When the ampoule was lowered and the inside level was lower than the outside one, the transfer reversed sign. In the case of ordinary surfaces, however, the inflow occurs at practically all values of ΔH and H, whereas in the case of Plexiglas ampoules, for which the outflow is described by curve 1 of Fig. 1, no transfer at all occurred at large values of H, and the level could stay unchanged for a long time. Gradual lowering of the ampoule led to the onset of inflow, starting with H at several millimeters. Even then, however, the inflow did not continue until the levels became equalized, as is usually observed, but stopped suddenly at values of ΔH far from zero (Fig. 2).

Special experiments performed simultaneously with two ampoules, one glass and the other Plexiglas, have shown that the indicated phenomena are observed for a Plexiglas ampoule but not for a glass one. This eliminates the possibility that the experiments were performed under non-equilibrium conditions. Both ampoules behave identically in HeI near the λ point, and no change of the liquid level with time was observed in either.

Thus, both outflow and inflow over Plexiglas ampoules exhibit singularities not observed with ordinary materials.

One cannot exclude the possibility that the indicated phenomena are connected with the electric state of the Plexiglas, which, as is well known, electrifies easily. When the ampoule is prepared and cooled, its surface can become electrified, and then the motion of the HeII film is subjected to the action of appreciable forces, which can change significantly the character of the transfer phenomenon. A better argumented evaluation of the nature of the described phenomenon will probably become possible when new experiments are performed with ferroelectric ampoules, and with an electric field of controlled direction and magnitude.

It should be noted that the possibility of regulating the film transfer process can be of considerable interest when it comes to producing infralow temperatures.

In conclusion, we take the opportunity to thank B.G. Lazarev and A.I. Shal'nikov for fruitful discussions.

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CONCERNING THE MECHANISM OF CHARGED-PARTICLE ACCELERATION IN A DYNAMIC Z-PINCH

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Acceleration of the charged particles responsible for the generation of x- and neutron radiation is frequently observed in a dynamic Z-pinch. To explain this effect, various mechanisms were proposed, but none agreed sufficiently well with the experimental data [1].

We begin our discussion of the mechanism proposed by us by listing the main experimental facts[1)] [1 - 3]: (1) the acceleration of the ions and electrons occurs simultaneously and to approximately the same energies; (2) the acceleration region is localized along the discharge axis and its transverse dimension

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[1)] This question will be discussed in detail in a separate article.

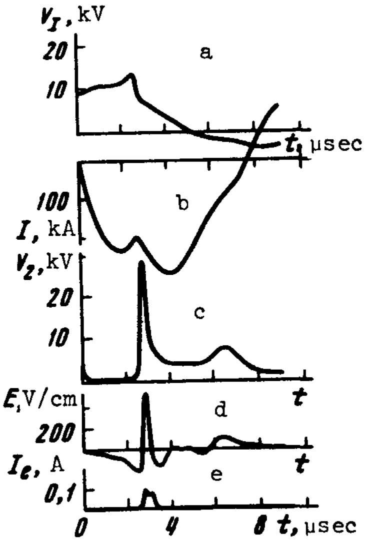

Fig. 1

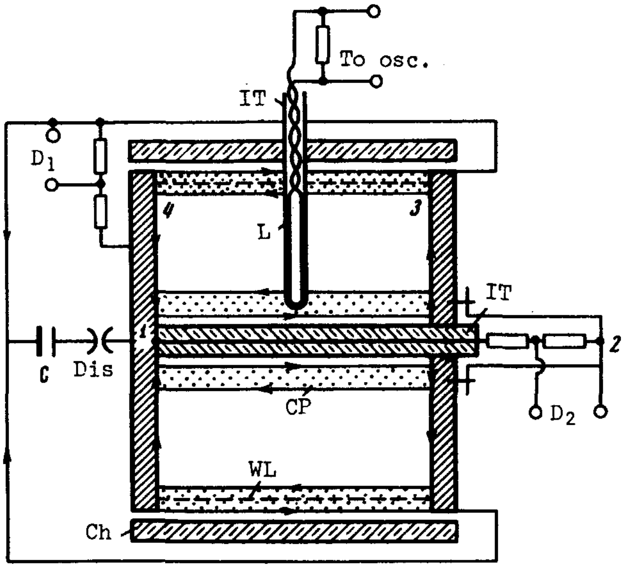

Fig. 2

Fig. 1. Oscillograms of a discharge in deuterium (V_0 = 20 kV) at $P_0 = 10^{-1}$ mm Hg: a) signal from voltage divider D_1, b) current in discharge current, c) signal from divider D_2, d) emf measured with loop L, e) electron current to Faraday cylinder.

Fig. 2. Diagram of apparatus and location of the voltage dividers D_1 and D_2 and of the loop L: Dis - discharge gap, CP - central pinch, WL - plasma layer at wall, IT - insulating tube, Ch - chamber wall. The arrows show the current directions. The dashed line is the zero-current-density line.

is several millimeters; (3) the electrons are accelerated to the anode and the ions to the cathode; (4) the most favorable for the particle acceleration is a discharge with pronounced "singularities" on the voltage and current curves; (5) the particles are accelerated during the growth of the discharge current but past the "singularity," i.e., after the maximum contraction of the pinch; (6) application of a longitudinal magnetic field does not eliminate the acceleration effect.

We have previously [4] called attention to the fact that it is important to take the restriking of the discharge into account if one is to understand the acceleration mechanism. The succeeding experiments have confirmed this point of view. The main results were obtained with apparatus having the parameters C = 48 μF and V_0 = 20 - 25 kV. The inside diameter of the chamber is 20 cm and the length 50 cm. We investigated discharges in hydrogen, deuterium, helium, air, and argon in the pressure range $5 - 2 \times 10^{-2}$ mm Hg. Figure 1 shows certain characteristics of the processes of interest to us for a discharge in deuterium.

Attention is called to the difference between the signals from the voltage dividers D_1 and D_2 (Fig. 2). In the time interval from $t = 0$ to $t = t_{\text{sing}}$, i.e., up to the plasma cumulation, this difference is connected with the fact that the divider D_2 registers only the ohmic component of the total voltage fixed by D_1. At $t > t_{\text{sing}}$ the divider D_2 registers an abrupt signal greatly exceeding the signal from D_1. It should be attributed to the restriking of the discharge and to the formation of a new plasma layer at the wall, which screens the central pinch from the applied voltage. During the restriking, a closed current sheath is produced under this layer and links with the magnetic flux of the pinch [4]. The flux is also completely linked by the circuit 1 - 2 - 3 - 4 - 1, thus making it possible to attribute the evolution of the signal from D_2 at $t > t_{sing}$ to the time variation of the flux. This is confirmed by control measurements of $d\phi/dt$ with the aid of the loop L.

The rapid decrease of the flux separated from that of the external circuit indicates large ohmic losses occurring mainly in the cold plasma layer next to the wall. The induced emf due to the decrease of ϕ acts on the source of the magnetic field, i.e., along the pinch. An emf of about 30 kV corresponds to $R \approx 3 \times 10^{-1}$ ohm. Within $\Delta t = 0.3 - 0.5$ μsec, approximately one-quarter of the magnetic energy of the field linked with the R-L circuit is dissipated.

The electrons accelerated along the pinch axis (Fig. 1e) were observed in all the gases employed by us. Their energy corresponded to the measured induced emf. The largest emf was registered in deuterium at $P_0 = 10^{-1}$ mm Hg. Its dependence on the type of gas was qualitatively close to that obtained by Brezhnev and Maksimov [5], who investigated the energies of the accelerated electrons.

The most effective acceleration of the particles in the axial region of the pinch is possible only if it contains simultaneously a sufficiently rarefied plasma and an appreciable electric field. A rarefaction region is produced by reflection of a converging shock wave from the axis [1, 6]. Estimates based on the assumption that all the particles in the rarefaction channel are accelerated, lead to reasonable values of the particle density in this channel. To satisfy the second condition, it is necessary that the current be localized at the pinch axis at the instant of second discharge ignition, corresponding to the cumulation of the plasma. As is well known, axial localization is automatically realized when the current in the pinch is increased ("inverse skin effect"). This is precisely the case realized in the "singularity" stage. The subsequent dissipation of the magnetic field energy maintains the localization of the current also after the "singularity"[2].

We note that a short-duration shift of the current towards the rarefaction channel boundary does not eliminate the emf induced in the channel. In this respect, there is an analogy with the linear betatron. The difference lies only in the method used to change the flux. In our case the flux is changed not by an external source, but by dissipation of the magnetic energy of a current sheath that is separated from the external circuit.

It is natural to assume that the longitudinal magnetic field can influence the acceleration to the same degree that it influences the plasma compression and the presence of the "singularities."

Thus, the proposed particle-acceleration mechanism explains the main features of the observed phenomenon. This mechanism can become manifest also in other pulsed discharges, such as a noncylindrical pinch, a plasma focus, etc.

We thank E.Yu. Khautiev for a discussion of the results.

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OPTOELECTRICAL EFFECT AND OPTOKINETIC DIA- AND PARAMAGNETISM

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1. A flux of electromagnetic waves (which we shall call optical) produces in a conducting medium placed in a magnetic field $\vec{H}$, which is not parallel to this flux, effects similar to the thermomagnetic effects [1, 2]. In particular, an electric current may be produced, with a density $\vec{j}$ given by

$$\mathbf{j} = \chi\mathbf{I}_k + \chi_1[\mathbf{I}_k\times\mathbf{H}] + \chi_2\mathbf{H}(\mathbf{I}_k\mathbf{H}), \tag{1}$$

where $\vec{I}_k$ is the Poynting-vector component parallel to the wave vector $\vec{k}$. This current can enhance (paramagnetism) or weaken (diamagnetism) the magnetic field inside the medium (optokinetic dia- and paramagnetism).

2. In the presence of an electromagnetic wave, the distribution function is $F = f_0 + f_1 + f_2 + f_3 + \ldots$, where f_0 is the equilibrium distribution function, f_1 and f_3 are proportional to the frequency ω of the wave and to double the frequency, respectively, and f_2 is independent of the frequency (f_2 and f_3 are quadratic in the fields of the wave).

We are interested in the functions f_1 and f_2; we supplement the corresponding kinetic equations, which are written out in [3], with terms that depend on the external magnetic field. We consider the case of a weak magnetic field ($\mu H/c < 1$, where μ is the mobility), and therefore confine ourselves to the calculation of the coefficient χ_1 in the term that is linear in H. The increment proportional to H in the distribution function f_2 is given by

$$f_2^{(1)} = \frac{e^3\tau^3 y}{2m^2c^2}\frac{\partial f_0}{\partial\epsilon}\mathrm{Re}\Big(\{y(1-x^2-2x\,\mathrm{tg}\,\phi)(\mathbf{H}_1^*\mathbf{H})\mathbf{E}_1-(1+x\,\mathrm{tg}\,\phi)\times$$

$$\times[[\mathbf{E}_1\mathbf{H}_1^*]\mathbf{H}]+c\tau_1 y[x+x_1-(xx_1-1)\,\mathrm{tg}\,\phi](\mathbf{E}_1\mathbf{E}_1^*)[\mathbf{k}\times\mathbf{H}]\}\mathbf{v}\Big)+\frac{e^3\tau_2^2}{2mc}\times$$

$$\times\Big(\Big\{2(\mathbf{E}_1\mathbf{v})(\mathbf{k}'\mathbf{v})[\mathbf{E}_1^*\times\mathbf{H}]+(\mathbf{E}_1\mathbf{v})(\mathbf{E}_1\mathbf{v})[\mathbf{k}'\times\mathbf{H}]+2\frac{\tau}{\tau_3}v^2(\mathbf{E}_1\mathbf{E}_1^*)[\mathbf{k}\times\mathbf{H}]\Big\}\mathbf{v}\Big)\times$$

$$\times\frac{\partial}{\partial\epsilon}\Big\{\tau\tau_1 yy_1[x+x_1-(xx_1-1)\,\mathrm{tg}\,\phi]\frac{\partial f_0}{\partial\epsilon}\Big\},$$

$$\mathbf{k}' = \mathrm{Re}\,\mathbf{k},\quad x = \omega\tau,\quad y = (1+\omega^2\tau^2)^{-1},$$

x_1 and y_1 are the same but with τ replaced by τ_1, and $\vec{v}$ is the carrier velocity. By averaging $f_2^{(1)}$ over the polarization directions and calculating the current, we obtain the coefficient χ_1: