EXPERIMENTAL CONFIRMATION OF THE EXISTENCE OF STATIONARY SELF-COMPRESSING PLASMA CURRENTS*

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It was shown in [1,2] that an axially-symmetrical flow of plasma under the influence of an azimuthal magnetic field can be accompanied by an appreciable contraction of the plasma. An analysis of this phenomenon, carried out by A. I. Morozov [3] under the assumption that the process is polytropic, has shown, in particular, that the maximum degree of compression of the plasma is determined by the expression

$$\frac{\rho_{max}}{\rho_0} = \left[(\gamma-1)\frac{c_{A0}^2}{c_{T0}^2}\right]^{1/(\gamma-1)}, \tag{1}$$

where γ is the polytropic exponent ($p \sim \rho^\gamma$), $c_T^2 = (\partial p/\partial \rho)$, and

$$c_{A0}^2 = \frac{H_0^2}{4\pi\rho_0} >> \frac{v_0^2}{2} + \left(\int \frac{dp}{d\rho}\right)_0.$$

The zeroes designate quantities taken at the "input" of the system.

Calculations by means of formula (1) show that it is possible to obtain large degrees of compression with rather modest discharge parameters.**

To confirm the existence of an effect of stationary compression of a plasma jet, we constructed the instrument shown schematically in Fig. 1, which we called a magnetoplasma compressor (MPC). The working gas (nitrogen) was fed to the discharge gap with the aid of a pulsed valve. Discharge of a capacitor bank with total capacitance 2400 μF, charged to 5 kV, produced a maximum current of 450 kA of half-cycle duration ~60 μsec. The effect of stationary compression was observed only when the central electrode was the cathode.

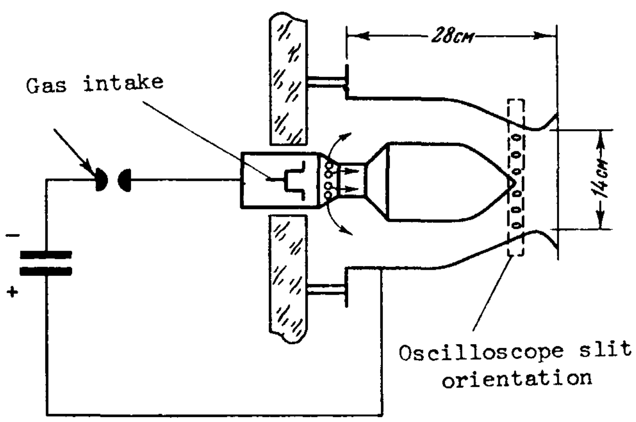

Fig. 1

The experiments have shown that the degree of compression increases with increasing discharge current. The stability of the discharge improved greatly after leads were symmetrized and longitudinal slots, which ensured symmetrical combustion in the ionization-front zone, were cut in the input part of the outer electrode [6,7]. A considerable stabilizing action was exerted at the start of the discharge by the presence of a residual pressure in the vacuum chamber ($p_0 \sim 0.1 - 1$ mm Hg).

During the first half-cycle of the discharge current, a brightly glowing zone of strong plasma compression, 1 - 2 cm in diameter and 5 - 7 cm long, was produced near the end of the central electrode. The plasma current behind this zone diverged at an angle ~90°.

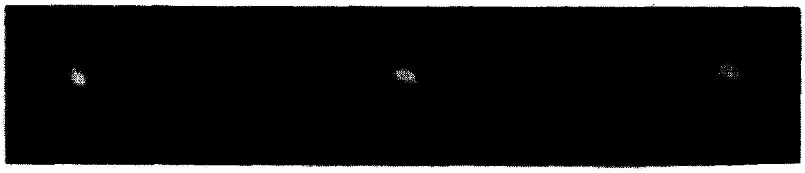

Fig. 2

Fig. 3

Figure 2 shows a portion of an SFR-camera photograph near the current maximum, taken from the end of the instrument. The brightly glowing spot at the center of the frame corresponds to the plasma compression zone ("focus"), and the light border corresponds to the edge of the outer electrode. The photographs were taken at a rate of 5×10^5 frames per second.

The oscillogram of the voltage measured directly between the electrodes duplicated well the form of the discharge current during the first half-cycle, and the voltage at the maximum was $\lesssim 250$ V. The current delivered by the MPC was ~10% of the discharge current, a value much lower than in ordinary coaxial accelerators [6,7].

The spectra of the plasma glow were taken through openings in the outer electode of the MPC (Fig. 3). They show that outside the "focus" the spectrum consists of lines of small width, and a continuous spectrum is observed besides the strongly broadened line spectrum in the compression zone. The spectrum contains for the most part the N II and N III lines. The line half-width was 0.3 - 0.4 Å in the peripheral regions and 2 - 5 Å near the compression zone. The electron temperature, determined from the relative intensity of N II, was ~2 eV on the periphery and increased towards the center of the "focus," where it reached 4 - 6 eV. The plasma density, estimated from the Stark effect, was $\sim(0.5 - 1.0) \times 10^{18}$ cm^{-3} in the maximum contraction zone, giving a compression ratio ~100.

Using the measurements of T_e it is possible to estimate the polytropic exponent γ and then compare the experimentally obtained degrees of compression with those calculated from formula (1). The agreement is acceptable. Thus, our investigation has qualitatively confirmed the existence of a compression effect under the influence of an azimuthal field.

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**Electronic computer calculations of two-dimensional nonstationary axially-symmetrical flow of a plasma of finite conductivity, performed in 1966-1967, confirmed the conclusions of [3] (see [4,5]).

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Callout in Fig. 1 should read "Spectroscope slit orientation instead of "Oscilloscope slit orientation."