DYNAMICS AND SPATIAL BOUNDARIES OF RETARDATION OF THE PLASMA CLOUD OF AN EXPLOSION IN A DIPOLE MAGNETIC FIELD

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In the framework of the ideal MHD approximation, we shall discuss the dynamics of a 3-D expansion of a spherical cloud of rarefied plasma into a vacuum in the presence of a nonuniform external magnetic field of dipole structure. When the plasma expands rapidly, for example, as a result of the energy released by the explosion, at the stage of an expansion that is nearly radial, an effective retardation of the boundaries of the cloud takes place as a result of the interaction of induced surface currents with the magnetic field. It is necessary to find the configuration and location of the plasma front as a function of time, and also to determine the limits of its propagation, which are caused by the retardation effect. Interest in this problem is primarily due to the study of nonstationary processes of an explosive nature in the cosmic plasma [1], in particular, to the analysis of the global instability of the earth's magnetosphere in estimates of the effectiveness of explosive methods of its protection from collisions with asteroids and comets [2, 3].

The problem was studied in a similar formulation only in the simplest case, i.e., in a uniform external field [4]. The case with a dipole field was examined in [5] for comparatively low explosion energies and correspondingly small deviations of the shape of the plasma formation from a sphere. In [6], we estimated the size and configuration of the retardation region in the field of a point dipole. On the whole, the problem has been little-studied because of the absence of the necessary 3-D nonstationary numerical models owing to the complexity of creating them. The proposed study is based on some simple relationships for generalized characteristics of motion – energy and pressure – and does not allow for the role of magnetic diffusion, which makes it possible to find the basic principles of the 3-D dynamics of retardation with a minimum number of initial parameters. The calculation model is compared with the results of an experiment on the expansion of laser plasma clouds in a dipole field on a KI-1 stand [7]. This approach is aimed at estimating the possibilities of the hydrodynamic method and obtaining preliminary data necessary for constructing more rigorous models.

1. Analysis of the Retardation Model. As in [4], which discussed the problem of expansion of a superconducting sphere in a uniform external magnetic field, it can readily be shown that the work of ponderomotive forces A on particles of an ideally conducting plasma cloud of changing shape during its expansion time t in a field of arbitrary configuration is equal to the work of forces of magnetic pressure $\mathbf{B}_s^2/8\pi$ on its surface S, written in the form

$$A = -\frac{1}{8\pi}\int_0^t\int_S \mathrm{B}_s^2\,(d\mathbf{s}\cdot\mathbf{v})\,dt, \tag{1.1}$$

where $\mathbf{ds} = \mathbf{n}_s ds$ is the surface element ($\mathbf{n}_s$ being the vector of the normal) specified by the radius vector $\mathbf{r}_s = \mathbf{r}_s(t)$ with respect to the point of injection (PI) of the cloud; $v = d\mathbf{r}_s/dt$ is the displacement velocity of this element; $\mathbf{B}_s = \mathbf{B}_s(\mathbf{r}_s)$ is the perturbed magnetic field on the surface of the element. Equation (1.1) allows for the fact that for conditions of complete displacement of the field from the volume occupied by the plasma ($\mathbf{B}_s\cdot\mathbf{n}_s = 0$), the surface density of the power of ponderomotive forces is proportional to the scalar product $\mathbf{n}_s\cdot\mathbf{v}$. An analogous factor does not arise in [4], since, when one assumes the sphericity of the cloud and a strictly radial character of motion

$$d\mathbf{s}\cdot\mathbf{v}/|\mathbf{v}| = ds.$$

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The kinetic energy of a cloud changes with time according to the equation

$$\mathscr{E}(t) = \mathscr{E}_0 + A\,(t)$$

($\mathscr{E}_0$ being the initial energy of radial expansion at t = 0). The dynamics of interaction of the plasma with the field also depends on the balance of the gasdynamic and magnetic pressures at the boundary surface:

$$2m_i n_i\,|(\mathbf{w} - \mathbf{v})\,\mathbf{n}_s|^2 = \mathbf{B}_s^2/8\pi.$$

Here $\mathbf{w}$ and n_i are the velocity and density of the ions in the Chapman–Ferraro boundary layer; m_i is the ion mass. In the radial expansion approximation ($\mathbf{v} = \mathbf{e}_r v$, $\mathbf{w} = \mathbf{e}_r w(r_s)$, $\mathbf{e}_r$ is the unit radial vector)

$$2m_i n_i\,(w - v)^2 \cos^2\chi = \mathbf{B}_s^2/8\pi, \quad \cos\chi = \mathbf{e}_r\cdot\mathbf{n}_s. \tag{1.2}$$

In contrast to [4], the pressure balance equation is used in a more general form, since Eq. (1.2) contains the factor $\cos^2\chi$, which depends on the angle of inclination of the plasma flow to the normal to the boundary surface, χ.

The motion of the plasma in an arbitrary direction from the point of injection to a small solid angle $d\Omega$ corresponds to the equation of differential energy balance, which for a spherical symmetry of the initial conditions is

$$d\mathscr{E}/d\Omega = \mathscr{E}_0/4\pi + dA/d\Omega. \tag{1.3}$$

Assuming that when t = 0, $w = v = v_0$, and using the customary approximation of inertial expansion, in which n_i = const/r_s^3, and the velocity distribution $\sim r/r_s$, we find $\mathscr{E}_0 = 0{,}3Mv_0^2$ (M is the combined mass of the cloud). We will express $d\mathscr{E}/d\Omega$ in the same approximation (i.e., without considering the effect of grouping of the plasma near the boundary surface as a result of retardation) in terms of the ion velocity on the front w:

$$d\mathscr{E}/d\Omega = 0{,}3Mw^2/4\pi. \tag{1.4}$$

Combining (1.1)–(1.4) gives the equation of motion of the boundary in the specified direction (in a similar form but neglecting the factor $\cos^2\chi$, this equation is also used in [8]):

$$dr_s/dt = [(\mathscr{E}_0 + 4\pi dA/d\Omega)/0{,}3M]^{1/2} - (\mathbf{B}_s^2 V/16\pi M\cos^2\chi)^{1/2},$$
$$4\pi dA/d\Omega = -\frac{1}{2}\int_0^{r_s} \mathbf{B}_s^2\cos\chi\, r^2 dr. \tag{1.5}$$

The first summand in Eq. (1.5) describes the change in the kinetic energy of expansion, and the second summand is related to the dynamic balance of pressures dependent on the effective volume of the corresponding cloud element $V \sim n_i^{-1}$. From the condition $dr_s/dt = 0$ one can find the radius of the boundary of complete retardation r_*. In the model with an expanding sphere in a uniform field B_0, this radius is expressed as follows [4]:

$$r_* = R_B = (3\mathscr{E}_0/B_0^2)^{1/3}$$

and is the asymptotic limit for an infinitely long time of complete retardation (in this case, use is made of the concept of finite retardation time τ_*, for which r_*/R_B is close to unity). In general, r_* is dependent on the direction, and the time of complete retardation may become finite as a result of a rapid increase of the second summand in Eq. (1.5) as V and $\cos^2\chi$ change. Obviously, the parameter V should correspond to the actual volume of the cloud in the late stages of expansion after an appreciable mixing of the trajectories as a result of reflection of the particles from the retarded boundary. In particular, such determination of V was used in [8], which studied the evolution of a superconducting plasma ellipsoid in a uniform external field (the retardation of a spherical cloud is actually the initial stage in that model). In our case, in describing the retardation stage, it suffices to confine oneself to the "local" determination $V \sim r_s^3$, which can be applied independently for each of the directions.

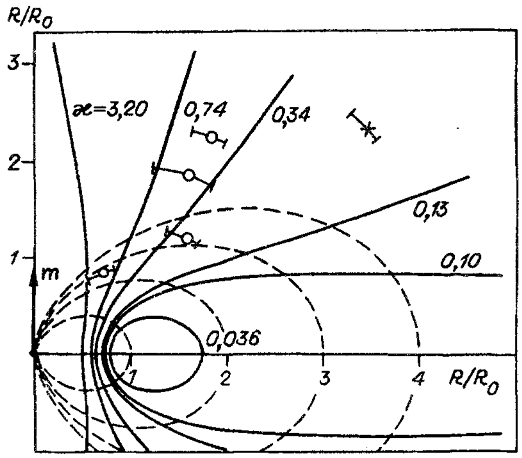

Fig. 1

On the basis of the equation of motion (1.5), we will discuss the problem of expansion of a plasma cloud in the field of a magnetic dipole, using simple approximations of a perturbed field.

2. Dependence of Retardation Boundaries on the Initial Energy of the Cloud. We will estimate the dimensions and configuration of the retardation region (RR) within the confines of which $dr_s/dt \geq 0$, as a function of a single parameter – the initial expansion energy $\mathscr{E}_0$. To that end, we first equate Eq. (1.5) to zero. Second, we neglect the influence of the pressure balance (according to the estimates, in the approach under consideration this influence is slight because of the marked nonuniformity of the external field); this is equivalent to the approximation of zero plasma energy at the end of the retardation stage ($w = \upsilon = 0$). Thirdly and finally, we set $\cos \chi = 1$. We obtain the equation of differential energy balance in the form

$$d\mathscr{E}_0/d\Omega \simeq \frac{1}{8\pi} \int_0^{r_*} B_s^2\, r_s^2\, dr_s. \tag{2.1}$$

In the quasispherical approximation, the initial field $\mathbf{B}_d(\mathbf{r}_s)$can be correlated with the external field $\mathbf{B}_s(\mathbf{r}_s)$ as follows:

$$B_s^2 = k_s\, B_d^2 = 3B_d^2/2, \tag{2.2}$$

which takes place for the square of the field, averaged over the angular dependence, on the surface of a superconducting sphere placed in a uniform field [4]. In general, the contraction ratio k_s is a variable local property determined by the shape of the plasma formation at a given instant. Equation (2.2) is conveniently used for the following reasons. When the size of the RR is large, the effective value of k_s is determined by averaging the ratio $\mathbf{B}_s^2/\mathbf{B}_d^2$ over time while allowing for a considerable rearrangement of the field structure and for the shape of the boundary surface. In addition, because of the strong dependence of Eq. (2.1) on the radius (for a sphere in a uniform field $d\mathscr{E}_0/d\Omega \sim R_B^3$), even a comparatively pronounced variation in k_s cannot lead to a qualitative change in the results of the estimates. Finally, in the limit of a weak manifestation of nonuniformity (when the dimensions of the cloud are small, $R_B << R_0$; see below), the relations (2.1) and (2.2) give known results [4].

The following notation will be used below. Let $\mathbf{m}$ be the magnetic moment of the dipole, R_0, the distance from its center to the PI, λ_0 being the latitude angle determining the position of the PI relative to the equatorial plane (EP) of the dipole. We introduce the angles $\lambda = \pi/2 - \theta$ and φ, where θ and φ are the polar and azimuthal angles of the spherical coordinate system for the right-handed cartesian triplet XYZ with the origin at the PI, at which the X axis is directed along the "expansion axis" connecting the PI and the dipole, and the Z axis lies in its meridional plane. We also use the dimensionless quantities of radius $b = r_s/R_0$ and energy

$$\varkappa = 3\mathscr{E}_0\, R_0^3/m^2 = (R_B/R_0)^3.$$

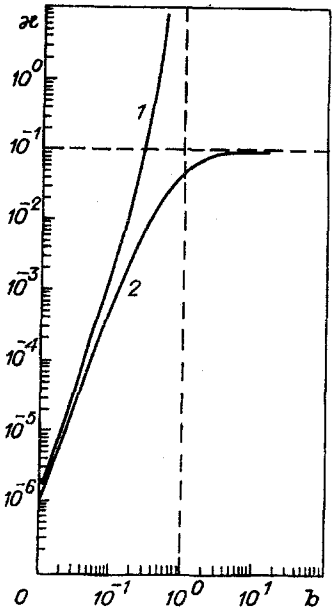

Fig. 2

This makes it possible to obtain from (2.1) a normalized integral equation of the boundary surface of the RR [6] (the coefficient 3/4 before the integral is omitted as negligible)

$$\varkappa = 3 \int_0^{b(\lambda_0, \lambda, \varphi)} \{3\sin^2\lambda_0\,[\xi(\mathrm{ctg}\,\lambda_0 \sin\lambda + \cos\lambda\cos\varphi) + 1]^2/Q^4 + Q^{-3}\}\,\xi^2\,d\xi, \tag{2.3}$$
$$Q = 1 + 2\xi\cos\lambda\cos\varphi + \xi^2.$$

Here $R_B = (3\mathscr{E}_0/\mathbf{B}_{d0}^2)^{1/3}$ is the normalized retardation radius corresponding to the value of the field $\mathbf{B}_{d0}$ at the point with radius R_0 at the equator. For specificity, we will examine the case of an equatorial location of the PI ($\lambda_0 = 0$). Figure 1 shows the meridional sections ($\varphi = 0$) of RR, calculated from Eq. (2.3) for different values of parameter $\varkappa$, which will be referred to as the energy criterion of interaction. The corresponding equatorial sections of the RR ($\lambda = 0$) are distinguished by somewhat large dimensions across the "expansion axis" as a result of smaller effective magnetic pressure. The critical value of $\varkappa$ is determined according to [6] as

$$\varkappa_c = \lim_{\substack{b \to \infty \\ \lambda = \varphi = 0}} \varkappa(b) = 3\int_0^{\infty} \xi^2\,d\xi/(1 + \xi)^6 = 1/10. \tag{2.4}$$

The boundary of the RR in the direction of field decay moves to infinity when $\varkappa \gtrsim \varkappa_c$. A rupture of the plasma into a cone determined by the calculated section of the RR takes place (see Fig. 1). When $\varkappa \ll \varkappa_c$, a "quasicapture" regime takes place, when an appreciable retardation is also observed in the direction of field decay. Figure 2 shows the retardation curves $\varkappa(b)$, corresponding to the solution of Eq. (2.3) in two directions ($\lambda_0 = 0$) – toward the dipole when $\lambda = \pi$, $\varphi = 0$ (b_+ – curve 1) and away from the dipole when $\lambda = \varphi = 0$ (b_- – curve 2):

$$\varkappa = 3\left|\frac{1}{3}(1 \mp b_\pm)^{-3} - \frac{1}{2}(1 \mp b_\pm)^{-4} + \frac{1}{5}(1 \mp b_\pm)^{-5} - \frac{1}{30}\right|.$$

When the PI is located outside the equatorial plane ($\lambda_0 \neq 0$), the value $\varkappa_c$, determined as in (2.4) when $\lambda = \varphi = 0$, increases as $(1 + 3\sin^2\lambda_0)/10$, which gives $\varkappa_c \to 0.4$ when $\lambda_0 \to \pi/2$. At the same time, the criterion of "rupture" strictly across the lines of force when $\lambda_0 = \pi/2$ is, according to (2.3), the relation $\varkappa \gtrsim \varkappa_c = 15\pi/32$ ($\lambda = \pi/2$, $\varphi = 0$ or $\lambda = 0$, $\varphi = \pi/2$). Therefore, $\varkappa_c \sim 1$ may be considered a generalized estimate for high latitudes ($\lambda_0 \to \pi/2$). We note that the "rupture" cone when $\lambda_0 \neq 0$ is oriented along the gradient line of the external field, a line which in this case does not coincide with the "expansion axis."

When the retardation radii along the "expansion axis" are small, we have ($\lambda_0 = 0$, $b << 1$)

$$b_{\pm} \approx [\varkappa/(1 \pm 9\varkappa^{1/3}/2)]^{1/3},$$

whence we derive the degree of asymmetry of the retardation boundaries

$$\eta = 1 - b_+/b_- \approx 3\varkappa^{1/3}.$$

In particular, for the parameters of the field experiment [9], the estimate is $\eta \sim 5\%$ ($\varkappa \sim 10^{-5}$), and for [10] $\eta \sim 50\%$ ($\varkappa \sim 10^{-2}$). In the "quasicapture" regime ($\varkappa \ll \varkappa_c$) during the characteristic retardation time $\tau_* \sim R_B/v_0$, the center of mass of the cloud shifts by a distance $\Delta R \sim \eta\varkappa^{2/3}R_0/2 \ll R_0$, and hence, acquires a velocity $u \sim v_0\varkappa^{1/3}$. The same estimate can be obtained for the velocity of a point magnetic dipole [5] equivalent to the cloud, accelerated by the external field gradient and having a moment which on the indicated time scale ranges from zero to $\mu = -\frac{1}{2}\mathbf{B}_{d0} R_0^3 \varkappa$. Thus, the estimates give a correct representation of the dimensions of the cloud also at the "emersion" stage without direct reference to models of its motion as a whole ($\varkappa \ll \varkappa_c$). In another limiting case (when $\varkappa \gtrsim \varkappa_c$), the calculated sections of RR have the meaning of time-integrated limits of plasma propagation in an external dipole field.

3. Method of Calculation of Retardation Dynamics. When plasma-front dynamics are studied by means of Eq. (1.5), it is necessary to take into account the characteristics of the distribution of the perturbed field, which were ignored in the estimate of the retardation boundaries. The above-mentioned slight sensitivity of the estimates to the value of the concentration ratio k_s refers primarily to the "rupture" regime, i.e., to the case of a large-scale RR ($R_B \gtrsim R_0$). The local behavior of k_s becomes significant when $\varkappa < \varkappa_c$, i.e., when the spatial scale is comparatively small. In particular, wherever the initial lines of force are perpendicular to the boundary surface, the value of k_s is close to zero as a result of plasma diamagnetism, resulting in an appreciable attenuation of the retardation effect. To allow for such characteristics, we use the perturbed-field approximation in the form

$$\mathbf{B}_s \approx -\frac{3}{2}[\mathbf{n}_s \times [\mathbf{n}_s \times \mathbf{B}_d]]. \tag{3.1}$$

The relation (3.1) becomes strict in the case of a superconducting sphere in a uniform field $\mathbf{B}_0 = \text{const}$ if this field is substituted for the local dipole field $\mathbf{B}_d(\mathbf{r})$. This approximation is based on an identity of the general form [11]

$$\mathbf{B}_s(\mathbf{r}_s) = 2\mathbf{B}_d(\mathbf{r}_s) + \int_S [\mathbf{n}_s \times \mathbf{B}_s] \times \mathbf{r}' ds/2\pi|\mathbf{r}'|^3,$$

in which is present the integral necessary for taking the curvature of the current surface S into account (vector $\mathbf{r}'$ is drawn from the current element to the observation point). In addition, it provides for the reduction to zero of the normal component of the resultant field ($\mathbf{B}_s\mathbf{n}_s = 0$) and corrects the contribution of the first summand to the tangential component, this contribution being equal to $-2[\mathbf{n}_s \times [\mathbf{n}_s \times \mathbf{B}_d]]$ and being due to the current in the plane tangent to the surface S at the observation point.

In the "principal" meridional section of the cloud, passing through the center of the dipole and the RR and coinciding with the plane of symmetry, one can treat (1.5) as a system of equations of motion of the elements of the plasma surface in directions different in angle λ. According to (3.1), this sector approximation is defined for a self-consistent field, since $\cos\chi = \mathbf{n}_s\mathbf{e}_r$ depends on the geometry of the boundary as a whole. In each time step of the integration of this system over the set of expansion radii $\{r_{sj}\}$, the vector of the normal (j being the sector number) is calculated:

$$\mathbf{n}_s(\lambda_j) = -\nabla F/|\nabla F|,$$

where $F = r - r_s(\lambda, t) = 0$ is the equation of the plasma boundary in the indicated section. Given below are the results of such a calculation of the retardation dynamics for the parameters of an experiment with laser plasma clouds in a KI-1 device.

4. Comparison with Experimental Data. For a comparative analysis, we will use the data of the experiment of [7], in which quasispherical clouds of laser plasma were produced by means of the bilateral symmetric action of a CO_2-laser pulse on a small caprolactam ball placed in a vacuum chamber near a current coil with moment amplitude $|\mathbf{m}| \le 10^7$ G·cm^3

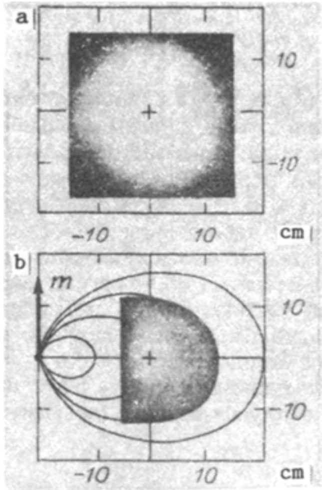

Fig. 3

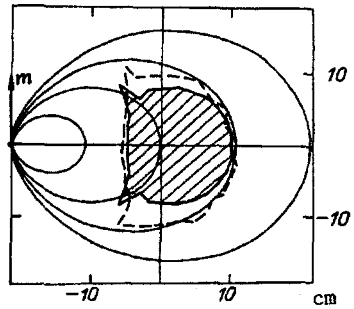

Fig. 4

Figure 3 shows laser plasma glow photographs obtained with the aid of a sensitive image-converter tube (ICT) in a method involving the injection of a weak neutral hydrogen background into the chamber [7] (the plasma glow was maintained by exciting the C^{4+} ions of the cloud in charge exchange processes). With a time resolution of ~ 10 nsec , the principal meridional section of the cloud was recorded at the instant $t = 0.7$ μsec from the start of the expansion in a situation with $\mathbf{B}_d = 0$ (Fig. 3a) and at the same instant, with $\mathbf{B}_d \neq 0$ (Fig. 3b). The injection took place in the equatorial plane ($\lambda_0 = 0$) at radius $R_0 = 22$ cm at a point with field $|\mathbf{B}_{d0}| \simeq 10^3$ G. The kinetic energy of the cloud (according to data obtained with Langmuir electric probes [12]) was $\mathscr{E}_0 \simeq 13$ J, the initial expansion velocity was $v_0 \approx 2.2 \times 10^7$ cm/sec, and the total number of charged particles was $\sim 10^{17}$. The edge of the glow on the ICTgrams corresponds to the front of the cloud, where the ion concentration drops to $\lesssim 10^{12}$ cm^{-3}. A comparison of Figs. 3a and 3b shows that the cloud boundary is retarded in all directions in conformity with the theoretical concept of the "quasicapture" regime (the corresponding value of the parameter is $\varkappa \approx 0.036 < \varkappa_c = 1/10$). The instant $t = 0.7$ μsec is intermediate at the retardation stage in this case, since the calculated boundary of the RR (shown in Fig. 1 by the curve for $\varkappa = 0.036$) is reached by the plasma in the direction of the dipole in ~ 0.3 μsec, away from the dipole in ~ 1 μsec, and across the "expansion axis" in ~ 0.5 μsec. The meridional section for $t = 0.7$ μsec was calculated from Eq. (1.5) for 16 sectors in the halfplane $0 \leqslant \lambda \leqslant \pi$ (when $\pi \leqslant \lambda \leqslant 2\pi$ the front exhibits mirror symmetry) and is represented by the shaded area in Fig. 4. Also shown here for comparison is the contour line, represented by dashes, corresponding to approximately one-half the level of the glow amplitude on the front of the ICTgram in Fig. 3b. The data of the calculation and observation practically coincide on the "expansion axis." In the direction across the axis, their quantitative agreement also is present, with the calculated front lagging slightly behind the front of the glow. The crescent shape of the meridional section is explained by the presence of two regions of minimum pressure which at $t = 0$ correspond to the directions $\lambda = \pm\pi/2$, then shift toward the dipole, following the curvature of the initial lines of force (see Fig. 4). We should add that when the plasma glow in the equatorial plane is observed, the ICTgram data also show that the calculated and measured boundaries of the cloud match at the stage of retardation in the "quasicapture" regime.

The "rupture" regime was studied mainly with the aid of electric probes that measured the angular distribution of the radial plasma flux per unit solid angle $dN/d\Omega$ in the meridional section of the dipole. In the absence of the field ($\mathbf{B}_d = 0$), the probes show a relatively isotropic nature of the expansion from the region of interaction of laser radiation with the target material. When $\mathbf{B}_d \neq 0$, as a result of reflection of the from the "magnetic wall" at the RR boundary, the probe located within the RR cone ($\varkappa > \varkappa_c$), will record an increase in $dN/d\Omega$ as compared to the situation without the field. If the probe goes outside the boundaries of the RR, the particle flux to it should decrease appreciably.

Figure 1 shows the locations of the electric probes corresponding to the level of one-half of the attenuation of the flux $dN/d\Omega$ in an experiment with the parameter $\varkappa \approx 0.7$ (circles) and $\varkappa \approx 0.13$ (cross). The precision of the experimental points demonstrated in Fig. 1 is related to the error of determination of this level from the observation angle. Taken as a whole, such points should describe the RR boundary for a fixed initial cloud energy $\mathscr{E}_0$. The accuracy of determination of $\mathscr{E}_0$ in the experiment was $\leq 50\%$, and therefore, a comparison of the data cited with the calculated sections of the RR in Fig. 1 suggests that the theoretical interpretations of the "rupture" cone within the indicated limits are consistent with the observations.

Preliminary measurements carried out with a system of two-component magnetic probes showed the presence of a full diamagnetic effect in the laser plasma cloud at the start of the expansion. Toward the end of the retardation stage, an anomalously rapid penetration of the field into the plasma takes place on a scale that is appreciably compared to the characteristic radius of retardation $R_0\varkappa^{1/3}$, with preservation of the near-zero field in the central portion of the cloud. nevertheless, in analyzing the experiment from the relevant standpoint, the influence of diffusion can still be neglected, since these results demonstrate a fairly effective retardation of the plasma by a nonuniform field, as well as the possibility of approximately describing its dynamics in the model with ideal conduction.

5. Discussion of Results. We have found the energy criterion of interaction of an explosion plasma cloud with a dipole magnetic field, defined by the parameter $\varkappa = \mathscr{E}_0/\mathscr{E}_M$, where $\mathscr{E}_M$ is the field energy integral of the dipole beyond the confines of a sphere of radius R_0 ($\mathscr{E}_M = m^2/3R_0^3$). In the case of equatorial injection, when $\varkappa \gtrsim \varkappa_c = 1/10$, "rupture" of the plasma front takes place across the field lines, and when $\varkappa \ll \varkappa_c$, the conditions are realized for the "quasicapture" of the plasma on a scale $\sim R_B = R_0\varkappa^{1/3}$ with the simultaneous transition of the boundary retardation stage to the stage of acceleration of the center of mass, owing to the magnetic pressure gradient. A generalized equation of the boundary surface was obtained, and the RR sections were calculated for different values of $\varkappa$. In the "rupture" regime, to the Rr boundaries correspond the boundaries of plasma expansion in the dipole field, according to the condition (1.2), as a result of a considerable delay of the front, the plasma flow is reflected from the "magnetic wall," remaining inside the RR "cone" (see Fig. 1). In the sector approximation and with allowance made for the self-consistent character of the changes in cloud geometry and magnetic perturbations, the plasma front retardation dynamics were calculated. Use was made of the comparatively simple method of approximate determination of the vector of the perturbed field on the surface of an ideally conducting cloud of arbitrary shape.

The calculated results are in satisfactory agreement with the analyzed data of an experiment on a KI-1 stand. We have confirmed the character of plasma motion, predicted in terms of an ideal MHD model, at the initial stage of retardation as a function of the parameter $\varkappa$.

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