Letters to the Editor

PARTICLE LOSSES AND CONFIGURATION OF A PLASMA JET MOVING IN A CURVILINEAR MAGNETIC FIELD

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THE motion of a plasma jet in a curvilinear magnetic field was investigated experimentally on several occasions [2-5]. These investigations have shown that the elementary theory developed by Schmidt [1] does not correspond to the real character of jet motion. However, these studies were limited to the plasma parameters in only one cross section of the jet that had passed through the curvilinear section of the field. We investigated a configuration and the particle losses in a plasma jet that had moved further in a homogeneous magnetic field. We found that in any section the plasma jet consisted of a "nucleus" of dense plasma (dielectric constant $\sim 10^3$), which moved along the field lines, and a plasma "tongue" ejected transversely to the field.

The experimental setup was as follows. A plasma gun placed in front of a magnetic mirror produced a plasma jet which moved along the magnetic field and passed in succession through a homogeneous-field section $H_\perp = 3$ kOe (solenoid length 50 cm and diameter 6 cm), a curvilinear section, and then again in a homogeneous field $H_0 = 1$ kOe (solenoid length 120 cm and diameter 24 cm). The region of the curvilinear field was produced at the junction between these mutually perpendicular solenoids; the average radius of curvature of the force lines was 6 cm. The plasma density in the jet was $\sim 10^{12}$ cm^{-3} and the electron temperature 5–10 eV. The configuration of the jet which had passed through the curvilinear section of the magnetic field and the total flux of charged particles through the given cross section of the chamber were investigated in a section where the field was homogeneous (H_0). In addition, the total flux of the particles in the field $H_\perp$ ahead of the turn was measured beforehand. The measurements of the particle flux were made with the aid of a flat screened probe which blocked the entire section of the chamber of 12 cm diameter. The measurement results are shown in Fig. 1. Curve 1 shows that the particle flux ahead of the turn depends little on the magnitude of the field and increases by not more than 20% when $H_\perp$ is varied from 1 to 5 kOe. The total number of ions passing through the curvilinear section depends approximately linearly on the absolute values of the field $H_\perp$ and H_0 (the ratio $H_\perp/H_0$ was kept constant in these measurements). This result agrees with the result of Eubank and Wilkerson [3]; however, as can be seen from a comparison of curves 2 and 3, the coefficient of proportionality depends on the distance from the receiver to the curvilinear section of the field. The measurements of the total flux of particles at different distances from the probe to the turn, at constant $H_\perp$ and H_0 (see curve 4) show that the particle loss occurs not only in the region of the curvilinear field, but also over the entire length of the jet in the uniform field H_0.

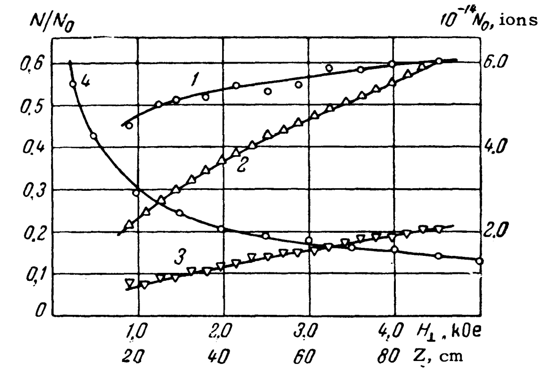

FIG. 1. Dependence of the total number of the ions (N_0) injected by the gun in a homogeneous magnetic field $H_\perp$, on the value of $H_\perp$. Curves 2, 3 – dependence of the ratio of N (the total number of ions passing through the cross section of the chamber at distances 10 and 80 cm from the turn) to N_0 on the value of $H_\perp$ at $H_\perp/H_0 = 3$. Curve 4 – variation of N/N_0 along the chamber of $H_\perp/H_0 = 3$ and $H_\perp = 2.7$ kOe.

The configuration of the jet which passed through the section of the curvilinear field was investigated with the aid of a luminescent screen operating in the ion-image mode [6]. A comparison of the photographs taken at different screen illumination times shows that a plasma tongue is ejected within 1–2 microseconds following the passage of the leading front of the jet through the turn of the field, in a direction opposite to the direction of the magnetic-field gradient. This tongue is produced simultaneously over the entire length of the plasma jet. During all the succeed-

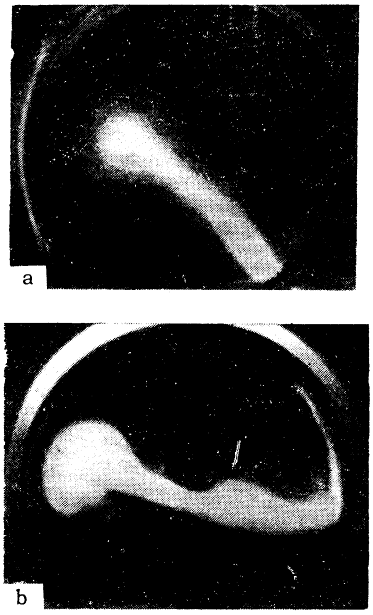

FIG. 2. Photographs of the glow of a luminescent screen located at 10 cm (a) and 80 cm (b) from the turn, 13 microseconds following the passage of the leading front of the jet through the section of the inhomogeneous field.

ing stages of the motion, the jet has a configuration similar to that shown in Fig. 2. This configuration is characterized by the presence of a nucleus, made up of the plasma moving along the force lines of the magnetic field, and a plasma tongue, in which the plasma drifts in the crossed fields E and H towards the outer wall of the chamber. Such a deduction agrees qualitatively with the curves of Fig. 1, and is confirmed by direct measurement of the electric field in the vicinity of the "nucleus" and the plasma tongue.

Since the plasma is not in magnetohydrodynamic equilibrium in a curvilinear magnetic field, it is clear that the motion of the jet should be accompanied by the ejection of plasma transverse to the field. The question is the character of the transverse motion and the rate of its development. The data given above show that under the conditions of our experiment the manifestation of the nonequilibrium nature of the plasma is the ejection of the plasma tongue, whereas the "nucleus" of the plasma jet does not experience any drift transversely to the field. The rate of escape of the plasma from the nucleus depends on the magnitude of the magnetic field, which determines the variation of the dependence of the number of particles passing through the curvilinear section on the value of H. On the whole, the velocity of plasma drift transverse to the field turns out to be in this case much smaller than predicted by Schmidt's theory

[1] G. Schmidt, Phys. Fluids 3, 961 (1960).
[2] Wetstone, Ehrlich, and Finkelstein, Phys. Fluids 3, 617 (1960).
[3] H. P. Eubank and T. D. Wilkerson, Phys. Fluids 4, 1407 (1961).
[4] Safronov, Voĭtsenya, and Konovalov, ZhTF 32, 678 (1962), Soviet Phys. Tech. Phys. 7, 495 (1962).
[5] H. P. Eubank and T. D. Wilkerson, Phys. Fluids 6, 914 (1963).
[6] Batanov, Ivanovskiĭ, Fedyanin, and Shpigel', Coll. Diagnostika plazmy (Plasma Diagnostics), Atomizdat, 1963.

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THE QUESTION OF THE POSSIBLE EXISTENCE OF A HEAVY CHARGED LEPTON

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EARLIER the writer [1] and Zel'dovich [3] have discussed the hypothesis that there may possibly exist in nature new charged heavy leptons, whose mass must exceed that of the K meson and belong to the same domain of phenomena as the muon mass. The most direct way to the experimental detection of such leptons is to be found in experiments on the electromagnetic production by γ-ray quanta or in clashing electron beams. [1-4]

Another possibility has also been indicated earlier, [2] when for the purpose of excluding neutral lepton currents it was suggested that there exist two new charged leptons e'^{+} and u'^{+}, which take part in weak interactions paired with the same respective neutrinos ν_e and ν_μ as the electron and muon. In this case one could expect the production of the new mesons in experiments with high energy neutrinos which are now being done at Brookhaven and at CERN. [5,6] We note that if observations were made with a hydrogen bubble chamber the only possible four-fermion process in the experiment with ν_μ would be the process involving the production of μ'^{+} (cf. [2]).

Assuming that the mass m_l of the heavy lepton is less than the mass of the intermediate boson, we have the following fundamental decay channels: