INVESTIGATION OF THE EFFECT OF AN EXTERNAL MAGNETIC FIELD ON THE DEVELOPMENT OF A PULSE DISCHARGE IN ARGON

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The results of measurements of the brightness of light flashes from a pulse discharge are given for argon in a quasistationary magnetic field H = 150,000 Oe and for zero field in the pressure range from 20 to 740 mm Hg. At pressures of 20 and 100 mm Hg the brightness of the discharge flashes was found to increase at H = 150,000 Oe. In the initial stage of the development of the discharge the rate of expansion of the discharge column was found to be lower in a magnetic field H = 150,000 Oe than in the case of zero external magnetic field.

It has been shown earlier [1] that if a pulse discharge in helium occurs in the presence of a sufficiently strong external quasistationary magnetic field the same brightness of the luminous column can be obtained at low gas pressures in the tube as at pressures exceeding atmospheric. However, in these experiments the authors were unable to exceed the value of brightness reached in a "hard" spark discharge in helium. [2] Consequently it was of interest to repeat these studies with a gas in which the phenomenon of brightness saturation occurs at relatively "soft" discharge conditions. Argon was used as such a gas; [2] the brightness saturation was observed in argon at a pressure of $\approx$ 1 atm and a rate of current rise di/dt $\approx 10^{11}$ A/sec, which could be attained under our experimental conditions.

The effect of a magnetic field on the discharge parameters in argon was investigated using the technique described earlier. [1]

Oscillograms of the flashes, shown in Fig. 1, indicate that the presence of a quasistationary longitudinal magnetic field of magnitude H $\approx$ 150,000 Oe does not increase the brightness of the discharge column at argon pressures from 300 to 760 mm Hg (oscillograms a, f, b, g). Noticeable increase in the brightness occurred only at gas pressures of 20 and 100 mm Hg (oscillograms c, h, d, i). The luminous intensity (oscillograms e, j) increased less than the brightness due to a nonuniform intensification of the brightness across the discharge-column diameter. [1] In spite of an approximate doubling of the brightness by application of a magnetic field to argon discharges at low pressures, it was not possible to exceed the limiting value of the brightness (see the table).

Photographs of the development of the discharge, obtained with an image convertor (Fig. 2), show that in the case of discharges in a magnetic field the rate of expansion $\dot{a}$ of the discharge column in the

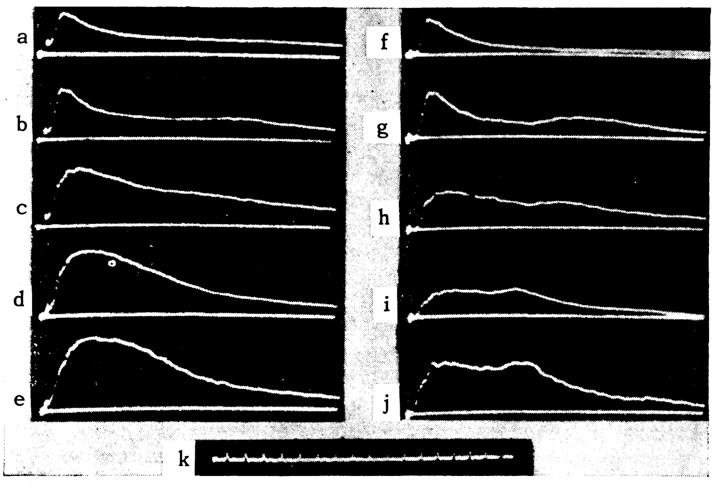

FIG. 1. Variation with time of the brightness (a, b, c, d, f, g, h, i) and of the luminous intensity (e, j) for flashes produced by a discharge in argon in a longitudinal magnetic field H = 150,000 Oe (a, b, c, d, e) and H = 0 (f, g, h, i, j). Oscillograms a and f were obtained at p = 760 mm Hg; b and g – at p = 300 mm Hg; c and h – at p = 100 mm Hg; d, e, i, j – at p = 20 mm Hg. Distances between neighboring time marks (k) represent 200 nsec. The ordinate scales are different: oscillograms c, d, h were obtained without neutral light filters; b and g were obtained with 5-fold light filters; oscillograms a, e, f, j were obtained with 16.5-fold light filters. The discharge parameters were C = 0.014 μF, L = 140 nH, U_0 = 15 kV.

Argon pressure, mm Hg	Discharge-column brightness, rel. units	
	$H=0$	H=150 000 Oe
740	100	100
300	37	37
100	5.5	8
20	4	9

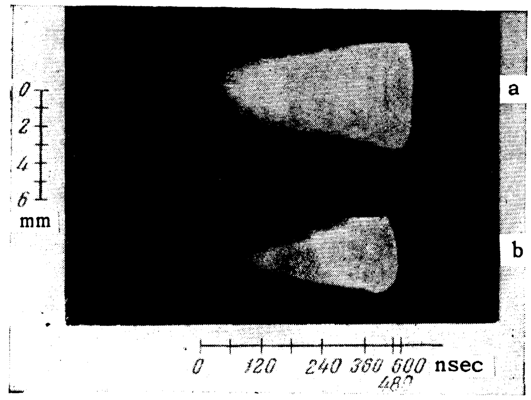

FIG. 2. Photographs of space-time displays of the discharge column: a) H = 0, b) H = 150,000 Oe.

initial stage decreases compared with zero field: for H = 150,000 Oe $\dot{a}$ = 7 km/sec, while for H = 0 $\dot{a}$ = 15 km/sec.

The pressure p in the discharge column, causing this expansion of the discharge channel, can be determined from the value of $\dot{a}$ using[3]

$$p = k_p \rho_0 \dot{a}^2, \tag{1}$$

where k_p is the "resistance coefficient," close to unity in magnitude,[3] and ρ_0 is the gas density before the discharge.

In the presence of a magnetic field, impeding the expansion of the discharge channel, the value p is given by the difference of the gas-kinetic (p_g) and magnetic (p_m) pressures, where

$$p_m = \frac{H_a^2}{8\pi}\left[1 - \left(\frac{H_{av}}{H_a}\right)^2\right], \tag{2}$$

H_a is the magnetic field intensity at the surface of the discharge column of radius a, and H_{av} is the average value of the field intensity in the plasma. Using the experimental data on the velocity of expansion of the discharge column, obtained with and without a longitudinal magnetic field H, we can determine the ratio H_{av}/H_a from Eqs. (1) and (2).

For discharges in argon at a pressure of 20 mm Hg the ratio H_{av}/H_a = 0.95 in the initial stage of the discharge at H = 150,000 Oe, which indicates that the field rapidly penetrates the plasma. Comparison of the results obtained earlier[1] and those reported here shows that in a heavy gas (argon) the influence of a magnetic field on the brightness of the discharge column becomes noticeable at lower pressures than in the case of the discharge in a light gas (helium). This is probably due to the high rate of expansion of the channel in helium which does not allow sufficient time for equalization of the magnetic field across the channel cross section, with the result that the ratio H_{av}/H_a is smaller for helium than for argon.

Thus, to increase the brightness of the discharge column it is necessary to increase the value of the quasistationary longitudinal magnetic field and the rate of rise of the current in the discharge in order to increase the rate of expansion of the discharge channel. We must remember, however, that the rate of rise of the current in a discharge has a natural limit,[4] and therefore the rate of expansion of the channel is also limited.[5]

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