means that actually one of the coefficients (E or F) is larger than in formula (1). Starting from the value of F, we can determine the electron density. An estimate yields $N \sim 1.5 \times 10^{22}$ cm^{-3}, which is in relatively good agreement with the 0.43×10^{22} cm^{-3} obtained form the value of the lenslike Fermi surface. A similar estimate with the employed value of E yields a result which is patently exaggerated. This confirms the previously expressed idea that the obtained Hall conductivity $\sqrt{\sigma_{xy}}$ is for some reason much larger than follows from the theory. Thus, the observed oscillations are apparently due to resonant excitation in the metal of electromagnetic waves with a discrete spectrum near the CR.

In conclusion, the authors thank A. A. Galkin for interest in the work, E. A. Kaner for a discussion of the results, and V. Gusakov for help in the reduction of the experimental data.

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PLASMA HEATING BY AN ELECTRON BEAM PRODUCED IN A TURBULENT LINEAR DISCHARGE

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It was shown in [1, 2] that when conditions for electron runaway are created in a current-carrying plasma, a two-stream instability is excited and leads to an interruption of the current, to a concentration of the potential drop in a small section of the plasma column [2], and to the transport of the entire current by the beam of the accelerated electrons; practically the entire energy stored in the external circuit is then transferred, in the main, to the accelerated electrons.

It can therefore be assumed that one of the explanations of the strong plasma heating observed in investigations of a turbulent linear discharge [3 - 5] is the excitation of a beam of accelerated electrons in the linear discharge, and the subsequent collective interaction of this beam of accelerated electrons with the cold plasma [6].

To verify this assumption, experiments were performed on plasma heating in a magnetic mirror trap ("probkotron") by an electron beam generated by a linear discharge and passing through the anode. The experiments were performed with the "Aspa" setup [7]. The vacuum chamber (Fig. 1) consisted of two sections, glass (4) and metallic (3), and was located along the axis of a solenoid producing a quasistationary magnetic field H_0 of intensity up to 2500 Oe.

Two coils (5, 8) of the trap (R = 2.5) were placed over the glass chamber (spaced 75 cm apart). An electrode (cathode) 10 was located outside the trap, on the end face of the glass chamber, and a second reticular electrode (anode) 9 of the straight discharge was located 30 cm away from the cathode. A capacitor (0.2 μF) was connected to the electrodes 9 and 10. A turbulent linear discharge was excited in this circuit, with the grounded reticular electrode 9 serving as the anode during the first half-cycle. The parameters of the

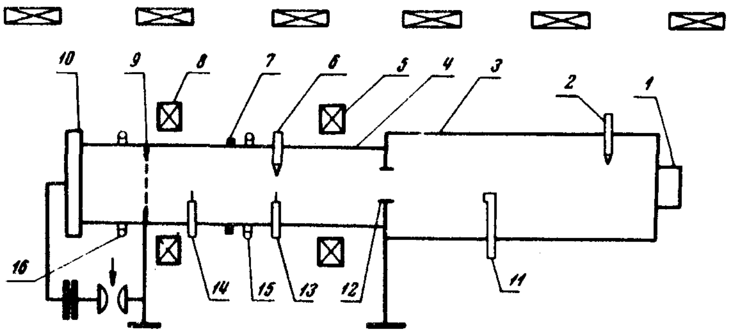

Fig. 1

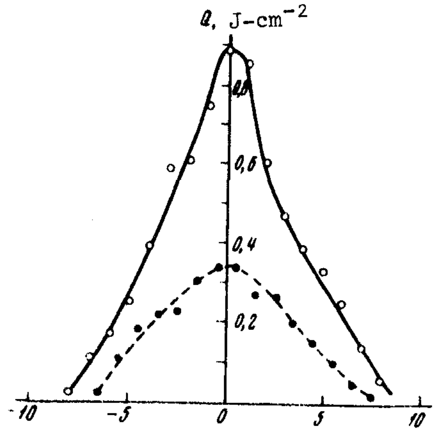

Fig. 3

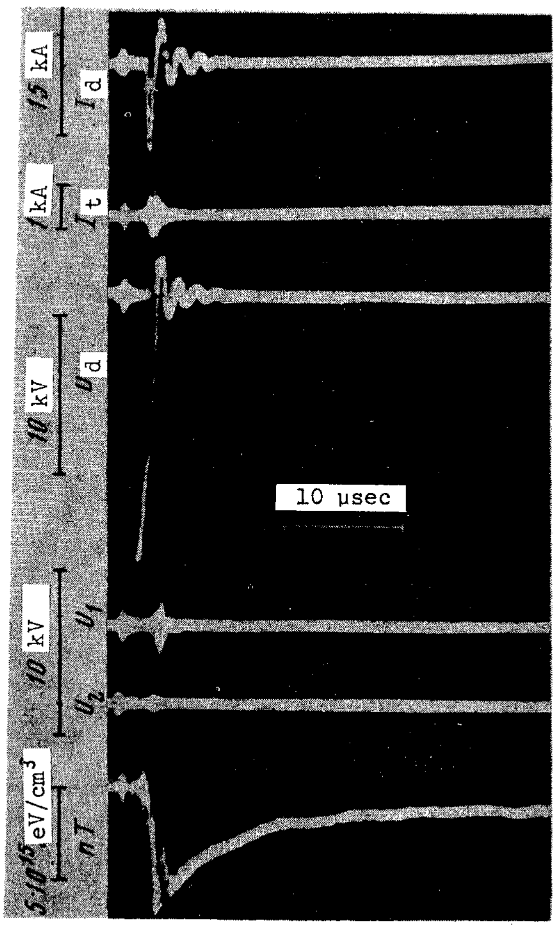

Fig. 2

Fig. 1. Experimental setup: 1 - coaxial plasma injector, 2 - thermal probe, 3 - metallic chamber, 25 cm dia, 3 m long, 4 - glass chamber, 20 cm dia, 15. m long, 5 - mirror coil, 6 - thermal probe, 7 - diamagnetic loop, 8 - mirror coil, 9 - redicular linear discharge anode, 10 - linear discharge cathode, 11 - electrostatic analyzer, 12 - metallic diaphragm, 10 cm dia, 13 - double electrostatic probe, 14 - single electrostatic probe, 15 - Rogowski loop, 16 - Rogowski loop.

Fig. 2. Oscillogram of linear discharge current I_d, trap current I_t, linear discharge voltage U_d, plasma potentials U_1 and U_2 at the locations of probes 14 and 13, and of the diamagnetic signal from loops 7. Plasma density $n_0 = 2 \times 10^{13}$ cm^{-3}, U_0 = 30 kV, working gas hydrogen, H_0 = 2000 Oe.

Fig. 3. Beam energy density distribution over the chamber cross section: o - in the trap plane, thermal probe at 1 meter from anode 9, ● - in metallic chamber 3, thermal probe 2 at 2.5 m from the anode 9. Plasma density (1 - 2) x 10^{13} cm^{-3}, U_0 = 30 kV, working gas hydrogen, H_0 = 600 Oe.

linear discharge were: frequency 5 = 640 kHz, and maximum current amplitude approximately 15 kA at an initial voltage 30 kV. The reticular electrode 9 and the metallic chamber 3 were grounded.

The voltage across the discharge gap and the potential of the plasma in the trap were measured with probes 13 and 14; the discharge current was measured with Rogowski loop 16, the current in the trap was measured with Rogowski loop 15, the diamagnetism of the heated plasma with loops 7, the drop of the beam energy with thermal probe 6 in the trap and thermal probe 2 outside the trap (2.5 meters from the anode 9), the beam-current density with analyzer 11, and the plasma density on the axis with double probe 13.

The sequence of the operations was as follows: the plasma injector was turned on at the maximum of the field H_0, after which the linear-discharge circuit was closed. During the first half-cycle of the linear discharge there is produced, in the main, a beam of accelerated electrons that carries almost the entire discharge current ($I \simeq 10 - 15$ kA), having an average directional-motion energy per particle $\varepsilon' \simeq 10$ kV, a beam electron density $n' \simeq 10^{11}$ cm^{-1}, a beam duration ~ 0.6 μsec and a beam current density ~ 100 A/cm^2. This beam passed through the reticular anode of the gas-discharge gap, penetrated through the entire plasma column in the trap, and was registered by thermal probe 2 and by analyzer 11. At a plasma density 2×10^{13} cm^{-3}, an almost aperiodic discharge is observed in the electron gun (Fig. 2). Probes 13 and 14 detect practically no change of the plasma potentials U_1 and U_2 in the trap. There is likewise no trap current I_t, as measured by the external Rogowski loop 15, by virtue of the fact that the beam penetrating through the plasma column excites a backward drift current that cancels out the beam current [8]. During that time, a strong heating of the plasma in the mirror machine is observed and is measured by the diamagnetic loops; the containment time is about 20 μsec and the plasma pressure nT is up to 6×10^{15} eV/cm^3. In the cross section of the trap, at a distance of 1 meter from the linear-discharge anode, the total energy carried by the electron beam is more than 80% of the energy stored in the capacitor bank (Fig. 3). At a distance of 2.5 meters from the anode, the beam energy is about 25% of the energy stored in the external circuit. The energy lost by the beam is determined by the collective interaction of the beam with the plasma [6].

When the initial plasma density is increased to 7×10^{13} cm^{-3}, the linear-discharge current is oscillatory, but the plasma heating in the plasma remains unchanged. At a plasma density $n \simeq 7 \times 10^{13}$ cm^{-3}, at a distance of 1 meter from the anode, we registered in the beam only about 30% of the external-circuit energy, and there was no beam at a distance of 2.5 meters.

In this experiment, the absorption of the energy by the accelerated-electron beam determines completely the observed energy dissipation by the "anomalous" resistance of the plasma column.

The magnetic-field range investigated by us, from 500 to 2000 Oe, the energy content of the plasma heated by the electron beam in the mirror machine increased linearly with the magnetic field intensity, reaching a value $nT = 6 \times 10^{15}$ eV/cm^3 at a field of 2000 Oe in the center of the trap. The maximum beam-heating efficiency, calculated for $nT = 6 \times 10^{15}$ eV/cm^3 and H_0 = 2000 Oe, is 1.7%. A concentration of the main potential drop in a small region of the plasma column [2, 3] and the transport of the bulk of the current by a small fraction (10^{-2} - 10^{-3}) of the plasma electrons, similar to those observed in [2] and in the present investigation, may occur also in toroidal setups with longitudinal magnetic fields exceeding the critical Dreicer field.

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SOME SINGULARITIES OF THE KINETICS OF A CURRENT PINCH

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The known experimental papers (e.g., [1, 2] contain information on current pinches in semiconductors only under stationary conditions, or else deduce the kinetics from the manifestation of effects in the external circuit. In the present paper we present the results of a study of the formation of a pinch and its displacement in a transverse magnetic field.

1. To investigate the illustration of the density of the current j over the sample cross section, we developed a method based on the measurement of the distribution of the voltage U along one of the contacts having a small longitudinal resistance. From the expression for the current along the contact and from the continuity equation in the one-dimensional case we can readily get

$$j = \sigma_k \delta \frac{d^2 U}{dx^2},$$

where σ_c is the conductivity of the contact, and δ is its thickness (the x axis is directed along the contacts, see Fig. 1).

Assuming that the conductivity σ_0 of the sample is constant, we get

$$U = U_0 \operatorname{sch} \frac{l}{2L} \operatorname{ch} \frac{2x - \ell}{2L},$$