SKIN EFFECT AND SHOCK WAVES IN AN INDUCTION GAS DISCHARGE

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A gas discharge induced at a frequency of 300 cps is investigated. The shock wave was found to detach itself from the current layer under the conditions of the experiment. The current distribution in the discharge chamber is determined by the nature of the skin effect for metallic conductors.

IN most experiments on induction gas discharges, the main attention was focused on phenomena occurring in the first or second half cycle of the current in the gas.[1] A study of a current that flows in the gas for a prolonged period is, however, very important. Great interest attaches here to an investigation of the influence of shock waves and of skin effect on the course of the processes in a gas discharge.

We investigated gas discharges in an axially-symmetrical magnetic field at a frequency f = 300 kcs. The magnetic field was produced by an oscillating discharge from a capacitor bank ($C = 0.36\ \mu f$, $U_C = 30$ to 50 kv) into an inductive copper turn (300 mm diameter, $L = 0.53\ \mu h$) of rectangular cross section (height h = 60 mm, thickness 3 mm). The copper turn encircled the vacuum chamber, which consisted of a glass cylinder (200 mm. dia., h = 30 mm), sealed on both sides by rubber-gasketed glass disks. The main experiments were carried out with the chamber filled with hydrogen and with air in the range $p = 5 \times 10^{-1}$ to 10^{-2} mm Hg. The maximum current in the gas was $I_g = 15$ kiloamp. From a comparison of the oscillograms of the current in the gas and in the copper turns it follows that the ratio of the plasma reactance to resistance is $\omega L/R \gg 1$.

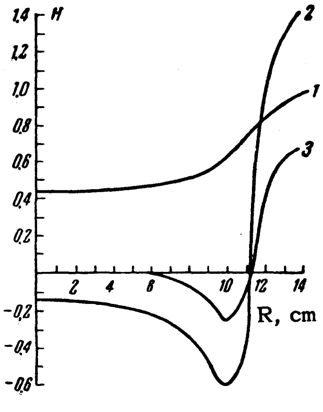

FIG. 1. Discharge in hydrogen, p = 0.05 mm Hg. Curve 1 – magnetic field in the absence of a discharge, 2 – magnetic field during the second half cycle of current, 3 – during the third half cycle.

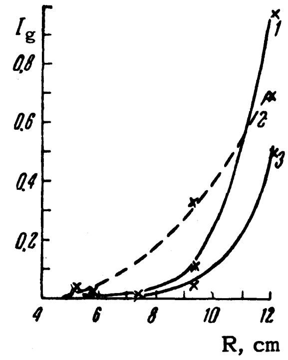

FIG. 2. Discharge in hydrogen, p = 0.05 mm Hg. Curves 1, 2, and 3 are for the first, second, and third half cycles, respectively.

The distribution of the magnetic field in the central plane of the discharge chamber is shown in Fig. 1. The field intensity in the center of the chamber is approximately 1500 oe. The current in the gas should contract towards the center of the chamber at the given magnetic field configuration under the influence of the electrodynamic forces.[1]

Figure 2 shows the distributions of the current in the gas along the radius of the chamber.* Adjacent to the side wall of the vacuum chamber is a current layer approximately 3 cm wide, in which 90 or 80 percent of I_g is concentrated. No motion of the current layer is observed during the entire discharge, nor does the character of the current distribution in the gas change. It is seen from the plots that after two half cycles of current almost the entire magnetic field is concentrated in the current layer, and there is no field in the center of the chamber.

A high-speed photograph (Fig. 3) shows that a glowing ring, approximately 3 mm wide and of the same height as the chamber, is produced at the wall of the vacuum chamber during the instant of breakdown. The ring contracts toward the center of the chamber, and its brightness at the center

*Figures 1 and 2 are plotted in arbitrary units, at the instants of time corresponding to the maximum current in the gas during different half cycles.

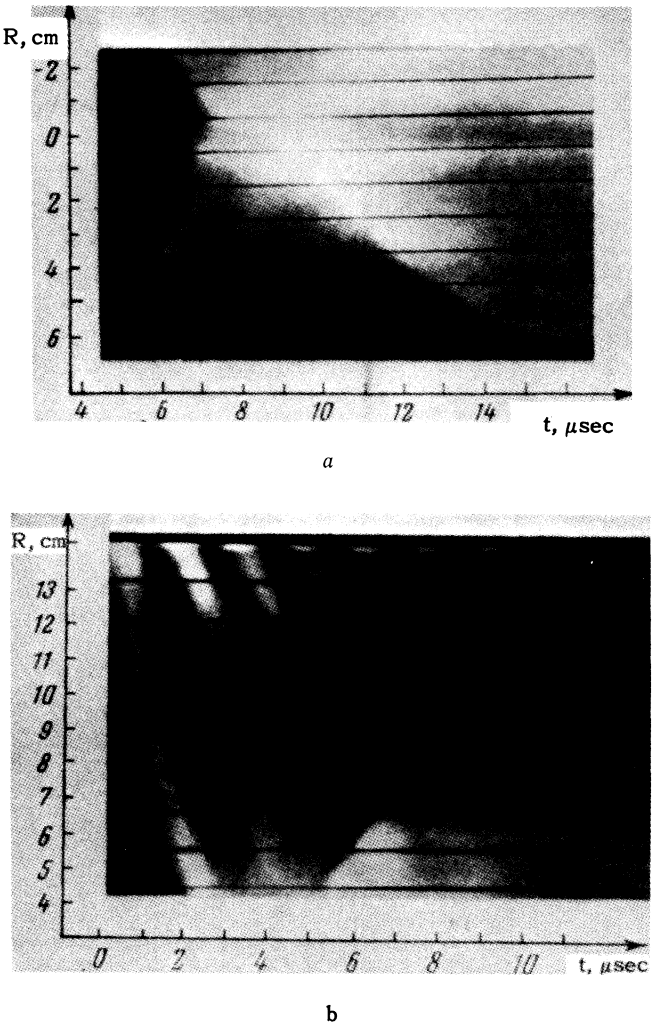

FIG. 3. High-speed photograph of a discharge in air. a – p = 0.07 mm Hg; b – p = 0.05 mm Hg.

increases greatly at the instant of contraction. The initial speed of motion of the ring, $v = 2 \times 10^6$ to 1.5×10^7 cm/sec, depends on the current in the gas, the pressure, and on the type of gas. It is in good agreement with the expression $v \sim (I_g/p)^{1/2}$ (Fig. 4). The rate of contraction of the ring decreases as the center of the chamber is approached.

Measurements made with high-speed transducers[2] have shown that the entire volume of the vacuum chamber becomes filled with ionized gas after one or at most two half cycles of current. From a comparison of the high-speed photographs and the voltage oscillograms obtained with high-frequency transducers it follows that the speed of propagation of the ionization along the radius of the vacuum chamber corresponds to the speed of the glowing ring.

The narrow glowing ring observed on the photographs, the contraction of which is accompanied by ionization of the gas, represents apparently the front of the shock wave. The character of the de-

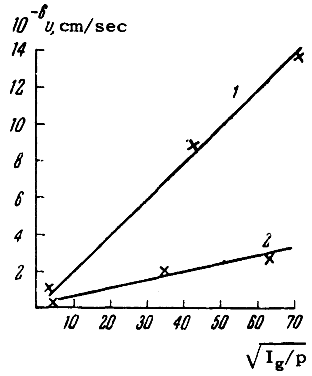

FIG. 4. Dependence of the speed of the shock wave on the ratio of the current in the gas to the pressure. 1 – for hydrogen, 2 – for air.

pendence of the speed of motion of the glowing rings on the gas pressure ($v \sim p^{-1/2}$) agrees with the results of experiments on shock waves.[3]

The character of distribution of the currents and magnetic fields in the presence of an ionized gas in the entire volume of the vacuum chamber is evidence of the existence of skin effect, which occurs in a plasma as it does in metal conductors.[4] The thickness of the skin layer, ~ 3 cm, yields an estimate for the conductivity of the plasma, namely $\sigma = 7 \times 10^{13}$ cgs esu.

In spite of the propagation of shock waves under the influence of the magnetic field, the current layer remains at the side wall of the chamber. This is probably due to the fact that during one half cycle of the field, the current layer does not have time to move away from the wall, owing to the short time of application of the force. The presence of a strong vortical electric field (E ~ 400 v/cm) produces a breakdown at the chamber wall during each succeeding half cycle of current. The presence of a clearly pronounced skin effect leads here to the shielding of the magnetic field in the inner regions of the chamber.

It should be noted that the glow of the plasma does not characterize the behavior of the current in the gas in this case.

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