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INFLUENCE OF TOROIDAL DRIFT ON PLASMA INJECTION TRANSVERSELY TO THE MAGNETIC FIELD

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Submitted 27 May 1965

One method of injection into magnetic traps, which has recently assumed a major role, is plasma injection transveresely to the magnetic field, using the effect of polarization interaction between the colliding streams [1-3]. An experimental check on the possibility of filling with plasma a toroidal trap with a bifilar stellarator field has demonstrated effective capture of the plasma [4].

It was observed in an investigation of the motion of plasma jets in a transverse magnetic field that the plasma penetrates quite well through the magnetic barrier, in spite of the fact that the magnetic pressure greatly exceeds the kinetic pressure ($H^2/8\pi >> p$). This effect is due to the occurrence of electric polarization of the plasma moving in the transverse magnetic field. This leads, in turn, to drift in the self-consistent crossed fields, with a velocity that coincides in direction with the initial velocity. In addition to conservation of the transverse motion, an intense plasma flux is observed along the field force lines, the longitudinal velocity of which can be of the same order as the transverse one. In the case of transverse injection of a plasma in a toroidal magnetic field, there should be superimposed on these motions also a toroidal drift due to the polarization fields produced by the centrifugal drift and the drift of the oppositely-charged plasma components in the inhomogeneous field. Indeed, the toroidal drift leads to fully defined electric polarization fields, which can either coincide with or be opposite to the electric fields produced when the plasma moves across the magnetic field. We can therefore expect the plasma distribution through the trap volume to depend on the initial conditions, namely on the direction of the plasma-current velocity vector relative to the magnetic-field gradient.

To check on these assumptions, we investigated the motion of a plasma in a toroidal magnetic field. The experiments were made in a set-up comprising a toroidal stainless-steel vacuum chamber (major and minor diameters of torus 120 and 10 cm, respectively). The chamber was placed in the magnetic system of a sectionalized solenoid, which produced a quasi-stationary field (maximum field ~ 3 kOe, half-cycle duration ~ 2×10^{-3} sec). The plasma was injected by means of two spark sources at the same azimuth in the plane of the torus ($\phi = 0$). The internal and external injectors are so located that they produce an initial plasma-current velocity parallel and antiparallel to $\overline{\nabla H^2}$, respectively. The plasma current captured in the trap was measured with local screened electric probes at different azimuths of the torus (ϕ = 45 and 135°).

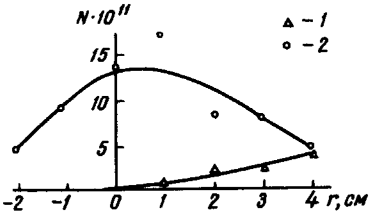

Fig. 1. Radial distribution of time-integrated particle flux for internal (1) and external (2) plasma injection. Measurement at 45° azimuth.

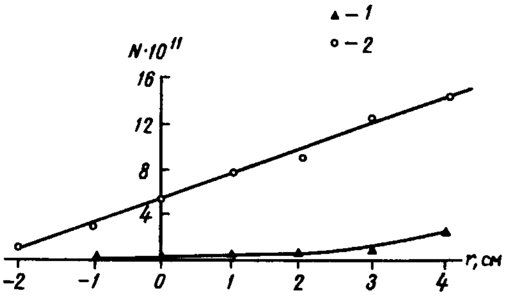

Fig. 2. Radial distribution of integral particle flux N for internal (1) and external (2) plasma injection. Measurement at 135° azimuth

Figures 1 and 2 show the radial distribution of the ions $N(r) = \int_0^\infty env\,dt$, where n is the density ($n_{max} \approx 5 \times 10^{11}$ cm^{-3}) and v the velocity.

It is seen from Fig. 1 that for the 45° azimuth the plasma injected by the external source has a bell-shaped distribution with a maximum shifted towards the exterior. The plasma configuration for internal injection is much different: first, the number of particles passing through the 45° azimuth is appreciably smaller; second, the distribution corresponds to the ordinary plasma distribution due to toroidal drift in a toroidal magnetic field.

As the plasma moves further in the toroidal field, it "drifts off" to the outer wall of the chamber (see Fig. 2). The distributions shown were obtained at an azimuth of 135°.

An interesting fact is the conservation of the plasma flux near the outer boundary of the chamber, as can be seen from a comparison of the fluxes at a 3 - 4 cm radius (Figs. 1 and 2). This phenomenon can apparently be attributed to the effect of the conducting boundaries.

As an additional check on the statement that the initial plasma velocity affects its propagation in a toroidal magnetic field, we can change the initial injection conditions not by varying v_0, but in some other manner. One possibility is to use spatial modulation of the magnetic field. Programmed variation of the magnetic field was effected in the injection region with the aid of a short solenoid placed inside the chamber. The magnetic field could be decreased to zero and its direction reversed within $\tau \sim 40 - 50$ μsec (τ was much larger than the injection time).

The motion of the plasma injected in a modulated field is radically altered. Figure 3 shows the distribution of the particle fluxes as functions of the magnetic field in the injection region, for the case of internal plasma injection. It shows also the schematic configurations of the longitudinal component H_l.

A distinguishing feature of the distribution at 45° azimuth is the clear-cut localization of the plasma, determined by the configuration of the magnetic field in the injection region; this occurs in the presence of a sign-reversing field. In this injection method, the plasma captured in the toroidal system passes through a region where adiabatic invariance is not con-

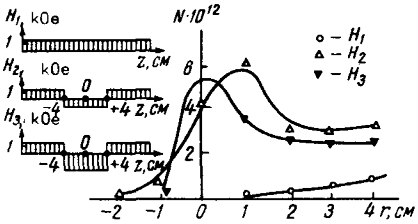

Fig. 3. Radial distribution of integral particle flux N for internal injection of plasma in a spatially-modulated field. The distribution of the magnetic field in the injection region at the corresponding values of H_i is shown schematically. The measurements were made at 135° azimuth.

served (region of zero field), and the configuration of the plasma jet is determined to a much lesser degree by the direction of the injection (external or internal) relative to the direction of the magnetic field gradient.

Thus, the sum total of the experimental results, namely the difference in the spatial distribution of the plasma injected parallel and antiparallel to the gradient of the toroidal magnetic field, as well as the appreciable influence of the spatial modulation of the magnetic field in the injection region on the configuration of the plasma flux, allows us to assert that the model proposed for the resultant drift is correct.

In conclusion, the authors consider it their pleasant duty to thank M. S. Rabinovich and I. S. Shpigel' for useful discussions, and N. V. Perov and V. M. Zykov for help in preparing and performing the experiments.

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GRAVITATIONAL RADIATION OF EXPLOSIVE ORIGIN

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Submitted 31 May 1965

One of the leading trends in modern development of general relativity theory consists in a search for new experiments for its verification. The most promising among such experiments are those involving generation and detection of gravitational waves [1-3]. Under discussion at present is the possibility of observing gravitational waves from the nearest short-period double stars [4] as well as from collapsing masses [5]. In the case of collapsing bodies, their gravitational self-closing greatly reduces the amount of radiated gravitational energy. In the case of expansion from a singular sphere, or in the case of explosion, no such limitation exists. The present note is aimed at estimating the power of gravitational radiation produced by explosively scattered matter during the course of various natural cataclysms.