INSTABILITY OF A PLASMA IN A MAGNETIC FIELD UPON TRANSITION FROM LOW TO HIGH PRESSURES

A. R. AKHMEDOV and A. A. ZAĬTSEV

Moscow State University

Submitted to JETP editor May 27, 1963

J. Exptl. Theoret. Phys. (U.S.S.R.) **45**, 1414-1415 (November, 1963)

Results are given of an investigation of helical instability of a positive column in a magnetic field. The gas (Ne and He) pressure was as high as 40 mm Hg. A gradual transition takes place from the instability observed at low pressures to the instability observed at high pressures. At pressures above 10 mm Hg, the critical magnetic field for the appearance of instability decreases with increasing discharge current.

THE results of recent experiments on the investigation of the macroscopic instability of a positive column in a longitudinal magnetic field and phenomena associated with it referring to pressures in the range approximately from 0.1 to several mm Hg were explained theoretically by Kadomtsev and Nedospasov.[1] They showed that the positive column became unstable against perturbations, giving it a helical form if the value of the magnetic field reached a certain critical value.

The appearance of a helical instability is not limited to the case of a low pressure plasma. A similar transition of the cylindrical form of the plasma column into a helical shape for a definite value of the magnetic field also takes place in the high pressure discharge.[2] In the present work, the conditions are studied for the appearance of a helical instability in the transition (intermediate) mode between low and high pressures. Measurements were carried out on plasma in neon and helium. In the experiments, the pressure was reduced to 40 mm Hg. Glass tubes of length 50 and 90 cm were used with an internal diameter of 2.6 cm. The tubes were placed along the axis of a coil of length 60 cm, which created an almost homogeneous adjustable magnetic field of 0—2500 G. The value of the discharge current varied from 0.02 to 1 A.

Figure 1 shows the change in the critical magnetic field (B_c) for producing an instability as a function of the pressure p. For neon in the given experiment, the entire curve was not obtained but only that part of it which pertained to not very strong magnetic fields. In the drawing, the crosses correspond to the data of Allen et al,[3] while the points represent the results of our measurements in a discharge current of 0.5 A. The upper curve

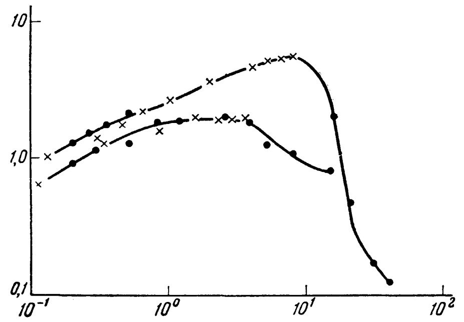

FIG. 1

represents results for neon, and the lower for helium. The curves show the continuous transition from the instability phenomenon observed at low pressure to the instability phenomenon at high pressure.

As is seen, the value of B_c increases with increase in pressure, passes through a maximum and then decreases. The increasing portions of the curves correspond to the region of applicability of the theory of Kadomtsev and Nedospasov; their result was obtained for the case in which the positive column was in the Schottky diffusion state. Upon increase in pressure above 5—10 mm Hg, the regime changes; the positive column gradually contracts, approaches a temperature inhomogeneity in the gas and increases the role of recombination processes in the loss of charged particles. The conclusions of the theory obtained by neglect of these factors are insufficient for a full explanation of the shape of the curves at high pressures. The rapid decay (more rapid in neon) following the maximum is evidently brought about by contraction of the column, with the approach of which the sta-

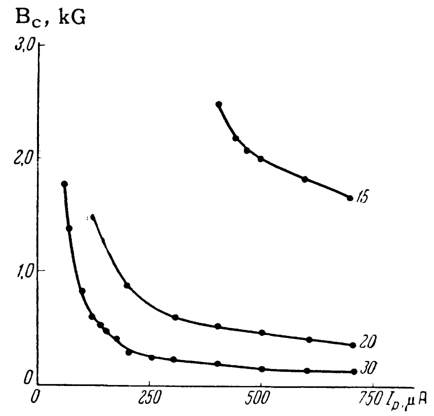

FIG. 2

bilizing effect of the walls on the plasma is decreased.

At higher pressures, many characteristic peculiarities of the instability phenomenon can easily be established by visual and photographic observation. In the transitions through the critical value of the magnetic field the positive column takes the shape of a right (left) spiral if the vectors of the electric and magnetic fields are parallel (or antiparallel). The radius of the spiral does not increase with increase in the field B and the current density j; this can be explained by the action of the force $\mathbf{j} \times \mathbf{B}$.

Curves are shown in Fig. 2 for the value of B_c as a function of the discharge current for neon (the numbers on the curves indicate the pressure in mm Hg). It can be seen that B_c decreases when the current increases. We note that at low pressures, the critical magnetic field is practically independent of the intensity of the discharge current.[3,4]

[1] B. B. Kadomtsev and A. V. Nedospasov, J. Nucl. Energy. C1, 230 (1960).

[2] W. Elenbaas, Selected Topics in Modern Phys. II. The High-pressure Mercury Vapour Discharge (Amsterdam, 1951).

[3] Allen, Paulikas, and Pyle, Phys. Rev. Lett. **5**, 409 (1960).

[4] A. A. Zaĭtsev and M. Ya. Vasil'eva, JETP **38**, 1639 (1960), Soviet Phys. JETP **11**, 1180 (1960).

Translated by R. T. Beyer
233