 2,78-2,86 mm. The stainless steel electrodes were used: disks of 10 cm diameter with rounded edge for homogeneous field and conical needle electrode (angle 30^{0} and curve radius 0,25 mm of a tip for solid dielectrics and 0,5 mm for liquids). The breakdown voltages of liquids were defined as average value of 20-30 measurements to point, and for solid dielectrics – breakdowns of 3-5 samples to point. Breakdowns were carried out on front (~0,15 μs) or the on amplitude of the voltage pulse of Marx generator with the impact capacity of 10 nF at the times breakdown 0,1÷ 0,3 μs.

The dielectrical characteristics of unrefined transformer oil with the resistivity 10^{10} ohm·cm and electric strength at alternating voltage E_b=80 kv/cm, drilling fluid on the oil-water basis with resistivity $2{,}9\cdot10^8$ Ohm·cm; distilled water with resistivity $1{,}5\cdot10^5$ Ohm·cm to a measuring chamber were investigated.

The dependence E_b (P) of rocks (granite, marble, limestone, sandstone) were measured on the samples in the electrode system disk-needle. The samples, in order to avoid the discharge overlapping, were placed in an oil-water solution which the pressure was passed through. Before placing in a chamber the samples were saturated by the solution during no less than 20 hours.

3. Pressure influence on the liquids electric strength

It is known that breakdown of condensed dielectrics in extremely inhomogeneous fields (needle-disk N-D) inheres an effect of polarity, i.e. E_b at (+N, -D)< E_b at (-N,+D). The reasons of the polarity effect are the less time lags of discharge initiation at anode and the greater speed of cathode directed channels growth [14]. The effect of the polarity is revealed more brightly in polar liquids. It achieves E_b (-N, +D)/ E_B(+N, -D)≤1,5 in centimeters water gaps in the fields with a high degree of inhomogenity. In our conditions it makes 1,3, in "dirty" oil ~1,1, Fig.1. The electric strength of water and "dirty" oil in inhomogeneous field didn't depend on pressure up to 350 atm. E_b and of oil-water solution increased to ~ 20 % with growth of pressure up to 25 atm, and then practically didn't change.

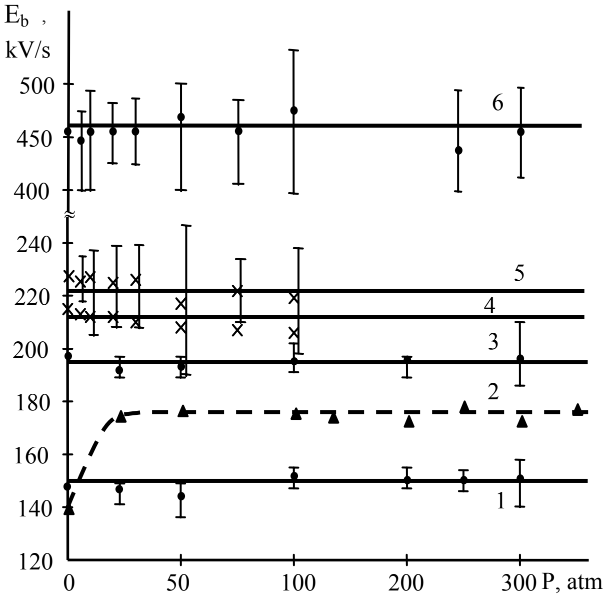

Fig.1. Electrical strength dependence on pressure
1 - water, positive needle, 2 – water-oil solution, positive needle, 3 - water, negative needle, 4 - oil, positive needle, 5 - oil, negative needle, 6 - water, homogeneous field.

If the absence of the E_b (P) dependence for inhomogeneous fields was revealed earlier [2, 7, 11], so an unexpected fact became the absence of marked increase of water E_b (P) for homogeneous field (curve 1, fig.1). The meaning E_b in homogeneous field, as it was expected, has a big dispersion ($\Delta E_b \cong 20\%$), but, in spite of the absence of water degassing and a relatively low resistivity of the water, i.e. the most probability of thermal formation of bubbles, the value of E_b wasn't changed. This result contradicts to the results [9, 13] and the approach, developing by authors [10,15] in which the breakdown of the liquids is initiated and developed in gas bubbles on electrodes. Oil-water solution with a density of 1,2 g/cm^3 contained abrasive particles, the surface of which absorbed gas, influencing on the initiation of the breakdown. Some increase of E_b with a rising of pressure up to 25 atm can be explained by the fact.

4. Pressure influence on solids electrical strength

The character of dependences E_b (P) for more porous rocks (granite 3%, limestone 5,5 %, sandstone 11,8 %) is similar to the dependence of E_b (P) of drilling solution in that samples were immersed. It is observed the increase of E_B up to P = 20-50 atm, and then the stabilization of E_b (P), fig.2. Electrical strength of slightly porous rocks marble (1 %) and polyethylene (0,005%) is practically unchanged. The influence of the material saturation degree, which determined by the pressure of liquid is clearly illustrated by relative electrical strength at 350 atm to E_b in normal conditions E_{350}/E_0 in depend on porosity, fig.3. The increase of relative strength with the growth of porosity is observed up to 40 % by filling pores under pressure.

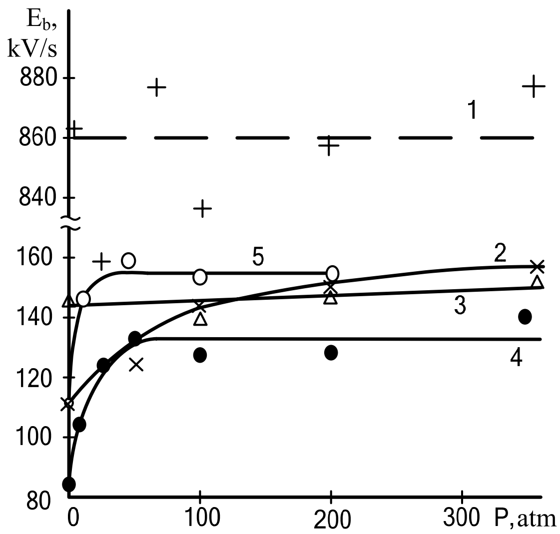

Fig.2. Electrical strength of solid dependence on pressure. 1-polyethylene, 2-sandstone, 3-marble, 4-granite, 5-limestone.

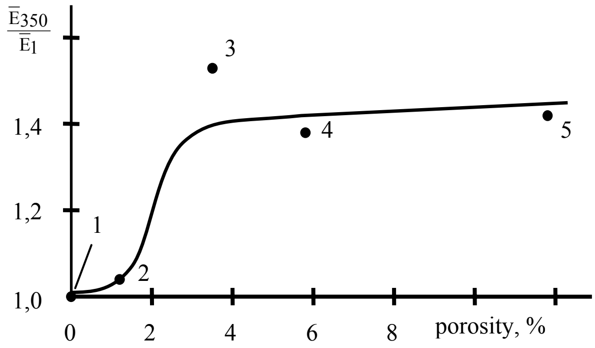

Fig. 3. Relative change of E_b dependence on porosity. 1 - polyethylene, 2 - marble, 3 - granite, 4 - limestone, 5 - sandstone.

5. Conclusion

Electrical strength of poorly cleaned water and non-cleaned oil in centimeters gaps and discharge time of 0,1 - 0,3 μs, doesn't depend on pressure. Electrical strength of porous materials increases with the pressure rising up to 20-50 atm by filling pores with liquids.

References

[1] Ushakov V.Y., *Insulation of Voltage Equipment.* Springer, V., 2004, 421 p.

[2] Kalyackii I.I., Krivko V.V., *Pulse Electrical Breakdown of Nonconductive Materials at High Pressure,* TPU Proc., 1966, v. 149, p. 163 (russian).

[3] Kolesov S.N., Messengik Y.Z., Volkov N.S., FAN, 1976, 183 p. (russian).

[4] Messengik Y.Z., Prut L.Y., Electrichestvo, 1982, № 6, p. 234 (russian).

[5] Park C.H., Kaneko T Hara V., IEEE Trans. Electr. Insul., 1982, 17, № 6, h. 234.

[6] Vorob'ev A.A., Vorob'ev G.A., *Electrical Breakdown and crushing of Solid Dielectrics,* Moscow, 1966, p. 280 (russian).

[7] Kalyackii I.I., Krivko V.V., *in Proc Dielectrics and Semiconducters Breakdown.* Energy, 1964, p.249. (russian)

[8] Hebner R.E., Kelley E.F., Fitz Patrick G.J., *Proc. 9th Int. Conf. Cond. and Breakdown in Diel,* Liquids. NY, 1987, p. 27.

[9] Fuhr J., Jones H.M., Aschwanden Th. // Proc. Int. Conf. Cond. and Breakdown in Diel. Liquids. NY, 1987, p. 411-415.

[10] Conrnay P., Lesaint O., *Proc. Conf. of Electr. Insul and Diel. Phenomena,* Ann Report. NY, 1994, p. 834-839.

[11] Balygin I.E., *Electrical Strength of Liquids,* Energy, 1964, 228 p. (russian)

[12] Ushakov V.Y., Klimkin B.N., Korobeinikov C.M., Lopatin V.V., *Pulse Liquid Breakdown,* Tomsk, 2005, 488 p.

[13] Abramian E.A. and all., *Megavolt accelerator,* Proc. doklad of Russian Science Academy, 1971, № 1, p. 56. (russian)

[14] Lopatin V.V., Ushakov V.Y. Chernenko V.P., Izv. Vuzov. Phys. – 1975. - № 3, p.98-106. (russian)

[15] Korobeinikov S.M., Melehov A.V., ThermoPhysics. – 2002, № 5, p. 706 (russian).